CRC Course

Madrid, 4 June 2010

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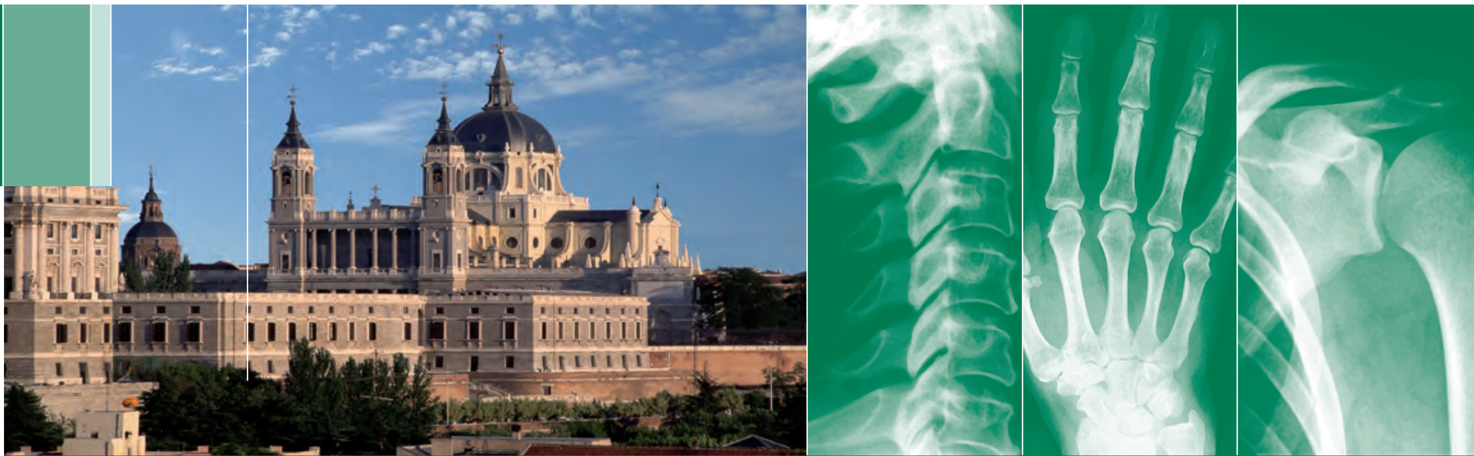

The Comprehensive Orthopaedic Review Course (CRC)

During the 11th EFORT Congress Madrid: 4 June 2010

Course highlights

- Basic science
- Metabolic bone disease
- Tumours (primary and secondary)
- Paediatrics
- Spine
- Lower extremity trauma
- Adult hip and knee reconstruction
- Sports knee
- Foot and ankle
- Hand and wrist
- Elbow and forearm
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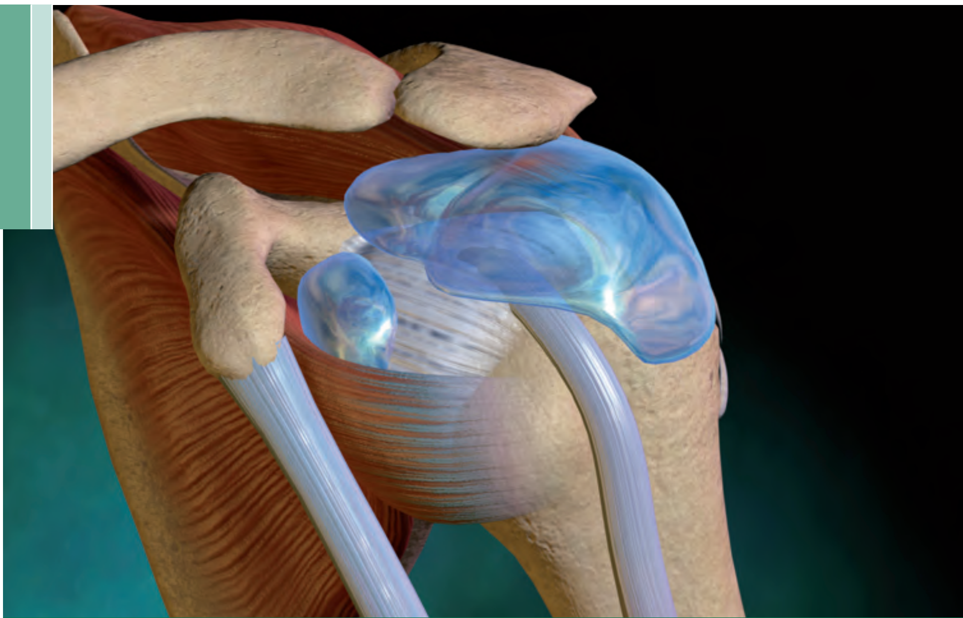

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Introduction
Welcome

Welcome to this second edition of the EFORT Comprehensive Review Course held in Madrid. This course although extensive in its coverage cannot be exhaustive but should provide a firm basis for study. The concepts presented are up to date knowledge and the speakers have provided many references. I would like to thank all the presenters and authors of chapters and I wish good and studious fun to the participants hoping that they will benefit from this collective effort!
Prof. Dr. Pierre Hoffmeyer, EFORT Vice-president

The Online Q&A Forum can be accessed via the following link:
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The full attendance of the CRC course entitles to 6 European CME credits (ECMEC's)

The Certificate will be sent to each participants by PDF file to the registered e-mail address after the course. If you have not yet registered your e-mail account with us, please contact the "Scientific Information" desk in the registration hall.

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Catastrophic events: The role of the Orthopaedic Surgeon

"Acute" catastrophic events, such as earthquakes, tidal waves, hurricanes, and in a less important way water-floods, landslides and industrial accidents, have the particularity to provoke a mass casualty situation where an important number of people are injured, out of proportion to the available personnel and resources necessary for optimal care; specialised resources from outside the devastated area are required.

Unlike more "chronic" catastrophic events, such as war or conflict situations, these "acute" events can not be predicted and emergency humanitarian medical teams generally reach the catastrophic event location after at least one or two days (Bar-Dayan 2000, Jain 2003, Noji 1990), that means lately after the "golden-hour" of trauma where life-threatened heavy polytraumatised patients should get medical support to have a chance to survive; unstable abdominal, thoracic, neurosurgical or pelvic trauma patients are generally already dead before the arrival of first humanitarian medical teams (Sheng 1987, Stein 2000).

Patients still alive usually present less-life threatening injuries, such as extremity crush injuries with or without associated fractures, extremity and more rarely axial (pelvic or spinal) closed fractures, wounds, compartment syndromes and post-traumatic soft-tissue or bone infections (Bar-Dayan 2000, Emami 2005, Jain 2003, Noji 1990, Sheng 1987, Stein 2000, Tahmasebi 2005).

In this perspective, the orthopaedic surgeon has a frontline role to perform adequate debridement and delayed primary closure of wounds, fasciotomies in some cases (Early 1994) as well as proper fracture immobilisation (plaster of Paris, traction, external fixation) or amputations (Bar-Dayan 2000, Emami 2005, Jain 2003, Marsh 2007, Stein 2000, Tahmasebi 2005).

Triage principles in mass casualty situations (greatest good for the greatest number and early evacuation of patients to "decompress" the disaster area) are also a major task for the orthopaedic surgeon, and must be differentiated from general practice triage considerations (greatest good for each individual) (Born 2007, Jain 2003, Marsh 2007).

In addition, all the common medical and surgical emergencies, such as obstetrics, gynaecology, internal medicine, paediatrics and psychiatry (as victims of mass casualty disasters are prone to sustain posttraumatic stress disorder), have to be addressed, emphasising the need for other physicians such as general surgeons, internal medicine specialists, paediatricians, gynaecologists, obstetricians and psychiatrists (Bar-Dayan 2000, Jain 2003, Tahmasebi 2005).

To illustrate this statement, we present the Swiss Humanitarian Aid action during the January 2010 earthquake in Haiti.

The first medical team reached the Port-au-Prince General Hospital on day 5 after the earthquake and quickly began surgical activities after 3 hours on site: the team consisted of one team leader (anaesthesist), one orthopaedic surgeon, one general surgeon, two anaestesists, two paediatricians, one general practitioner, one anaesthesia nurse and three polyvalent nurses, had light equipment (surgical tools, dressing and casting material, some drugs) and used some material already present in the Port-au-Prince General Hospital (operation tables, some drugs). The team focused on providing medical and surgical care to children and traumatised pregnant women. The data collected during the first 10 days are presented in this communication and emphasise the early need for trained orthopaedic surgeons when such catastrophic events occur.

In conclusion, orthopaedic surgeons have a major role to play in the triage and care of mass casualty injured patients, and should therefore be prepared and trained for such an occurrence (Born 2007, Emami 2005, Ginzburg 2010, Jain 2003, Marsh 2007).

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Basic science, metabolic bone disease

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Biomechanics of musculoskeletal tissues – Biomaterials (trauma, prosthetics)

Introduction

This lecture will consider biomechanics of bones and joints that are applied due to movement by people and then the biomaterial considerations relevant to orthopaedic implants. Biomechanics and biomaterials are obviously both huge subjects but so only the areas of each of importance to orthopaedic surgeons will be considered.

Biomechanics and Biomaterials

The mechanics of moving objects, including the human body, are governed by Newton's Laws of Motion. The 1st Law states that "a body will remain in a state of rest, or move at constant velocity, unless acted upon by a force". The 2nd Law states that "a body acted upon by a force will change its velocity in proportion to the applied force". While the 3rd Law says that "when two bodies exert a force upon each other the force acts on the line connecting them and the two force vectors are equal and opposite". What do these laws mean when applied to the human body? Firstly for anything to start moving a force has to act on it, secondly how fast it moves depends on the magnitude of the applied force. The applications of these two laws to the human body are relatively obvious, muscles act by contracting and thus generating a force. What needs to be considered is that shortening a muscle against no resisting force requires no muscle force, what produces the force is the muscle shortening against some form of resistance. The third law is commonly restated as "every action has an equal and opposite reaction" and it is this law combined with the first law that is used in calculating forces generated in the body and how these effect the movement of parts of the body.

The second basic element needing to be considered in biomechanics is the behaviour of levers. Archimedes (287-212BC) is quoted as having said "Give me a fulcrum and I will move the world". We can analyse the behaviour of the human body as a mechanical system by modelling the bones as levers, the weight of components of the body as the loads which need to be moved and the muscles as the applying forces. Levers come in three classes, depending on the relative positions of the fulcrum, the pivot point about which the lever moves, and the load force which the force which needs to be moved and the effort force which is the force doing the moving, that is the muscle force in the body. An example of a Class I lever is the child's seesaw, where the fulcrum is in the centre and the two people are the load and effort forces. In the human body there are few Class I levers, one example is at the head where the C1 vertebra acts as the fulcrum, mass of the head is the load force and is anterior to this fulcrum, while the extensor muscles of the neck supply the effort force. In Class II and III levers the fulcrum is at one end of the lever and the load and effort forces are to the same side of the fulcrum. In Class II the load force is between the fulcrum and the effort force while in Class III the effort force is between the load force and the fulcrum and the Class III lever is the most common type of lever found in the body. As the forces multiplied by their distance from the fulcrum have to balance where the effort force is nearer the fulcrum than the load force the effort force has to be higher than the load force.

Force is measured in Newtons (N) in the SI (Système International) unit scheme. 1 Newton is the force exerted by 1 kg (kilogram) when accelerated at 1ms-2, thus force exerted by 1kg on earth is 9.81N as the acceleration due to gravity on earth is 9.81ms-2. One simple way to remember the value of a Newton is that the force exerted on earth by a typical apple weighing about 100g is about 1N.

In analysing the biomechanics of the body we can consider a simple action, holding a weight in the hand with the forearm held horizontal and the upper arm horizontal. The weight is acting downwards and to be held still the upwards forces in the arm through to the body must be equal and the moments about the elbow joint must be equal. If we assume the weight of the lower arm is 20N and the weight held in the hand is 10N (thus approximately 2kg and 1 kg mass respectively) and that the length from the elbow joint to the hand is 300mm and to the the centre of mass of the forearm is 130mm with the line of action of the biceps muscle being 50mm. We can calculate that the force in the biceps has to be 112N.

If we apply similar calculations to a person standing on one leg and making appropriate assumptions of distances in the body then we can calculate that the load on the femoral head is 2.58 times the subject's body weight and that the forces in the abductor muscles is 1.77 times body weight. If these simple calculations are compared with the data from an instrumented hip prosthesis (Bergmann, Graichen et al. 1993) then it can be seen that the forces calculated using a simple two dimensional analysis can give a good estimate of the actual forces occurring in vivo. These types of analysis can be applied throughout the body.

The final factor to be considered is the number of load cycles applied during walking and other activities. (Wallbridge and Dowson 1982) found that the number of load cycles applied to the legs dropped from an average of 2 million per year when people were in their 20s down to 0.5 million in their 80s. The interesting factor was that they also measured some joint replacement patients and found they these people were applying more load cycles than the average for their age group. In the hand Joyce and Unsworth (2000) estimated similar number of load cycles for the fingers, but estimated that the loading the fingers considered of two groups, high movement with low loads interspersed with limited motion but high loads.

Biomaterials
"A biomaterial is a non viable material used in a medical device, intended to interact with biological systems" according to (Williams 1999) and to function successfully it needs to be biocompatible, that is it "has the ability to perform with an appropriate host response in a specific application" (Williams 1999). The behaviour of a material in the body depends on two factors: the effect the implant material has on the body and the effect the body has on the implant material. The reaction to an implanted material (and thus implant) can be divided into four types: **Toxic,** that is it kills cells in contact with or away from implant, **Bioinert,** that is produces no response by the body and which never truely occurs as there is always a response to implantation, but when the response is minimal the material is called bioinert. **Bioactive**, which is encourages an advantageous response from the body and this will depend on where the implant is placed in the body and thus the required bioactive response and finally **Biodegradable** where the implant breaks down in the body to non-toxic components which are excreted by the body. The effects the body has on an implant can be defined as the response of the material to the internal environment of the body from the physiological environment, protein absorption, which is a particular problem with polymers, degradation whether required or not and finally corrosion, which particularly applies to metal implants.
When we are considering the mechanical properties of a material these are measured using stress, which is the force per unit area and strain which is a measure of the change in dimension and the ratio of these two is called Young's Modulus or stiffness. Further important mechanical factors are the ultimate strength, that is how much force a material can take before it breaks, the ductility, the amount a material deforms before it breaks and toughness which is a measure of how fast a crack progresses through a material once fracture starts. When choosing a material for use in the body one of the considerations is the mechanical properties of the material compared to those of the body component being replaced.
Cortical bone has Young's modulus of 7-25GPa, strength of 50-150MPa and a fracture toughness of 2-12 MN m-3/2, while cancellous bone has modulus of 0.1-1.0GPa and compressive strength of 1-10MPa (Currey 1998; Currey 2006). Cortical and cancellous bone are both brittle, but being able to react to their mechanical environment can be considered to be "smart" materials. **Cancellous bone** behaves as a typical foam, that is increasing the density (or decreasing the porosity) increases the stiffness and strength (Gibson and Ashby 1999). Ligaments and tendons have non-linear mechanical properties with the stiffness increasing as the load increases.

Materials can be defined into four basic groups: metals, ceramics, polymers and composites. **Metals** are normally used as alloys, that is small or larger amounts of other atoms are added to tailor the properties. Metals are reasonably stiff, ductile, that is they deform before they fracture, they generally have good fatigue properties and can be plastically deformed, that is they can be bent into new shape and remain in that shape as is used in the moulding of fracture fixation devices. The major metals used in orthopaedics are the stainless steels, the cobalt chrome alloys, titanium and its alloys. Stainless steel used in medical applications is usually 316 or 316L and consists of 18% chromium, 13% nickel, 2.5% molybdenum, and the rest is iron. The presence of the chromium leads to the alloy being "stainless" as a chromium oxide layer is produced on the surface, which does not easily oxidise further. Stainless steel has a Young's modulus of 210 GPa, is ductile, can be deformed (cold worked) and the fatigue properties are acceptable. Cobalt Chrome alloy consists of 27-30% chromium, 5-7% molybdenum with the rest cobalt. This formulation means that there is no nickel which is important for those patients who are nickel sensitive. Nickel sensitivity rates are variable within Europe and can reach over 20% in the Scandinavian population. Cobalt chrome has a Young's modulus of 230 GPa, a higher fatigue limit than Stainless Steel and has good wear properties. There are three major groups of titanium: commercially pure which is >99% titanium, Ti-6%Al-4%V which is therefore 90% titanium, 6% aluminium and 4% vanadium and finally the shape memory alloys which are approximately 50:50 titanium:nickel, with the exact composition being used to control the temperature at which the shape memory effect occurs. Most titanium alloys have a lower Young's modulus of 106 GPa, the wear debris is black in body thus looks unsightly to the surgeon, but this wear debris is not known to produced significant extra problems compared to other wear debris which may be as present in the body but is not as obvious to the surgeon. Titanium is notch sensitive, that is any notches or other sharp corners lead to significant reductions in the fatigue life, and also is heat treatment sensitive. (Cook, Thongpreda et al. 1988) showed that with appropriate heat treatment the fatigue limit, that is the fatigue load at which the specimen does not break was 625MPa, but if a porous coating was applied with an inappropriate heat treatment this fatigue limit was reduced to 200MPa. More recently newer titanium alloys are being developed which have yet lower Young's moduli, at 42GPa, thus bringing their stiffnesses closer to those of cortical bone (Hao, Li et al. 2007).

Bioceramics can be divided into 2 major groups, the bioinert which are principally zirconia (ZrO_2) and alumina (Al_2O_3) and the bioactive mainly hydroxyapatite ($Ca_{10}(PO_4)_6(OH)_2$) and tricalcium phosphate ($Ca_3(PO_4)_2$). The bioinert ceramics are principally used for articulating surfaces as either ceramic-on-polymer or ceramic-on-ceramic. Initially Al_2O_3 was preferred as ZrO_2 can be morphologically unstable but now PSZ (Partially Stabilised Zirconia) is available. Al_2O_3 has been used by Sedel in Paris for more than 30 years as ceramic-on-ceramic hip replacements (Nizard, Pourreyron et al. 2008). In the initial implants the individual grains in the ceramics components were large and failures occurred, now grain size is reduced and failures have reduced to >1:2000. However, very close tolerances on head-cup dimensions are needed so matched pairs are supplied to reduce the fracture risk.
Bioactive ceramics are used in five major applications: bulk implants, that is space filling implants, porous when used as implants for ingrowth or scaffolds for tissue engineering, granules used to bulk out or to replace bone graft, coatings which are either plain HA or HA+TCP (also called biphasic CaP - BCP) and finally as injectable where the calcium phosphate, with or without some calcium sulphate and other additives, is mixed in the operating theatre, injected into the body and sets *in situ*.

Polymers used in orthopaedics are primarily ultrahigh molecular weight polyethylene (UHMWPE), polymethylmethacrylate (PMMA), other methacrylates, polyesters, poly(glycolic acid) and poly(lactic acid) and finally the hydrogels. Polyethylene was introduced by Sir John Charnley in 1960 as the first metal-on-polymer joint replacement. Charnley initially used polytetrafluoroethylene (PTFE) as the bearing surface for his hip replace

ments and found such drastic wear that after 1 year joint motion was seriously reduced. He originally High Density Polyethylene (HDPE), which was replaced in 1970s with Ultra High Molecular Weight Polyethylene (UHMWPE) and now a range of Enhanced Polyethylene (partially cross linked) or heavily irradiated PE are used to reduce the production of wear particles. PE is used as concave bearing surfaces against metal or ceramics such as acetabular cups, the tibial plateaux of knee replacements, patella buttons etc. PMMA bone cement is used to fix (grout) joint replacements in place thus is used to space fill. It is supplied as a two phase materials, the powder phase is pre-polymerised polymethylmethacrylate beads plus benzoyl peroxide which initiates the polymerisation of the liquid monomer with a radiopacifier in the form of barium sulphate or zirconia. The liquid phase is methylmethacrylate monomer plus N,N dimethyl–p-toluidene. It is mixed in theatre when polymerisation starts due to the benzoyl peroxide producing free radicals that initiate the polymerisation of the MMA monomer. The rationale for the use of pre-polymerised beads and monomer is that the polymerisation process is exothermic, that is produces heat, and the monomer shrinks by approximately 21% during the polymerisation process. By using about ⅔rds pre-polymerised and ⅓ monomer the exotherm and skrinkage are both reduced. When in the "dough" state it is inserted into patient, under pressure and then implant pushed into the cement. Initially cement was hand mixed but now mixing is always performed under vacuum as this reduces the porosity (Wang, Franzen et al. 1993) thus improving the mechanical properties and reduces the exposure of theatre staff to the monomer fumes. Opacifiers are added to bone cement as being a polymer it is not visible on radiographs, but the opacifiers provide their own problems, acting as brittle fillers and thus reducing the mechanical properties and when the cement breaks up can become embedded in articulating joints increasing the wear in the joint and the presence of opacifier particles can lead to resorption of bone around the implant (Sabokbar, Fijikawa et al. 1997). Finally, antibiotics are added prophylatically to bone cement to reduce the risk of infection (Jiranek, Hanssen et al. 2006).
The major degradable polymers used are Poly (lactic acid) PLA and Poly(glycolic acid) PGA. Chemically these break down to lactic and glycolic acid, which the body breaks down to CO2 and H2O and excretes. Typically PGA is used in degradable sutures as PGA has fast degradation within the body. Due to its lower degradation rate PLA is starting to be used for fracture fixation in low load bearing applications the form of internal fixation plates. The current problems with degradable polymers is the strength and degradation rate. In attempts to improve the strength fibre reinforcement and ceramic reinforcement has been used (Bleach, Nazhat et al. 2002; Huttunen, Törmälä et al. 2008).

Composites are two phase materials were the two phases can be seen as separate either with the naked eye or using a microscope, that is the two phases can be differentiated on the micron scale. Artificial composites are generally used to optimise the properties of the two phases. The individual phases interact be it mechanically or functionally. The major groups of composites are polymer reinforced with ceramics/glasses, polymers reinforced with different polymer or polymer form such as drawn fibres of a polymer in a amorphous matrix of the same polymer, an example is the PLLA in PLDLA used in some degradable fracture fixation plates. Ceramic metal composites, which are also known as metal matrix composites a few of these have been developed for medical applications and finally ceramic-ceramic composites, but neither of these but have as yet reached clinical applications. In a composite there is normally one continuous phase called the matrix and a second phase called the filler distributed in the matrix as particles, fibres or fabric. Generally phases chosen as when specific properties of one phase are "good" in the other they are "bad", but by getting right balance of phases can balance the properties to optimise the material. Applications of biocomposites in medical applications is beginning to increase (Tanner 2010). The earliest ones were bioinert, but now bioactive implants are beneficially interacting with the human body.

Conclusions

In conclusion when placing implants in the body there are two major interacting factors that need to be considered for the survival of an implant in the body. The first is how heavily is it being loaded and the second is what is it made of. Without appropriate interactions between both of these factors an implant will not be successful

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16. Williams, D. F. (1999). The Williams Dictionary of Biomaterials. Liverpool, Liverpool University Press. Diagnostic Work Up and Recognition of Primary Bone Tumours

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Diagnostic work up and recognition of primary bone tumours

Whilst we know that the frequency of metastases of bone is unknown we know that bone sarcomas occur at approximately the rate of six cases per million, therefore in the United Kingdom we are likely to see 360 cases per annum. They present in a number of ways. The commonest is by pain, secondly by swelling which is more common in children, occasionally by pathological fracture and rarely by alteration of leg or arm alignment. It is a disease essentially of young people, although rare below the age of five years. Diagnosis is dependent upon consideration of the problem. Symptomatology of persistent pain or swelling should lead to an x-ray. X-ray should lead to recognition of a radiological abnormality. Review of the radiological abnormality would suggest:

1. What is the lesion doing to the bone?
2. What is the bone doing in response to the presence of the lesion?
3. Are there any characteristic features detectable?

Radiological consideration should be given to the age of the patient, the site of the lesion within the bone and the radiological appearance. Having established the consideration that a primary bone tumour may be present it is important to stage the patient locally and distally. Local staging essentially takes place by an MRI, distal staging takes place by CT scanning and Technetium Bone Scanning or occasionally by PET Scanning. Once the lesion is staged it is important to obtain a tissue diagnosis. Most commonly throughout the world this is performed by targeted (CT, plain radiographs or Ultrasound) Jamshedi needle biopsy. This method is 98% accurate in peripheral malignancies in centres of excellence. If pathological excellence is not available then open biopsy should probably be considered. It has long been understood that open biopsy leads to larger local contamination and clinical morbidity in the paper of Mankin dating back to 1982 shows that it worsens prognosis in 8% and therefore increases the risk of amputation. Once staging and biopsy are complete then the tumour is placed into Enneking's classification clinical staging system which is as pertinent today as when it was first described. In the late 1970s all malignant primary bone tumours apart from chondrosarcoma are given neo-adjuvant chemotherapy and then subjected to resection and reconstruction. It is beyond the scope of this lecture to discuss methods of reconstruction, but the use of endoprosthesis will be described briefly.

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Diagnostic algorithm and treatments options: In bone metastasis

Oncology management is becoming an increasingly more serious task in orthopaedic and trauma surgery. A significant number of patients, who have solitary or multiple bone metastases can survive on cytostatic treatment for years.
The significance of the treatment of bone metastases is indicated by the fact that they are 80-100 times more common than primary malignant bone tumors. Various cancers have very different „bone affinities" as concerns their metastases (Table 1.).
In 65-85% of bone metastases the primary site of the tumor is in the breast, lung, kidney and prostate. The bones most frequently involved in decreasing sequence are: lumbar, dorsal, cervical spine, ribs, proximal femur and tibia, skull, pelvis, sternum and humerus. Only 1-2% of these secondaries affect the short tubular bones of the hand and foot.

Symptoms: Deep intermittent pain that is independent of the movement, often presents weeks or month before the X-ray changes are detected. The case history (primary cancer!) and laboratory tests must be thoroughly evaluated. In 10-30% of cases the first episode is a pathologic fracture of a lytic metastasis of kidney or lung cancer. Osteoplastic metastases of prostate cancer rarely break and have good propensity to heal.

Imaging: In suspected cases, e.g. when there is local bone pain after history of tumor, an X-ray is taken of the area in question and CT, MR (occasionally PET-CT) scans are added if necessary. In spine, in the opposite of spondylitis the tumor involves single vertebral bodies, invading the intervertebral space only in later stage. In the long tubular bones, the lesion may be central, though it is more often eccentric, involving the cortex. Periosteal reaction is in most cases absent. Bone scan is also extremely important to decide if the process is single or multiple (Fig. 1.a. and b.).

Prognostic factors: The most sensitive prognostic factor is the origin of the primary tumor (Table 2.). In cases of breast, prostate, thyroid and kidney cancers, the expected survival time is much longer than in cases of lung cancers or bone metastases of melanoma (Fig. 2. and 3.). The life expectancy is poor (Table 3.) when the primary tumor is unknown or inoperable, or when the primary is discovered at the same time as the metastases, if the metastases are inoperable, multiple or multiorganic.

Surgical treatment: The surgical intervention can be palliative or curative. The aims of palliative surgical treatment are: to alleviate the pain, to prevent the imminent fracture, to osteosynthesize and strenghten the bone in case of pathologic fracture using the less invasive technique, to reconstruct the motion and mobility of the patient ensuring a better quality of life. There is a broad range of the possible surgical procedures for reconstruction of the defect, i.g. plating (Fig.4.), intramedullary nailing (Fig.5.), curetting the defect and filling up with bone cement or insertion of a normal (Fig.6.) or tumor endoprosthesis. Intramedullary nailing is advantageous for it is stable weight-bearing, and even if the tumor progresses, loosening of the implant is not likely. In 10-20% of the cases a curative-type radical tumor excision (Table 4.) is warranted using limb-saving surgery and reconstruction of the defect by modular tumor endoprosthesis or allograft.

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FIGURES:

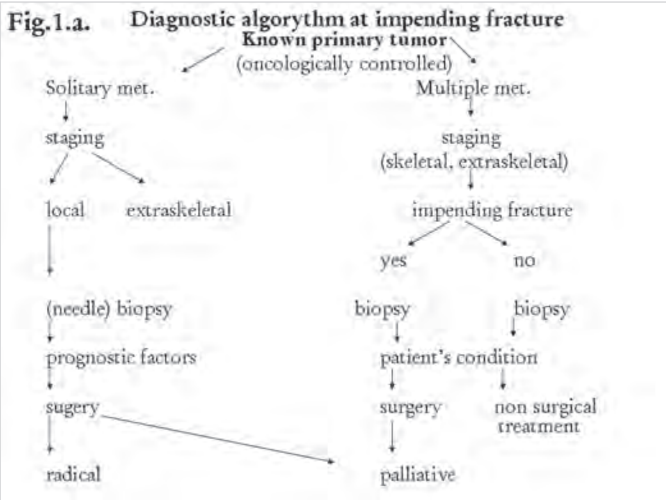

Figure 1a:
Diagnostic algorythm at impending fracture (Known primary tumor)

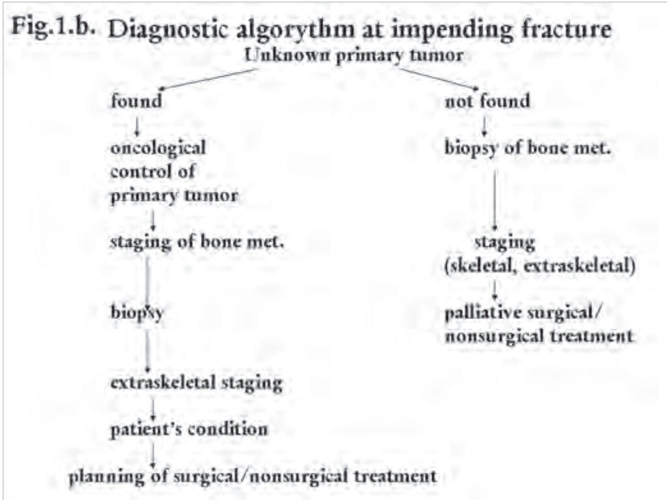

Figure 1b:
Diagnostic algorythm at impending fracture (Unknown primary tumor)

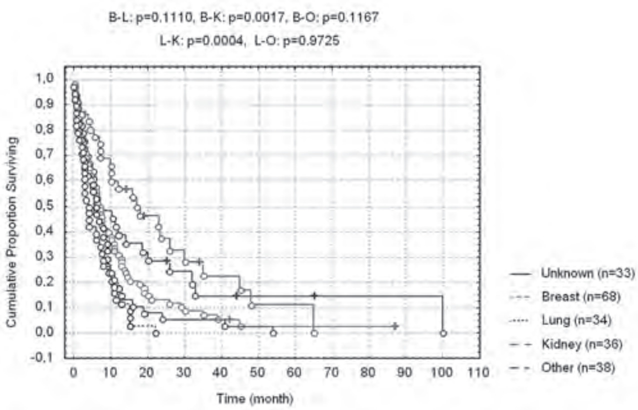

Figure 2:
Survival according to the primary site in 209 metastatic patients

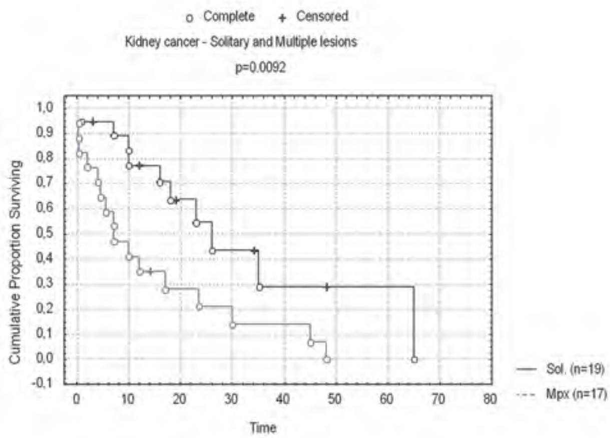

Figure 3:
Survival according to the solitary and multiple manifestations of bone metastases in kidney cancer

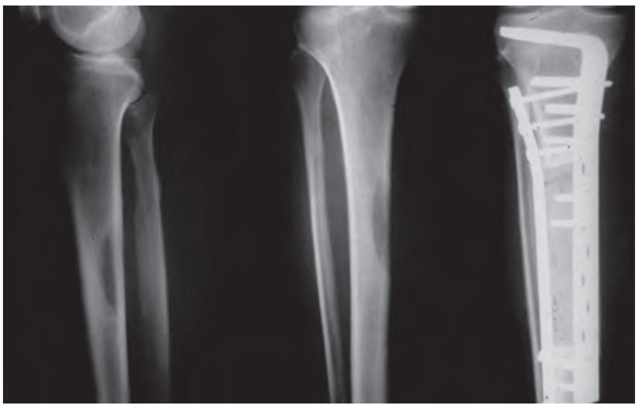

Figure 4:
Plating with cementation

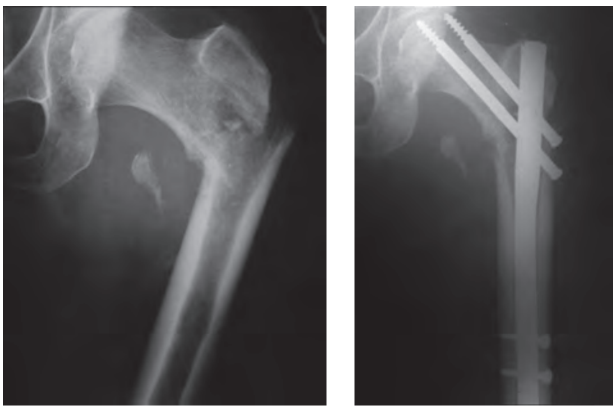

Figure 5:
Intramedullary nailing

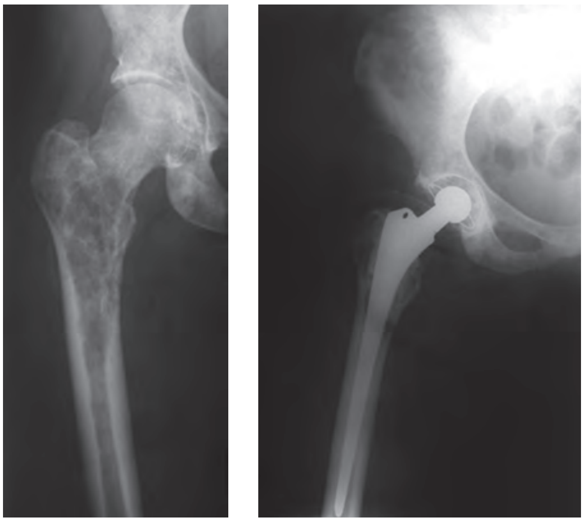

Figure 6:
Conventional cemented revision endoprosthesis

TABLES:

Table 1.
Characteristics of skeletal metastases

- In 65-70 % of bone metastases the primary site is: lung, breast, kidney and prostate
- Imaging: lytic, mixed or sclerotic lesions
- Periosteal reaction is usually absent
- 10-20% are solitary at recognition but multiplication occures in 1-3 yrs
- Pathological fracture in 20% of the cases
- Risk of pathological fractures:
  - more than 2 cm,
  -lower limb (peritrochanteric region)
  -lytic type

Table 2.
Favourable prognostic factors

- Primary site: breast, kidney
- Interval between primary tu and met: more 4 yrs
- Solitary metastases
- Radical excision
- Grade 1, less vascular metastases (kidney)
- Chemo-,radio-, hormone sensitive tumors

Table 3.
Unfavourable prognostic factors

- Primary tumor: unknown, or oncologically uncontrolled
- Primary site: lung, liver, pancreas, or melanoma
- Axial location
- Multiple/multiorganic metastases
- Short doubling time of metastasis
- Radio-, chemotherapy resistency
- Synchron or metachron appearence of metastases
- Poor general condition of patient

Table 4.
Indications for radical excision

- Oncologically controlled primary tumor site
- Solitary bone metastasis
- Positive prognostic factors
- Conditions present for radical excision

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The growing skeleton (infections, dysplasias)

The skeleton is a mosaïc of growth plates; each growth plate has a uniform structure but the morphology can be spherical (example: femoral head) or rectangular (example: distal femur). Each growth plate has its own velocity. There is a perfect harmony and interaction in the chondroepiphysis (example: hip or elbow).
Enchondral ossification is a basic process with three phases: Mesenchymal, cartilaginous, and ossification phases.
The upper and lower limb where there will be the first ossification center is were there will be the most important growth: Proximal humeral epiphysis, distal femoral epiphysis.

The growing skeleton and infection
Neonatal septic hip is an emergency; the infection process can destroy the growth plates of the femoral head and leads to head diformity with hip dislocation and severe limb discrepancy more than 10 cm.
Axial deformity, shortening, incongruency are the consequences of a paediatric infection involving a growth plate.

The growing skeleton and chondrodystrophy
Any abnormality inside the growth plate: disorder of the cellular process, disorders of the chemical and physical matrix lead to a growing deformity of the skeleton. Two examples:

- Achondroplasia: short limb and normal trunk and spinal stenosis
- Morquio's disease: short trunk and abnormal epiphysis.

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Specific fractures

Specific types of trauma in childhood
Specific fractures in children are particular by the biomechanics of child's bone, the presence of growth plate and epiphysis and the type of trauma.

A. Obstetrical trauma
1. Clavicular fracture displaced/undisplaced
2. Lesion of the brachial plexus
3. Proximal humeral fracture (epiphysis not visible on the X-rays)
4. Cervical or upper thoracic fracture with or without neurological impairment
5. Proximal femoral fracture

B. For babies and small infants: battered children syndrome
1. Specific fracture:
2. Corner fracture
3. Multiple asynchron fracture,
4. Fracture of the rips
5. Skull fracture.

C. Upper arm lesion due to fall : infants without established balance fall often with upper arm reception causing
1. Wrist or
2. Elbow fracture.

D. Infants and young adolescents: mainly pull out fractures at the ligaments insertion than ligamentar lesions.

Epiphyseal fractures
The easiest classification is the Salter Harris Thompson classification. More complicated fractures classifications like Odgen or AO fracture are also described in the literature.

Salter Harris classification:

Salter I : epiphyseal line fracture and displacement without fracture of metaphysis or epiphysis.
Salter II : epiphysis is intact, the fracture line goes partially through the epiphyseal line and through the metaphysis.
Salter III : fracture through the epiphysis and through part of the epiphyseal line.
Salter IV : fracture through the epiphysis and the metaphysis.
Salter V : compression of the epiphyseal line without visible displacement.

The type II is the most frequent.
Every time that a fracture involves the epiphysis itself, perfect reduction is mandatory. Types IV and V are more prone to growth disturbances, long term follow up and good knowledge of bone growth mechanism are mandatory for the treatment of this type of fracture.
Peterson describes a fracture which involves the metaphysis with secondary fracture line directing to the epiphyseal line with classification of four categories of increasing involvement of the epiphyseal line.

Specific diaphysal and metaphysal fracture
- Greenstick fracture
- Torus fracture
- Plastic fracture
- Subperiosteal undisplaced fracture
- Metaphyseal Peterson type fracture

Specific Children Fractures by anatomical location

A. Fingers:

The most common lesions are crush fractures of distal phalanx with soft tissue injuries and proximal phalanx epiphyseal fracture. The index and small fingers are the more often involved.

Mallet finger with partial or total epiphyseal fracture.

B. Former arm:

Radial fracture and Galleazzi, distal ulna dislocation

Ulna fracture or incurvation with radial head dislocation (Monteggia) (four types depending of the direction of dislocation).

C. Elbow:

Condylar fracture, supracondylar fracture, elbow dislocation with or without epitrochlea pull out. Radial head fracture/dislocation

D. Acromioclavicular fracture:

During growth, the fracture line goes through the epiphyseal line, at the lateral end of the clavicul, coraco-clavicular ligaments remain attached to the periosteum. Open reduction is advised.

E. Hip:

Femoral neck fractures are associated (Delbet type are associated with femoral head or femoral neck of both necrosis depending of the trauma energy).

F. Knee:

Fracture of the tibial spine. Classification of Meyers-McKeever depending on the displacement.

Fracture of the tibial tuberosity.

Fracture of the patella., Sleeve fracture, osteochondral fracture and patella dislocation.

G. Ankle fractures :

Triplane fractures, Tillaux-Chaput fractures, McFarland fractures. Osteochondral fractures of the talus.

This is not an extensive description of fractures in the growing skeleton but it’s mandatory to know:

- the possibility of pathologic fracture, bone fragility, bone tumour or lytic lesion.

Fracture can occur without radiological signs

Epiphyseal fracture in small children, undisplaced fracture.

There is a lot of anatomical and development variations in the growing skeleton,. a radiological atlas must be consulted for every specific case.

The mechanic resistance of the periosteum, the speed of bone healing, remodelling due to remaining growth are three features that influence fracture treatment in children towards conservative treatment.

Surgical treatments are mainly indicated for largely displaced instable fractures and epiphyseal fractures, fractures in polytraumatized children or open fractures. Approaching to the end of growth, treatments applied to adults are also indicated.

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Neuroorthopaedics

1. Introduction, definition and causes of cerebral palsy:
Cerebral palsy is a convenient term to describe neurodevelopmental conditions that are recognized in childhood and persist throughout life. The 2005 International Committee definition is as follows:

> *Cerebral palsy describes a group of disorders of the development of movement and posture, causing activity limitation, that are attributed to nonprogressive disturbances that occured in the developing fetal or infant brain. The motor disorders of cerebral palsy are often accompanied by disturbances of sensation, cognition, communication, perception, and/or behavior, and/or seizure disorder.*

Cerebral palsy (CP) is the most common cause of physical disability affecting children in developed countries, with an incidence of 2.0 to 2.5 per 1000 live birth. CP can be the result of a malformation, injury, or infection of the developing brain in utero, during birth, or in very early childhood. The majority of causes have antenatal antecedents, and many causes are multifactorial. A minority are result of birth trauma or asphyxia. Prematurity and low birth weight are the leading associations with CP in developed countries. Maternal birth canal infections and viral infections of mother and child are increasingly implicated in the aetiology of CP. These include toxoplasmosis, rubella, cytomegalovirus, and herpes simplex infections (TORCH). Kernicterus as a cause of CP has decreased dramatically since the widely used prophylaxis with anti-D immune globulin G in the Rh-negative mother, intrauterine transfusions of the fetus, and phototherapy.

That way CP results from damage to the central-nervous-system occurring within the first 2 years of life. The main clinical characteristics for orthopaedic surgeons are:
- movement disorders due to spasticity,
- muscle weakness,
- dystonia,
- ataxia, and
- rigidity.

In patients with complex gait deviations, an instrumented clinical gait analysis is usually performed to determine optimal therapeutic strategies. Treatment plan can consist of a variety of options such as surgery, physical therapy, pharmaco-therapeutic (e.g. Botulinum toxin type A) treatment, or orthotics. For operative treatment there are many possibilities but generally it includes corrections of bony deformities and soft tissue procedures. Often several surgical interventions are performed in one session, i.e. by so called single event multilevel surgery approach (SEMLS).

2. Classification of CP by motor disorder type:
Motor type is classified using terms to describe muscle tone and abnormal movements.

- **Spastic:** ca. 70%, characterized by increase in velocity-dependent stretch reflexes. The most common, most predictable, and most amenable: all hypertonic CP types (except pure athetosis) develop contractures and deformities.
- **Dyskinetic:** ca. 15%, includes many terms and subtypes (e.g., dystonia and athetosis). The most variable and least predictable motor type.
- **Mixed:** ca. 10%, the most frequent combination is spasticity and dystonia.
- **Hypotonic:** ca. 2.5%, common in infancy. Most become hypertonic with time.
- **Ataxic:** ca. 2.5%, Characterized by poor balance and coordination, but no contractures and few deformities.

3. The Gross Motor Function Classification System (GMFCS):
The Gross Motor Function Classification System (GMFCS) is a 5 level classification system that describes the gross motor function of children and youth with cerebral palsy on the basis of their self-initiated movement with particular emphasis on sitting, walking, and wheeled mobility. Distinctions between levels are based on functional abilities, the need for assistive technology, including hand-held mobility devices (walkers, crutches, or canes) or wheeled mobility, and to a much lesser extent, quality of movement.
The focus of the GMFCS is on determining which level best represents the child's or youth's present abilities and limitations in gross motor function. Emphasis is on usual performance in home, school, and community settings focusing on what they really do, rather than what they are known to be able to do at their best (capability). It is therefore important to classify current performance in gross motor function and not to include judgments about the quality of movement or prognosis for improvement.

Children who have motor problems similar to those classified in "Level I" can generally walk without restrictions but tend to be limited in some of the more advanced motor skills. Children whose motor function has been classified at "Level V" are generally very limited in their ability to move themselves around even with the use of assistive technology.

GMFCS E & R between 6th and 12th birthday: Descriptors and illustrations

GMFCS Level I

Children walk at home, school, outdoors and in the community. They can climb stairs without the use of a railing. Children perform gross motor skills such as running and jumping, but speed, balance and coordination are limited

GMFCS Level II

Children walk in most settings and climb stairs holding onto a railing. They may experience difficulty walking long distances and balancing on uneven terrain, inclines, in crowded areas or confined spaces. Children may walk with physical assistance, a hand-held mobility device or used wheeled mobility over long distances. Children have only minimal ability to perform gross motor skills such as running and jumping.

GMFCS Level III

Children walk using a hand-held mobility device in most indoor settings. They may climb stairs holding onto a railing with supervision or assistance. Children use wheeled mobility when traveling long distances and may self-propel for shorter distances.

GMFCS Level IV

Children use methods of mobility that require physical assistance or powered mobility in most settings. They may walk for short distances at home with physical assistance or use powered mobility or a body support walker when positioned. At school, outdoors and in the community children are transported in a manual wheelchair or use powered mobility.

GMFCS Level V

Children are transported in a manual wheelchair in all settings. Children are limited in their ability to maintain antigravity head and trunk postures and control leg and arm movements.

GMFCS descriptors: Palisano et al. (1997) Dev Med Child Neurol 39:214-23
CanChild: www.canchild.ca

4. Classification of CP by topographical distribution:
Hemiplegia, diplegia, and quadriplegia each make up about one third of CP in population based studies. Monoplegia and Triplegia are very uncommon. When a child appears to have a lower-limb monoplegia, ask him or her to run. Mild hemiplegic posturing is frequently seen during running and absent at rest.

- **Monoplegia:** One limb only, most cases are found to be hemiplegia if examinated carefully.
- **Hemiplegia:** One side of the body affected.
- **Diplegia:** Both lower limbs affected, minimal involement of the upper limbs.
- **Triplegia:** Three limbs affected.
- **Quadriplegia:** All four limbs affected. A better term may be „whole body involvement".

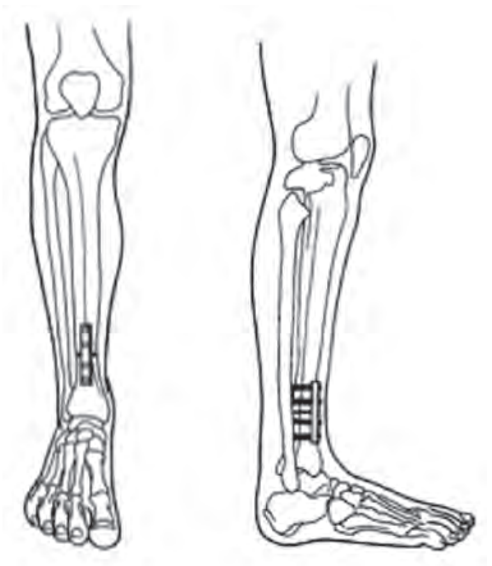
5. Treatment principles:
Treatment principles must be individually tailored to the child's need as determined by a comprehensive evaluation which includes careful physical examination, if indicated radiological analysis and instrumented gait analysis. The gross motor function classification system (GMFCS) is a prognostic tool and should not be used as an outcome measure. But the preoperative GMFCS level is very important to define each child's need and the treatment plan. The basic neurological disease does not heal.

The aims of orthopaedic treatment should be: good quality of life, represented by:
- pain reduction or no pain
- functional improvement (walking, working)
- patient's mobility (and as well sitting and transfer functions)

The treatment principles are:
1.neurological ("management of spasticity")
2.orthopaedic ("correction of biomechanics" by conservative and surgical options):
- muscle length
- muscle strength
- Lever arms
- Restoration of RoM

The natural history of gait in children with bilateral spastic CP is one of deterioration. Single Event Multilevel Surgery (SEMLS) is performed in order to prevent deterioration and to improve gait in patients with bilateral involvement of the lower extremities. This multilevel approach was first described in the 1980's. This approach reduces the amount of hospital stays for the child (so called "birthday syndrome") and corrects all the deformities in one operative session (usually performed in children with GMFCS level II and III).

6. Common problems in children with CP and treatment options:
A. Foot & ankle
Equinus is the commonest deformity in CP and consequently affects balance, standing, and gait. Muscle tendon lengthening always carries a danger of muscle weakness. Hence it is very important to avoid overcorrection at the level of the calf muscles, as there is a high risk for crouch gait.

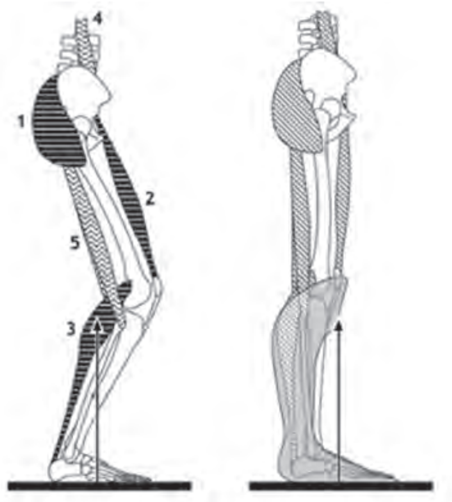


Lever arm dysfunction at the level of the tibia for example can be corrected by supramalleolar osteotomy (SMO).
SMO fixed with a locking Compression plate (LCP)

B. Knee

Crouch gait is characterized by excessive ankle dorsiflexion, excessive knee flexion, increased hip flexion, and variable pelvic postition (see graphs on right side).

1. hip extensors
2. knee extensors
3. ankle plantar flexors
4. iliopsoas
5. hamstrings

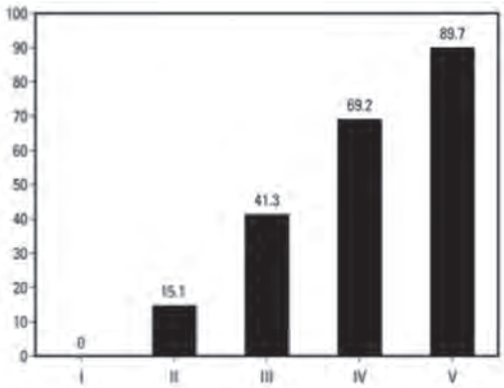


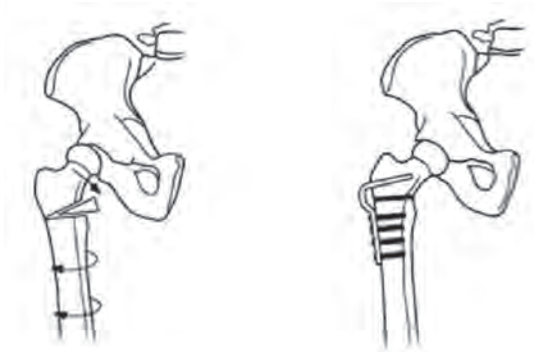
Treatment principles for crouch gait are:

a. correction of lever arm dysfunction (see hip, VDRO)
b. lengthen muscles that are contracted
c. correct fixed joint-flexion contractures (usually only the knee)
d. shorten muscles that are excessively long
e. deal appropriate with the affected biarticular muscles

C. Hip

The incidence of hip displacement (a migration percentage >30%) strongly correlates with the GMFCS level:





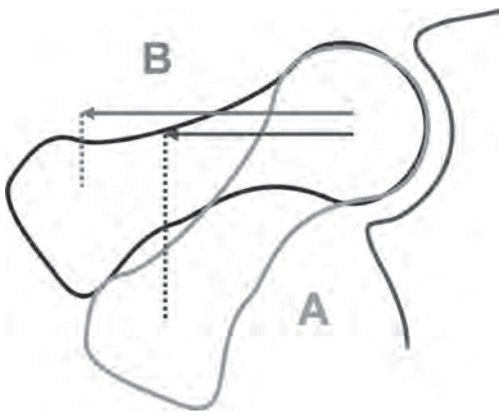
VDRO (proximal) fixed with an AO blade plate

It is better to prevent hip displacement (lengthening of the hip adductors and flexors or proximal femoral varus-derotation osteotomy (VDRO)) than to try to treat established hip dislocation (open hip joint reconstruction). Preventive surgery is more effective in younger children who are at least partially ambulatory and have mild-to-moderate degrees of displacement. More severe displacement or dislocation of the hip may require the use of femoral and/or pelvic osteotomies to correct both femoral antetorsion and coxa valga, angular or rotational abnormalities, and acetabular dysplasia.

Correction of the lever arm dysfunction at the level of the hip by VDRO:

The graphs show the hip joint in the transverse plane
The dotted lines represent the femoral antetorsion.

A: preoperative the femoral antetorsion is increased and the lever arms for the hip abductors are short
B: postoperative situation with normal femoral antetorsion and optimised lever arms for the hip abductors



D.Spine

Scoliosis, like hip displacement, is frequent in nonambulant children and GMFCS IV and V, but is rare in ambulant children (GMFCS levels I,II, and III). An idiopathic-type curve is occasionally seen in children with hemiplegia, but severe neuromuscular curves are found only in severly involved children. Neuromuscular curves are long thoracolumbar curves with pelvic obliquity and tendency to early onset and rapid progression. The curves are much more severe in the sitting position than in the recumbent position (because of gravity). Severe neuromuscular curves are diffcult to brace, and bracing is not effective. Therefore documented curve progression and loss of function are the important indications for surgical correction of spinal deformities.

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The foot

Abnormalities of newborn's feet
At birth, all new parents marvel at the look of their babies's tiny feet. For that reason, any anomaly or abnormality will be the cause for major emotionally concern for the family. More and more often, the orthopaedist is called to examine the feet of the new-born babies in the nursery and is also confronted with the moral distress of the parents. Therefore, it is important for general orthopaedists to have basic knowledge about the most common abnormalities of newborn's feet, and also their treatment.

The examination of the feet is part of the complete exam of newborn babies with proper skills, the foot examination can be performed quickly and allows early detection of most newborn foot problems, using few diagnostic studies. The foot should be divided and also examined in three anatomic regions; the hindfoot or rearfoot (talus and calcaneus); the midfoot (navicular bone, cuboid bone, and the three cuneiform bones); and the forefoot (metatarsals and phalanges). The various foot regions, just as the ankle joint should be moved through their respective ranges of motion, and also assessed for flexibility or rigidity, unusual positions, and lack of motion. In the event of foot abnormality, the reducibility of the deformity should be assessed.

Common newborn foot abnormalities include pes adductus, metatarsus varus, clubfoot deformity, pes calcaneovalgus (flexible flatfoot), congenital vertical talus (rigid flatfoot), and multiple toe's deformities, such as polydactyly, syndactyly, overlapping toes, and amniotic bands. Most treatments include conservative measures, such as observation, stretching, and repetitive cast's application to correct foot position. Unfortunately, surgery may be required in severe cases which are not resolved after conservative therapy. Persistent cast treatments and cases that require surgical correction should be referred to a specialist with expertise in the treatment of foot deformities in children.

This review course presents the current status of knowledge and treatment options available for common newborn foot abnormalities. Over the past 10 to 15 years, more and more success has been achieved in correcting most of common foot abnormalities, such as clubfoot, metatarsus varus, or flexible flatfoot, without the need of the surgery. For example, Ponseti's technique –which involves a series of gentle manipulations to stretch the soft tissues, followed by the application of a cast to hold the foot in position - became the "gold standard" for the clubfoot's treatment.

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The hip

The growing hip is fragile, vulnerable. Strict respect of the different growth plates of the femoral chondroepiphysis is a priority. Any injury, any disease can disorganize this subtle equilibrium; **motion, congruency, coverage and sphericity** are the basic requirements. Acetabulum and femoral head are interdependent.

Developmental hip dysplasia
Early diagnosis, early treatment, quick normalisation; a continuum: dysplasia, subluxation, unstable dislocation, fixed dislocation; 10 per 1000 newborns; primiparity, breech delivery, postural deformities, family history are risk factors. A nursery screening program allows successful treatment. Clinical examination is difficult. The Barlow test is provocative. The Ortolani sign reduces a dislocated hip. In doubt, do not hesitate to perform a dynamic ultrasound. Systematic ultrasonography is controversial. Pavlik harness is indicated when the hip is dislocatable or dislocated.

Acute and chronic slipped capital epiphysis
Weakening of the perichondral ring of the physis.
Puberty, obesity, limp, pain.
Treat quickly.
Differentiation must be made between:

1. acute, inability to bear weight, unstable
2. chronic, ability to bear weight, stable
3. acute on chronic.

Screw fixation is the current technique. Chondrolysis and avascular necrosis are the most serious complications. Treatment of severe unstable hip is controversial: closed reduction or open reduction (?) with screw fixation.

Legg Calvé Perthes
Cyclic and ischemic disease. Three main factors: age, extent and containment; the younger is a child and the greater is the chance to have a good result (spherical head). Early differentiation between benign and severe form is essential; treat only severe forms; stiffness, obesity and ages > 6 years are pejorative factors; before 6 years of age, 80% of hips will get back to sphericity; between 6 and 9 years, 45%, and after 9 only 20%. Motion is essential to maintain. Whatever the age or the extent, **containment is a priority.** Early surgery in severe forms after 6 years improves results. In **LCP disease**, the surgeon proposes and the growth plate decides! (A. Dimeglio).

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Spine Trauma

This review course presents the current status of knowledge and treatment options available for spinal fractures, including cervical and thoraco-lumbar areas. Several classic and more recent references are given in this syllabus.
Several spine textbooks are available for spine care, including management of traumatic injuries(Frymoyer 1997; Vaccaro, Betz et al. 2003).
For surgical techniques and implants, the *AOSpine Manual* volume 1 ("Principles and Techniques") and volume 2 ("Clinical Applications") is a valuable tool(Aebi, Arlet et al. 2007). More information can be found on the AO website: *http://www.aofoundation.org*

Initial Management of Spine Fractures of Polytrauma Patients and Spinal Cord Injury
Spinal fractures very often result from high-energy trauma and affect a very young age class of the population. In fact, most of those lesions are due to motor vehicle accidents (MVA). Depending on the fracture morphology, the occurrence of neurological lesions varies in average between 20% and 55% (Magerl, Aebi et al. 1994). Initial management of polytrauma patients follows ATLS guidelines (ABCDE). A rigid collar should be applied at the scene of the accident to protect the cervical spine and the patient is carefully mobilized (log roll). First priority is given to lifesaving procedures, airway protection and cardiopulmonary resuscitation (ABC) that also have the benefit of protecting the spinal cord from secondary ischemic damages, and then attention is driven towards neurologic function (D). Once vital functions have been stabilized, surgical management can be decided (Patel, DeLong et al. 2004; Harris and Sethi 2006). For several years, administration of methylprednisolone in spinal cord injuries has been considered as a gold standard, based on the results of the NASCIS studies. Several drawbacks of the studies have been later emphasized and the systematic use of methylprednisolone has been discontinued in all major trauma centers (Fehlings 2001; Hawryluk, Rowland et al. 2008; Rowland, Hawryluk et al. 2008). Other potentially neuroprotective drugs are currently under evaluation.

Injuries to the Cervical Spine
Injuries to the cervical spine are separated into injuries to the upper cervical spine including the cranio-cervical junction (C0-C2), and injuries to the lower cervical spine (C3-C7).

Injuries to the Upper Cervical Spine
Fractures of the *occipital condyle* result from high-energy blunt trauma. Various radiologic classifications are available(Anderson and Montesano 1988; Tuli, Tator et al. 1997). More recently, an interesting clinical decision diagram has been proposed by Maserati et al.(Maserati, Stephens et al. 2009) Surgical treatment is usually recommended in case of neurologic compromise and demonstrable cranio-cervical misalignment(Maserati, Stephens et al. 2009).

Atlanto-occipital dislocation is a rare injury and often immediately lethal, especially type II according to Traynelis' classification, where the brain stem and upper spinal cord are submitted to traction(Traynelis, Marano et al. 1986). Children are particularly predisposed to this type of injury. Clinical diagnosis can be very tricky in these patients who also frequently suffer from significant cerebral trauma and a low score on the Glasgow Coma Scale. Radiologic diagnosis is not always straight forward either and we will go through the different measurement methods that have been described. Occipito-cervical fusion is usually recommended in surviving patients.

Fractures of the *atlas* (C1) also result from high-energy trauma, usually axial compression. Jefferson's fracture (1920) is also called burst fracture of C1 and consists of 4 fracture lines on the axial ring. There is an up to 50% occurrence of other cervical spine fractures, in particular of C2. Treatment is guided according to the presence or absence of C1-C2 instability (C2 transverse ligament). MRI is a helpful tool in that matter. Most of the C1 fractures are treated conservatively by halo-vest or another external contention. Surgery is indicated in fractures with C1-C2 instability and usually consists in occipito-cervical fusion-instrumentation. If the lateral mass of C1 allows it, then a C1-C2 fusion with pedicle screws can be attempted.

Fractures of the *odontoïd* (C2) can be of several types (C2 tear drop type is excluded here): fractures of the dens and traumatic spondylolisthesis. They both occur with significant traumatic energy in flexion or extension.
Fractures of the *dens* are classified according to Anderson and D'Alonzo's publication of 1974(Anderson and D'Alonzo 1974). Type I fractures consist of avulsion injuries at the tip of the dens. Type II fractures occur through the base of the dens and Type III fractures extend into the body of the C2. Spinal cord neurologic deficit can occur in up to 10% of the patients. Type I and III are usually treated with external immobilization with a high success rate. Type II fractures are more problematic due to a higher risk of pseudarthrosis, especially in patients older than 40 years and in presence of posterior displacement. Surgical treatment technique for acute type II fractures will depend on the direction of the fracture line: sin-

gle anterior dens screw or posterior C1-C2 fusion. Pseudarthrosis is treated by posterior fixation and fusion.
Traumatic spondylolisthesis is also wrongly referred to as *"hangman's fracture"*.
Combinations of extension, flexion, distraction, and axial loading of the cervical spine can cause it. The fracture line goes through the isthmus or the pedicle of C2, which are very close anatomically. The modified Effendi classification is the most frequently used system (Effendi, Roy et al. 1981; Levine and Edwards 1985). Non-surgical treatment in type I and surgical treatment in type III are well recognized. Treatment of type II fractures is more controversial and will depend on several factors, including degree of instability, age, and possible skin issues precluding external immobilization.

Injuries to the Lower Cervical Spine
They result from four "cardinal" force vectors: *distraction, hyperflexion, hyperextension* and *axial compression*. Various classification schemes have been described, but none has reached a consensus amongst spine specialists (Allen, Ferguson et al. 1982). It is not the purpose of this course to go through the details of classification systems of the lower cervical spine, which are quite complex. During the course, we will explain the main principles of diagnosis and treatment. Treatment decision is based on neurologic status, degree of displacement and degree of instability, which can be either mainly osseous or mainly ligamentous. MRI should be ordered in case of doubt, like in teardrop fractures, which can result from hyperextension (non-surgical treatment) or from hyperflexion (severe disco-ligamentous injury which needs surgical treatment), but for which diagnosis might be difficult to make on plain standard XR's.

Injuries to the Thoraco-Lumbar Spine
The same initial management principles are to be applied as for cervical spine injuries.

Classification of Thoraco-Lumbar Fractures and Decision Making
A complete and clear summary of current and historical classifications of thoracolumbar fractures can be found in the landmark publication by Magerl et al. in 1994 (Magerl, Aebi et al. 1994). This AO classification is currently the most frequently used classification system in scientific publications. However for all-day practice, a few studies have now shown that interobserver reliability is quite low as soon as observers go past the first level of classification (types A, B or C) (Wood, Khanna et al. 2005).
Choice of treatment is not only based on radiological aspects of the fracture, but also on general health condition of patients. For the same type of fracture, decision regarding type and timing of treatment can differ whether the patient is for example polytraumatized with neurologic lesions or monotraumatized without neurologic deficit.
There are several well-known radiological exams that have been in use since long to characterize the fracture morphology, like standard Xray views and CT scan. The AO classification is based on those two types of exams (Magerl, Aebi et al. 1994). More recently, possible ligamentous lesions have come to a closer attention with the frequent use of MRI. Taking into account imagery improvements and the patients' neurological condition, a new classification system has been proposed by the Spine Trauma Study Group: the Thoracolumbar Injury Classification and Severity Score system or TLICS (Vaccaro, Lehman et al. 2005; Patel, Dailey et al. 2009).

Non-surgical treatment
At the beginning of the 20th century, before the advent of surgical treatments, fractures of the thoraco-lumbar spine were treated by bracing. Lorenz Böhler (1885-1973), an Austrian trauma surgeon, described reduction and bracing techniques for spinal fractures as well as deformities resulting from such fractures (Böhler 1929). Some of these bracing techniques are still used nowadays.
Depending on the amount of deformity and anatomical localization of the fracture, non-surgical treatment can be prescribed: functional treatment without bracing, or bracing with or without external reduction maneuvers. Modern manufacturing techniques allow us to apply light custom-made polyethylene braces. Handmade braces under strict supervision of the treating surgeon can sometimes still be needed, especially when external reduction maneuvers are needed.
Another important factor of non-surgical treatment is muscular strengthening exercises while wearing the brace.
With the advent of modern less aggressive surgical techniques, we might be facing in the upcoming years a shift towards surgical treatment in lesions that would have been classically treated conservatively.

Surgical Treatment
If surgical treatment is seldom controversial in thoraco-lumbar fractures with neurologic injuries, there is currently no consensus on what should be done for patients without neurologic deficit (Wood, Buttermann et al. 2003; Wood, Bohn et al. 2005). In these cases, surgical indication is based on evaluation of stability using biomechanical principles, but also, we have to admit, on "local" philosophical viewpoints, depending on the surgeons' training. Three criteria are generally applied for treatment decision: *neurologic stability, mechanical stability* and *deformity* (local and regional).

Neurologic stability is defined as protection of the spinal cord from any other damage. It is not the purpose of this review course to go too much into details of neurologic damage and how to prevent it from worsening, but some crucial points will be presented. Emergent decompression and stabilization is mostly recommended in partial or progressive neurologic deficit. It is also noteworthy to acknowledge that the use of corticosteroids should not be recommended anymore in the current management of spinal cord injuries due to the fact that there has been no clear scientific evidence of any benefit from this drug, which can have serious adverse effects (Fehlings 2001; Hawryluk, Rowland et al. 2008; Rowland, Hawryluk et al. 2008).
Mechanical stability is defined as the ability of the spine to allow a physiologic range of motion while protecting the neural structures of the spi-

nal canal (White and Panjabi 1990). Although it may seem as a simple and obvious definition in theory, in practice it is not such. When mechanical instability results in neurological instability, the decision process for treatment can be quite simple. When only mechanical instability is suspected based on trauma mechanism and radiological criteria, it can be more challenging. For that purpose, MRI has made its debut a few years ago to help assess possible ligamentous injuries, not or less well detectable on standard Xray views or CT scan (Lee, Kim et al. 2000).
Kyphotic *deformity* can be local (vertebral kyphosis) or regional, between upper and lower endplates of adjacent vertebrae (traumatic regional kyphosis). The cut-off amount of kyphosis between non-surgical and surgical treatment will vary depending on anatomical localization of the fracture. Typically, a regional kyphosis of max 15° is tolerated for fractures between T11 and L1. For fractures above, greater deformity angles are tolerated and for fractures below, smaller angles.

The safest and quickest option for emergent decompression and stabilization of a thoraco-lumbar fracture with neurologic deficit is a classic posterior midline approach. Posterior stabilization can be achieved using short segment fixation techniques or longer constructs, in porotic bones for example.
A second anterior approach for additional decompression and reconstruction, if needed, can be postponed until the patient's general condition is stabilized. The load-sharing classification system can be useful in deciding whether there's a need for an anterior vertebral body reconstruction or not(McCormack, Karaikovic et al. 1994).

For fractures without neurologic deficit, treatment approach is based on the evaluation of mechanical instability, amount of deformity (kyphosis), but also other factors such as age, level of activity or socio-economic aspects.

New trends in surgical treatment of thoraco-lumbar fractures
Trauma and spine surgeons have always been striving to offer the best possible treatment while reducing aggressiveness of surgery. Several technical and implant innovations have been made these last years and help us to reduce soft tissue damage.
Video assisted endoscopy is an option to perform corpectomies and anterior column reconstruction. Obviously, there still is a need for a minimal skin incision size to get the implants in place. Other techniques addressing the anterior column (vertebral body) are cementoplasties (vertebroplasties) or balloon kyphoplasties. These techniques have since long been recommended for management of painful osteoporotic fractures of patients of 60 years or older, unresponsive to medical treatment (Wardlaw, Cummings et al. 2009). A great controversy has however recently risen from two recently published randomized studies (Buchbinder, Osborne et al. 2009; Kallmes, Comstock et al. 2009). Biologically active cements have also been proposed for the treatment of fractures in younger patients, but seem to be more friable. Those treatments are currently being evaluated by ongoing clinical studies, and in our opinion, indications of cementoplasties in high energy spine trauma have to be discussed separately from indications in osteoporotic fractures.
Less invasive posterior based stabilization techniques are now also available and can interestingly be applied in osseous lesions (type A fractures and type B with predominantly bony lesions). They consist in percutaneous pedicle screw and rod placement. There is an obvious interest in applying these techniques in patients with high risk of perioperative cardiopulmonary complications.
More interestingly will be to assess the results of combinations of all these less invasive surgical techniques. To give an example, a fracture stabilization by posterior percutaneous pedicle screw fixation combined to percutaneous vertebral body fracture reduction and injection of a bioactive cement, such as it is already done nowadays in several trauma centers across Europe.

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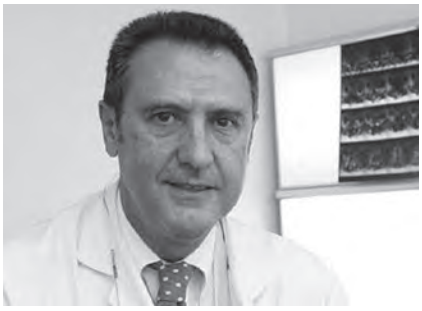

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Degenerative

Degenerative Conditions

The outer annulus in a normal disk is mostly type I collagen; the inner nucleus is type II collagen. With age, the ratio of keratin sulfate to chondroitin sulfate increases and water content decreases, leading to a cascade of secondary degenerative events (spondylosis), starting with disc height loss, and sometimes associated with disck herniation or calcifi cation. These changes in turn can result in increased segment motion, compensatory osteophytes, buckling of ligamentum, and facet arthrosis, all of wich can cause neural impigment. The clinical presentation of spondylosis can be manifested as axial neck pain, radiculopathy and/or myelopathy in the cervical spine and low back pain, radicular pain or claudication in the lumbar area.

Cervical degenerative disease

The prevalence of degenerative cervical conditions is only less than of low back pain.Cervical nerve roots exist above their corresponding numbered pedicles. (C6 exists between C5 and C6.) Nonsurgical treatment should be attempted for the vast majority of patients with cervical radiculopathy. Many forms of nonsurgical treatment relieve the pain but may not alter the natural history of the disease.

Surgical management provides excellent and predictable outcomes in patients with progressive neurologic dysfunction or failure to improve despite time and nonsurgical treatment. Either an anterior or a posterior approach can be selected in the appropriate circumstances, understanding that neither is perfect and each carries its own set of pros and cons. Cervical myelopathy is typically a surgical disorder. Early treatment, before the onset of permanent cord injury, is recommended. An anterior approach is indicated in patients with myelopathy arising from one or two disk segments. Laminoplasty is indicated in patients with multilevel involvement (three or more disk spaces). A combined anterior-posterior approach is indicated in patients with multilevel stenosis and kyphosis, or those with postlaminectomy kyphosis. The surgical procedure chosen must be tailored to the patient's specific pattern of stenosis, comorbidities, and symptoms. Strict adherence to a blind algorithmic protocol should be avoided.

Lumbar degenerative disease

Up to 85% of patients will experience low back pain at some point their lifetime, and it usually resolves in a matter of weeks The mainstay for treatment of acute low back pain is nonsurgical. The vast majority (90%) of symptomatic LDHs improve with nonsurgical management. A paracentral disk herniation will aff ect the traversing nerve root, not the exiting nerve root. For example, an L4-5 left paracentral HNP will result in an L5 radiculopathy, not an L4 radiculopathy. An intraforaminal or extraforaminal HNP will aff ect the exiting root. The absolute indicators for surgical management of LDH are cauda equina and a progressive neurologic defi cit. Both are rare. Lumbar spinal stenosis is typically associated with exertion. The diff erential diagnosis includes hip pathology, vascular disease, and peripheral neuropathy. The five main types of spondylolisthesis are degenerative, isthmic, traumatic, dysplastic, and iatrogenic. In situ posterolateral L5-S1 fusion is indicated for children and adolescents with a low-grade spondylolisthesis.

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Paediatric

When a child, with a spine deformity, is first seen by an orthopaedic surgeon accurate evaluation and documentation of all findings are imperative; Family and patient history are taken. Physical examination and imaging evaluation are for most of the cases enough to classify scoliosis according to their etiologies i.e. idiopathic, congenital, neuro-muscular, syndromic or symptomatic. One must keep in mind that idiopathic scoliosis in children are painless.
We will focus our presentation on idiopathic scoliosis (IS).

Low dose x-ray diagnostic imaging such as EOS provides a new modality for three dimensional scoliosis evaluations. Specific criteria are requested for MRI studies i.e. skin abnormalities along the spine, idiopathic scoliosis in a male, left thoracic, kypho-scoliosis, neurological abnormalities at physical examination including pes cavus and/or unilateral amyotrophic calf.
Age-related classification according to age at onset in IS are;
For SRS: infantile (0-3Y), Juvenile (3-7Y), adolescent (10-18Y) and adult (either primary degenerative or "de novo").
For BSS: early onset scoliosis (< 7Y) and late onset.
Location-related classification in IS are based on apex localisation:
Thoracic: apex: T2 to Disc T11/12, Thoraco-lumbar: apex: T12 to L1, Lumbar: apex: Disc L1/L2 to L4.

Several classifications have been proposed. An ideal classification must answer the following items:
Be based on objective criteria for each curve type. Must be comprehensive and include all curve types. Must take into consideration the sagittal alignment. Must help to define treatment/surgery that could be standardized. The reliability inter and intra observers must be good. Must be easy to understand and to apply in the daily practice. Must reflects the current concept of a 3-dimensional analysis of scoliotic deformities and must consider the skeletal age.
King classification does not answer all these criteria. Lenke's classification answers almost all these criteria except that Lenke's classification is not easy to apply in daily practice covering 54 different types of curve.
Etiology of idiopathic scoliosis is still not fully understood. We will present in our talk the main etiologic hypothesis.
Progression-equation which quantifies the risk for progression is a helpful tool.
For example in a child in between 10 and 12 Years of age, if the curve is less than 19° there is a 25% risk for progression. If for the same child the curve is more than 40° the risk for progression is 100%.
For scoliosis more than 30° at maturity the curve size still continues to increase during adult life. Thoraco-lumbar curves are the more prone for such an evolution.
The observed deaths are three times the expected deaths for the group of patients with an infantile scoliosis.
The frequency of back pain in a scoliotic population is the same as the general population.
According to the SRS report from the bracing and non-operative committee published in 2000:

> *"After extensive review, it is our opinion that bracing and surgery are the only scientifically proven methods of treatment for idiopathic scoliosis. There is no scientific rationale for any other methods of treatment".*

Bracing period seems to have no negative long terms effects as measured by Mental subscales of SF-36, patient general well-being index or SRS 22 scale.

In early onset idiopathic scoliosis, according to Mehta, serial casting followed by bracing is the first step of treatment in "malignant" types.
If the curve relapsed different surgical techniques can be proposed in a growing child such as Akbarnia dual growth rods, Campbell VEPTR, Mac Carthy procedure. None of these techniques are complications free. Infection, anchorage breakages of the devices, proximal junctional kyphosis, are the more frequent complications.
New magnetic devices are experienced to overcome the need for repetitive surgeries to lengthen the devices.
For late onset scoliosis there are a lot of devices available on the market.
Except specific cases anterior approach is less and less used for surgical correction.
Screws rather than hooks are more and more used for curve correction.
Hybrid constructs with screws and hooks or screws hooks and ligaments give satisfactory results.
Modern spine surgery needs to be performed in a secure way the use of intraoperative somatosensory evoked potentials (SSEP) and neurogenic

mixed evoked potentials (NMEP).
We performed a prospective study on 300 spine monitoring. Values of sensitivity and specificity of the monitoring showed slight differencies between patients under four years old versus older patients. There was no false negative outcome. Various tendencies were highlighted. There were more true positive alerts for secondary aetiologies than for idiopathic ones, for revision spine surgeries than for index ones, for boys than for girls.
Idiopathic scoliotic deformities range from a 10° right thoracic curvature in a fourteen old girl for who no treatment is needed to a 70° curvature in a 2 years old patient. For the latest if serial casting and bracing are not working the treatment is still challenging and a wide area of research is still open.

Lower extremity trauma

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Pelvic Ring Fractures - Acetabular Fractures - Hip Fractures.

1. Fractures of the Pelvic Ring.
Pelvic Ring: A ring constituted by both innominate bones and sacrum. Fractures of Pelvic Ring: High-energy trauma. Potentially severe because of retroperitoneal bleeding. Associated to some other severe lesions. Life threatening problem. Need prompt and proper diagnosis and treatment!.

Pelvis Anatomy.
Bone: Left and Right innominate bones, and sacrum. A ring with an anteroposterior (AP) diameter, and a transverse diameter (T), perpendicular to AP.

Ligamentum: Essentials! as pelvic joints are very little stable. Ligaments fix pelvic bone together. 2 main ligament groups: Shorts: Sacroiliac ligaments (anterior and posterior), and Longs: Sacro-sciatic and sacroischiatic.

Pathophysiology:
- Isolated lesions: Lesion of Shorts ligaments: Anterior: Innominate bones open apart. Posterior: Innominate bones override to each other. Lesion of Long ligaments: Always together with short ligament lesions: increases the displacement caused by anterior or posterior ligaments rupture. The pelvis displaces by opening or overriding its bones (Rotational instability), NEVER by ascending or descending its bones (Vertical instability).
- Combined lesions: Shorts: Anterior + Posterior: Rotational + Vertical instability. Always requires Some long ligament lesions. Vertical instability. Vertical instability ALWAYS is accompanied by rotational instability.
  Major risk of retroperitoneal bleeding: Rotational open instability or/with vertical instability. Vertical instability or/with open rotational instability.

Classification (3 Types)
Type A.
Ring diameter normal, only a non-important bone fragment. Rotational and vertical stability of pelvic ring. Mild risk of bleeding. Treatment by rest in bed and hemoglobin control for a few days. Seating and walking allowed.
Type B. (3 Types)
- B1: "Open book". Unilateral opening of sacroiliac joint, and symphysis pubis opening. Caused by an anteroposterior trauma. Rupture of short anterior ligaments (lesion of long ligaments increases displacement). Transverse diameter widens. Major risk of retroperitoneal bleeding.
- B2: "Lateral Compression". Unilateral posterior opening of sacroiliac joint, and symphysis pubis overriding. Caused by lateral compression trauma. Rupture of short posterior ligaments (lesion of long ligaments unlikely, but possible, not always: increases displacement). Transverse diameter narrowed. Little risk of bleeding.
- B3: Bilateral lesion. Figure 1.

Type C.
Vertical instability. Uni or bilateral. Lesion of all ligaments (shorts and longs). Always vertical trauma associated to some other mechanism (shearing force, anteroposterior, etc.). The most severe type!!.

Bone lesions: Anterior lesions: Forward to the hip joint. Posterior lesions: Backward to the hip joints. - Anterior isolated lesions provoke no vertical displacement. -Posterior lesions: Provokes vertical displacement. - Combined lesions: Ligamentum and bone lesions.

IN ANY CASE: Enlarging lateral diameters or provoking vertical displacement either by a ligamentum or bone lesion: RISK OF MAJOR RETROPERITONEAL BLEEDING.

Diagnosis.
1. Clinical diagnosis.
- ATLS support diagnosis protocol. Careful examination (avoid provoking pain-) or major mobilization: increases risk of bleeding and shock).

2. Radiological diagnosis.
- X-rays.
  - AP view: Easy to see major displacements. May be enough in case of extreme emergency.

- Inlet view: 45º oblique view from cranial. "See" inside the pelvis. Checks for anterior or posterior displacements.
- Outlet view: 45º oblique view from caudal. "See" outside the pelvis. Checks for superior or inferior displacements.

- CT-scan.
  - Coronal views: Superior displacements. Allows for details.
  - Sagital views: Anterior or posterior displacement. Allows for details.
  - Axial views: Anterior, posterior, lateral or medial displacements. Most useful.
  - 3D reconstruction: Very useful for general view of pelvis. Good help before surgery. Be careful!: Displacement of less than 2-3 mm impossible to be seen: minimizes displacement.

CT SCAN: Maybe avoidable in extreme emergency (time consuming). But always before elective surgery.

Current recommendation: (More accurate and quicker diagnosis):

Early Total Body Scan (ETBS). If available: In some 20 seconds full body scan. Allows for x-rays retrieval. Also allows for some other diagnosis, such as spinal problems. - FAST Abdominal Ultrasound. - Angiography. Very interesting, give more information on bleeding, and possibility of embolization. But: Time consuming (up to 2 hours), and not all vessels can be embolized. Valuate the emergency!: Acting promptly versus angiography.

Treatment.

Damage Control Protocol (DCP): Maybe the pelvis is not a priority. Be sure for pelvis, femur bone, and spine. In any case: Try to close the pelvic ring straight away if you palpate it is open apart Fig. 2.

Type A Fractures.

Usually no risk of bleeding. Expectation for some 2-3 days. Only blood tests. Very infrequent necessity of open reduction and internal fixation (ORIF): only in case of cosmetic displacement, or visceral injury (very rare).

Type B Fractures.

- B1. Close the ring as an emergency, and fix it with external fixation (2 supracetabular pins are enough)!. Caution: Fixation rods must not obstruct abdominal approach for eventual laparotomy. Keep the fixator for two months or remove it after a few days (when the patient is stable), and convert it into an ORIF: anterior plating. Posterior sacroiliac fixation unnecessary (only when a combined little vertical displacement, less than a real vertical instability, exists): Iliosacral screwing. Monitorize bleeding and haemodinamic stability during the following hours and days.
- B2. Usually is not an emergency. ORIF: Phannestiel approach and plate in symphisis pubis.
- B3. Treat both sides according to what has been said above. Figure 2.

Type C Fractures.

Highest risk of retroperitoneal bleeding!. Close the ring anteriorly by external fixation and posteriorly by C-clamp (better, if possible, by iliosacral screw). Monitorize bleeding. Cooperate with other specialists: Rectal and vaginal examination (rule out that there is not an open fracture). Always secondary reconstructive surgery with plates of less invasive techniques, as fragment malpositioning may cause malunion or non-union: very incapacitating.

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2. Fractures of the Acetabulum.

Usually not life threatening fractures (difference from pelvis fractures). Anatomy: Considered two columns: Anterior column: Iliopectineal ramus. Posterior colum: Ilioichial ramus. (Anterior and Posterior Columns: Inverted Y). X-rays projections, Classification, and Approaches all defined by Letournel (Paris).

Diagnosis.

1. Clinical diagnosis. Examination may provoke pain).

2. Radiological diagnosis.

- X-rays.

- AP wiew: Not easy to see all major displacements.
- Obturator view: Patient positioned 45ºoblique onto normal side: Anterior column + Posterior Wall.
- Iliac view: Patient positioned 45º oblique onto pathological side: Posterior Column + Anterior Wall.

▪ CT-scan.
- Planar: Coronal, sagital, and axial views: Most useful.
- 3D reconstruction: Very useful for general view of pelvis. Good help before surgery. Be careful!!: Displacement of less than 2-3 mm underestimated.

Classification.
1. Simple fractures (5 types):
Anterior column, anterior wall, posterior column, posterior wall, transverse (Both column fractured, but, at least, a part of the articular joint remains proximally connected with the axial skeleton).
2. Associated fractures (5 types):
T-type, Transverse + Posterior wall, Posterior Column + Posterior wall, Anterior column + posterior hemitransverse, Both Columns (no part of the joint remains connected to the axial skeleton: differences to transverse).

Treatment.
Indication:
Surgical. Displacement > 2mm in young people. Weight bearing surface diminished. Coexistence with pelvic fracture. Bad predictors for surgey: Delay more than 3 weeks in undertaking surgery. Malrreduction. Femoral head lesion.
Non-surgical. Good congruence, particularly old people. Local or general infection. Osteoporosis (Total Hip Replacement). Soft tissue lesion. Poor general health.

Approaches:
1. Kocher- Langenbeck approach. Posterior Column. Posterior Wall. Transverse (low). Transverse + posterior wall. T-type. Two-columns (rarely). Anterior column (sometimes possible to be reduced through greater sciatic notch).
2. Ilioinguinal. Anterior Column. Transverse (high). T-type. Two Columns. Posterior Column (by pushing lamina quadrilatera).
3. Stoppa. Alternative mainly for Ilioinguinal.
4. Extended or Combined. Extended iliofemoral, Triradiate, others.
   Elderly people or very comminutive. Joint Replacement (Acute or Delay: discussed).

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3. Fractures of the Hip.
Very important public health problem. Two main types: Intracapsular and extracapsular. In elderly people the main etiology is physical, sensorial, and mental situations provoking falls.

Intracapsular fractures.
Femoral head fractures. Usually from hip dislocation. Problems with arterial supply. Young patients: Osteosynthesis with screws by anterior short iliofemoral approach and dislocation. Older people: Joint Replacement. *Femoral neck fractures.* Also vascular supply problems. Acute reduction and synthesis with screws (subcapital fractures) or sliding screw-plate (dynamic hip screws) in transcervical or basicervical fractures. Late cases or elderly people maybe worthy going straight for joint replacement.
Extracapsular fractures.
Intertrochanteric hip fractures. Choose between intramedullary hip screw devices (IM), or sliding hip screws (SHS). IM allows for less invasive procedure. No differences as far as operative bleeding is concerned. Morbidity and length of stay do better for SHS. In more complex fractures IM behaves biomechanically better.
Pathological fractures.
Metastatic: Common in intertrochanteric and subtrochanteric regions. Bad prognosis patients (less than 3 months lifetime): Intramedullary fixation. Good prognosis patients (more than 3 months lifetime): Proximal resection and total arthroplasty with special modular femoral stem. Fatigue fractures: New issue due to biphosphonates long-term treatment. Suspend medication and perform osteosynthesis.

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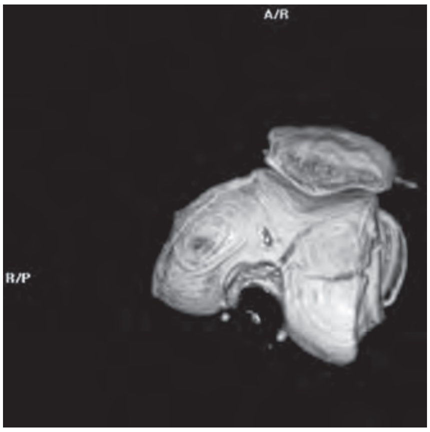
Internal fixation in proximal femur, knee and tibia

The main objectives of surgical treatment in these fractures are anatomical reduction of the articular surface and achieve a correct limb alignment. As the fracture diagnosis is frequently with simple radiographs in supracondylar fracture it is important, in high energy fractures, to obtain an AP view of the pelvis, as these fractures have concomitant hip or acetabular fractures which are frequently missed.
CT scan is usually necessary to better understand the fracture pattern and correctly evaluate the fracture type for surgical planning.



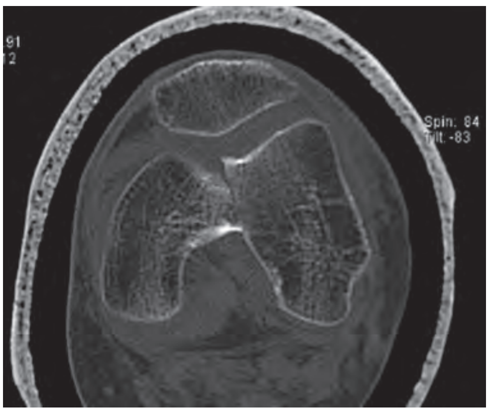
Femur
Distal femur fractures have two clinical and epidemiological presentations:

- The first type is osteoporotic mainly in elderly women following low energy trauma with minimal intrarticular involvement.
- The second type is a result of high energy trauma and is seen in young male patients with complex intrarticular affectation.

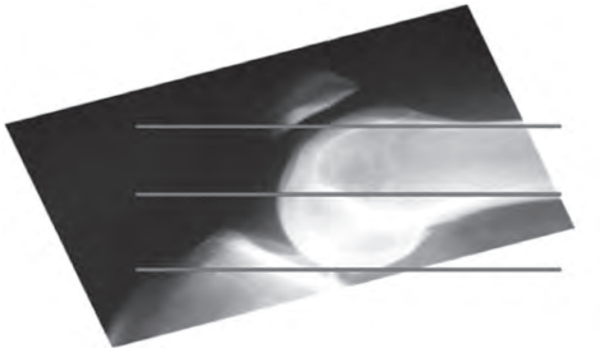
The main objectives of treatment are, firstly to restore the articular congruity “Fix the joint”, and secondarily restore the alignment of femur “Fix the joint to the shaft”.
The approach should be adequate for the fracture (minimally or maximally) giving sufficient exposure to correctly reduce and synthesize the components.

When operating on distal femur fractures the following points should be kept in mind:

1. The Condylar block is frequently rolled backwards by the pull the leg muscles.
2. In the Xray even when no fracture is seen in the frontal plane it should be assumed to be present.
3. Also to be kept in mind is the coronal plane fracture (Hoffa).
4. Metaphyseal conminution is frequent also.
5. And finally, keep in mind the patella.



If posterior condylar fracture is present, it will not be addressed by standard retro nails or most plates. New generation retro nails have oblique screws in order to address this problem.



Today's implant for distal femur

- Traditional plates
- Retronails
- Internal fixators

Retrograd nails

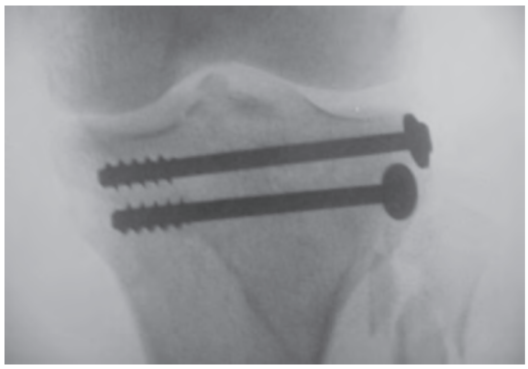
- Ideal indications: Extraarticular, obese patients, bilateral, segmental, simple intraarticular.
- Problem: anterior knee pain, intraarticular protusion.

Locking plates

- Ideal indications: Osteoporotic bone, Periprosthetic fracture, complex intraarticular fractures.

There are situations in which retro nail is not feasible for example the stiff knee, as you need to bend it for insertion, and when the medullar canal is filled.
If you use a locked plate you must obtain reduction before the plate is placed. The plate does not help to obtain reduction as do blade plates (DCS). The correct reduction of the metaphyseal/diaphyseal component of the fracture needs to be obtained before the distal screws are placed. When a blade plate is placed in the proper place in the distal femoral block, the surgeon is assured that the proper frontal plane angulation has been achieved.

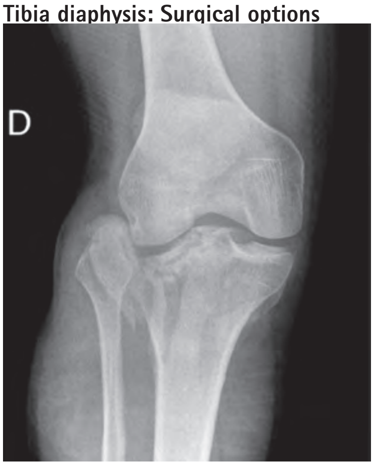
Tibial plafond
Unicortical fracture: Butteress plate, non locking or screws
Bicondylar fracture:



- Medial compartment is convex to the tibial side; axial load transmission leads to split fractures in mediolateral direction.
- The lateral compartment is convex to the femoral side; axial load transmission leads to multifragmetary depression with broadening of the lateral joint.


Bycondilar fracture: bringing plate, locking system
Double plating: C type with posteromedilal shearing fracture

Tibia diaphysis: Surgical options



- Intramedullary Nails:
  - New generation tibia nail with better locking options
  - Blocking screws
- Locking plates

Fractures in the proximal one-third of the tibia are prone to malalignment, with the prevalence of that complication reported to be as high as 84%. The most common type of malalignment is apex-anterior and valgus angulation.

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Foot and ankle trauma

An overview concerning foot and ankle trauma can be divided in 3 topics: expectations from severe trauma, the missed injuries and the up-to-date surgical techniques.

1. Expectations from severe trauma [1, 2, 3, 4]

a. In general foot trauma rarely needs emergency treatment. Exceptions are open injuries, incarcerated soft tissues, manifest compartment syndrome of the foot, and neurovascular injury. At 10 years follow-up there are significantly worse results functionally in patients with below knee injuries in polytrauma. Only half as good in physical function, form physical, bodily pain, ability to wear shoes and social function as their control counter parts Specific matched injuries tend to have worse outcomes.
b. Basic principles of management allow maximising function by aligning the foot under the tibia, keeping the foot flat to the floor, making the foot foot-shaped and stabilising the joints to keep that position. Managing the soft tissue threat remains mandatory but early amputation could be thought about according to unreconstructable neuro-vascular and skin damages. Compartment syndrome, proximal or distal must be detected and treated.
c. Early trauma treatment will avoid later soft tissue release. Early mobilisation (stable and rigid fixation) will avoid excessive stiffness, long term swelling and post trauma disease
d. Production of balance from ankle to hind foot to forefoot is vital by restauring the mid foot columns length, the alignments of the hind foot and the stability of the ankle ligaments (fig. 1a and 1b)

2. Missed injuries [5, 6]

They are numerous even the "subcutaneous" position of most of the anatomic structures in foot and ankle.History and a physical exhaustive examination are mandatory.

- We have to maintain an high index of suspicion regarding a so-called **ankle sprain**
  - during snow-board practice which is in fact a fracture of the lateral process of the talus. This is a functionally severe lesion, leading in most of the cases to non union or subtalar joint OA.(fig 2a and 2b)
  - during down-hill ski which is in fact an acute dislocation of the fibular tendons leading to recurrence and tears.
- Be aware when **a midfoot sprain** is occurring, especially with an high velocity. *The fracture/dislocations at the Lisfranc joint* are overlooked in more than 20 % of cases (fig 3a and 3b)and lead to a very severe functional imbalances and disability in the foot (fig. 4a and 4b).
- Be aware when **a medial sprain** is occurring, involving to a flat foot by misdiagnosed *lesions of the MCL and spring ligament leading to a TTP insufficiency.*
- a soft foot trauma in diabetes condition, can reveals *a Charcot foot* leading very quickly to severe deformations.Early strong surgical procedures are recommended (fig. 5, 6, 7)

3. New surgical procedures

A lot of innovations in procedures, cartilage substitution, and navigation have be pointed out in foot and ankle surgery. New trend or routine techniques for the future?

- **Minimal invasive surgery (MIS)** is proposed in various situations as such as LODA (arthroscopic assistance), Achilles rupture, Lisfranc dislocation, malleolar fracture, calcaneus fracture. **[7, 8,9, 10]** (fig 8, 9, 10, 11, 12)
- **New implants** have been developed
  - in term of design adapted to the foot and ankle) (plate, screw,pin,anchor....)
  - but also in term of materials (Titanium alloy)
  - even using bioabsorbable components for scew, pin or plate. [12, 13, 14]
  - silicone implant for lesser rays can help in very difficult conditions as such as dislocation or severe unreconstructable fractures! (fig. 13, 14)
- **Regenerative surgery** with chondrocyte transplantation, bone marrow differenciation or BMP are in progress.
- **Computer assisted surgery** could be proposed to improve the accuracy of correction using post-traumatic arthrodeses in ankle, mid or hind foot [10, 11] (fig.15a,b)

Conclusions

The foot and ankle surgery is a young concept in comparison to hip or knee surgery. The severe trauma treatment must keep the foot the right shape with joints mobile as possible according to surgical biomechanical concepts. The perfect assessment with clinical and imaging data is mandatory to avoid misdiagnoses in the foot and ankle, which could lead to very severe disability. New trends need future scientific studies to be confirmed.

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ILLUSTRATIONS

Figure 1a: CML and spring-ligament lesions leading to a valgus of the hindfoot on the Meary'view

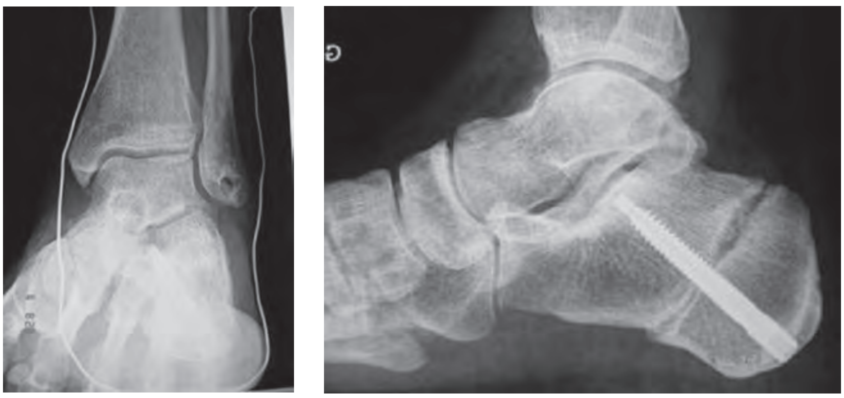

Figure 1b: reinsertion of both ligaments augmented by a medial translation osteotomy of the greater tuberosity of the calcaneus

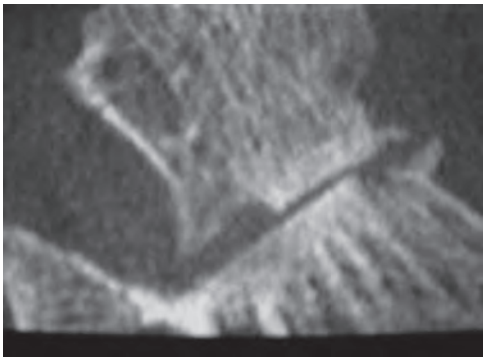

Figure 2a: subtalar joint osteoarthritis following a fracture of the lateral process of the talus

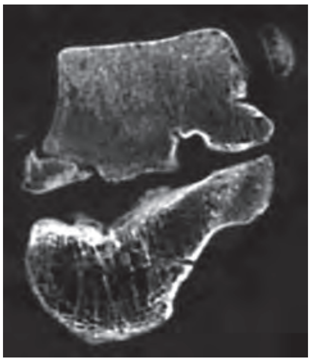

Figure 2b: non-union of a fracture of the lateral process of the talus

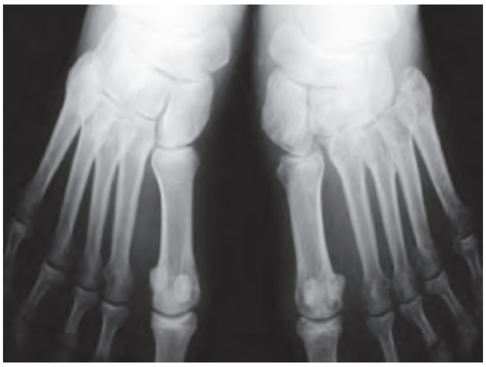

Figure 3a: Left midfoot injury on a dorsal view

Figure 3b: the same case on the lateral view, demonstrating the dorsal dislocation of the Lisfranc jointthe lateral process of the talus

Figure 4a, 4b: a neglected severe Lisfranc disruption

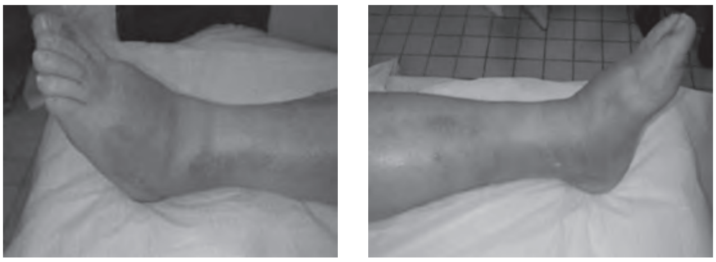

Figure 5a, 5b: clinical aspect of a soft trauma in a diabetes patien

Figure 6a, 6b: AP view, AP view one month later

Figure 7a, 7b: a strong and bulky fixation is mandatory to prevent a re-dislocation

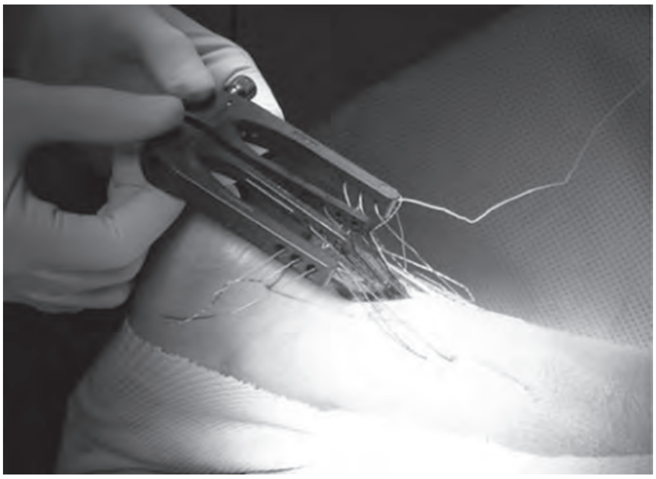

Figure 8: MIS of Achilles' rupture using the Achillon' device

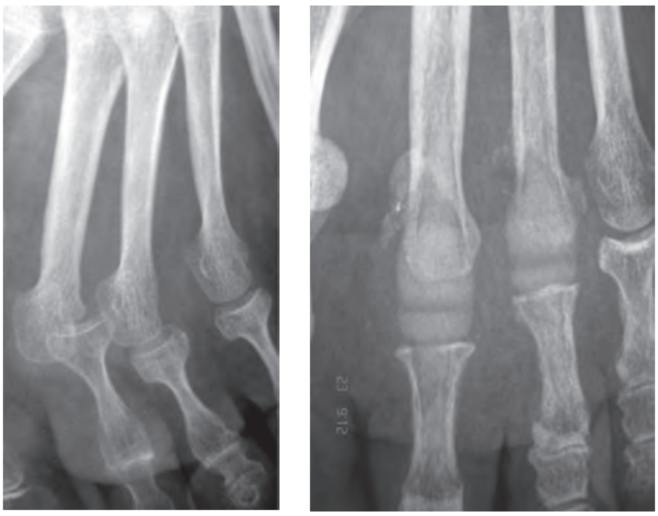

Figure 13a, 13b: dislocation of both MPJ2 and 3, treated by silicone hinge implant (Gauthier' prosthesis)

Figure 14a: trials stem before implantation

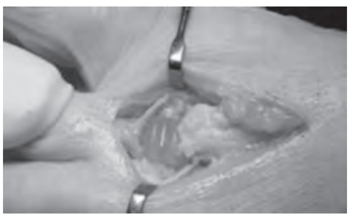

Figure 14b: definite implant in situation

Figure 15a, b: CAOS of the hindfoot

Figure 10a, b: severe skin lesions in a calcaneus fracture with a percutaneous screwing

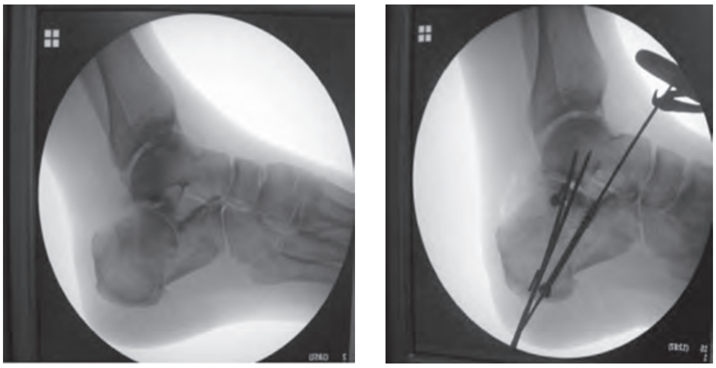

Figure 11a, b: fluoroscopic views during the surgical procedure to assess the reduction and the correct positioning of the screws

Figure 12: clinical aspect, some weeks after surgery

Figure 9a: stress fracture of the medial malleolus

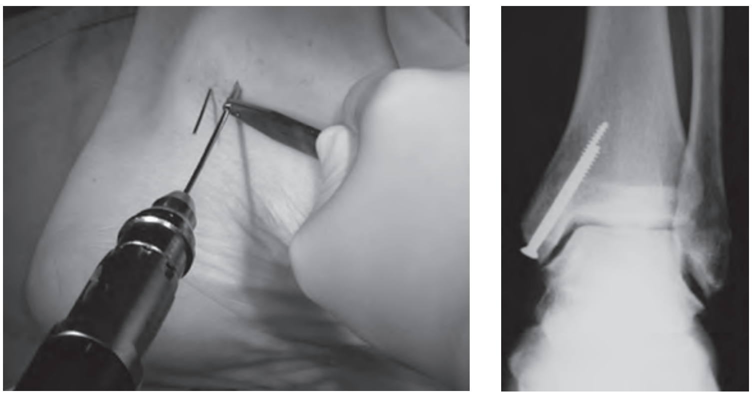

Figure 9b: osteosynthesis using a percutaneous approach

Adult hip and knee reconstruction

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General aspects

Total hip and knee replacement are among the most successful elective surgical approaches being introduced within orthopaedic surgery. Developed in the 1960'ies and 1970'ies, respectively – both types of replacement have been through a detailed evolution, today used in several designs world-wide.
Across Europe, still more hips are being replaced per year than knees. However, the incidence are getting close to each other every year (average 170 total hip replacements (THR) per year per 100.000 inhabitants; and average 140 total knee replacements (TKR) per year per 100.000 inhabitants) (1, 2).

Cemented versus non-cemented design
Both THA and TKR were introduced as total cemented designs, but both have also been through the era of fully non-cemented designs – over hybrid designs – back to the total cemented implants. Today, still most THA and THR are total cemented implants (1, 2). During the last two decades, mainly Sweden has analysed and focused detailed on technique and quality of cementing technique (3). Hereby, survival of the implants has been significantly improved (3). However, in THR it is a general trend that younger patients are operated with non-cemented designs – the elderly by cemented or hybrid designs (1, 3, 4). In TKR, majority of operations are performed as total cemented (2).

Deep venous thrombosis
Deep venous thrombosis (DVT) and deep infection (DI) are serious complications after both THR and TKR. Therefore, prophylaxis against DVT both prior to and / or during surgery are mandatory across Europe.
DVT are published with an incidence as high as 30% after both THR and TKR if no prophylaxis is given (5). However, even after modern prophylactic treatment with low molecular weight heparin products – up to 13% has been published to develop DVT – most of these asymptomatic (6) The emphasize the real reason for DVT prophylaxis – to prevent the serious pulmonary embolism (5). Today, new products have been introduced to the marked, enabling per oral treatment to take over the former daily subcutaneous injections. It is however still debated what postoperative prophylaxis should be given to THR and TKR patients mobilized on the day of surgery and being described 2-3 days after the operation.

Deep Infection
DI after total joint replacement can ultimately result in amputation of the replaced limb. Although being very rare, such necessary final treatment is still shown. Besides, DI has a dramatic negative impact on sickness of the patient, mobility and the overall survival of the implant. It was shown already in the 1960'ies that preoperative prophylaxis with antibiotics reduced the incidence from round 4-5% to less than 1%. Today, prophylaxis with antibiotics is mandatory prior to both THR and TKR (2, 4), resulting in less than 0.5% of replacement being infected. Most frequently found bacteria in DI is Staphylococcus Aureus, sensible for broader antibiotics like Dicloxacillin and second generation Cephalosporins.

Treatment of the early infected THR and TKR is recognised to involve a detailed debridement of the soft tissue, exchanging removable modular components and longer-term intravenous antibiotics (7). This strategy can be used within the first 6-8 weeks after the index operation. DI occurring later than 8 weeks and recurrent DI, are in general both in THR and TKR treated with removal of the implant, meticulous debridement of the soft-tissue, a period without a prosthesis and intravenous antibiotics – pronounced two-stage revision technique (8). By using such a strategy – and depending on the bacteria involved, the success rate is published to be approximately 70% in THR and 50% in TKR (8). Re-infection after two-stage treatment of primary DI are in high risk for ending as Girdlestone status in THR and knee fusion in TKR (8).

Survival of THR and TKR
Survival of THR is reported in the National Arthroplasty Registers to be approximately 92% after 10 years (1, 3, 4). Main reasons for revision are aseptic loosening, instability/dislocation and deep infection. Survival of TKR are in the register found slightly higher after 10 years (94%) with aseptic loosening of the tibial component and deep infection being dominating reasons (2).

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Adult hip and knee reconstruction

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Hip reconstruction: Osteotomy and joint replacement

Several disorders of the growing hip (i.e. developmental dysplasia-DDH, tilt deformity with consecutive impingement, perthes disease) and avascular necrosis in the adult age are relevant mechanical risk factors for the development of hip osteoarthritis. In early disease stages with only minor morphological signs of cartilage degeneration osteotomies can help to preserve the joint. Indications are mild pain, absence of advanced radiographic osteoarthritis and an understanding of the procedure by the surgeon as well as the patient.

In adult patients with dysplastic hips pelvic osteotomies are more often performed than femoral osteotomies, as their reorientative potential is higher and they have less disadvantages. Common techniques are the Toennis "Triple osteotomy" and the Ganz "Bernese periacetabular osteotomy". Both have a signifi cant potential to correct a pathologic acatabular coverage, although potential complications are associated with these major surgical procedures (i.e. risk of neurovascular damage, non-union and under-/over-coverage).
In avascular necrosis of the femoral head (AVN) femoral osteotomies are a treatment option in limited disease stages (ARCO II-III) with minor defect size (Kerboul-angle lower than 200°). In advanced stages or larger defect sizes the outcome is not encouraging. The Sugioka "rotational osteotomy" is rarely performed and technically very demanding.
In patients with a "tilt deformity" due to growth disorders or mild and often unrecognized slipped capital femoral epiphysis (SCFE) symptomatic femoroacetabular impingement might result. Surgical treatment options with dislocation of the femoral head through trochanteric osteotomy and open off set reconstruction have been developed.

In patients with advanced hip osteoarthritis joint preserving osteotomies generally are not any more indicated. If conservative treatment options over suffi cient time periods (at least 3 to 6 months) fail and patient complain of signifi cant pain and/or functional impairment, total joiunt replacement might be indicated.
Different options regarding choice of implant and fi xation technique (i.e. "conventional" cemented, cementless, hybrid, hemiarthroplasty, surface replacement, neck preserving stems) as well as bearing materials (UHWM-polyethylene, highly-crosslinked polyethylene, metal-onmetal, ceramic-on ceramic) are available. Generally there is a tendency to recommend cementless prosthesis with hard bearings in younger and active patients, while cemented implants and conventional bearings are indicated in elderly and less active patients. All options, however, have their advantages and also disadvantages in special situations. Therefore general recommendations regarding the application of certain techniques or materials in any case are not possible.
Surgical exposure is possible via anterior, lateral, posterolateral as well as medial approaches and "minimally invasive" procedures have recently been developed. There is not enough evidence until now, however, to recommend these techniques generally.
Although THR is one of the most eff ective medical procedures, patients and surgeons must be aware of potential complications. Therefore, certain general steps should be done in every hip replacement surgery, which include

- controlled/safe patient positioning and check of correct side
- adequate soft tissue management (including repeated irrigation to prevent heterotopic bone formation)
- intraoperative control of leg legth and off set with trial prosthesis
- intra- and or postoperative x-ray control
- adequate treatment to prevent periprosthetic infection (single-shot antibiotics) and thrombosis (pharmaceutical and non-pharmaceutical options)
- immediate postoperative control of neuro-vascular status of the operated leg

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Knee reconstruction: Osteotomy and joint replacement

Summery
Several treatment options for the osteoarthritis of the knee in the middle-aged patients to preserve the joint are available. Osteotomies around the knee are well known and different procedures have been reported over years. However, not all results have been described as good. The most important factors for a successful result are preoperative planning, proper patient selection and a reproducible surgical technique with modern angle stable implants. The deformity to be corrected should be analyzed on a standing, three-joint radiograph, the choice of the side of the osteotomy should consider the joint line. The open wedge osteotomy at the tibia has several advantages compared to the closed wedge osteotomy. Greater corrections should be done by a double level osteotomy to keep the joint line horizontal. Base for successful modern surgical cartilage repair procedures in the knee joint is a stable joint with a normal limb. A necessary additional osteotomy around the knee should always to be considered.

Total knee replacement is a very successful procedure. Excellent long-term results have been reported. However, not all patients are satisfied with the prosthesis. Early revisions within two years after the implantation have been described. Correct alignment, rotation, balancing and fixation are the base of a excellent result. One of the most important issues for success are the soft tissue release techniques. The measured resection technique and the flexion gap balanced technique are the two current philosophies of implantation. The epicondylar line is accepted as the center of rotation for the femoral component. Replacement of the patellar or not, posterior stabilized or cruciate retaining prosthesis, cementing or not are the old controversies in total knee replacement. Navigation, minimally invasive techniques, mobile or fixed inlays, new materials (trabecular metal, highly crosslinked polyethylene), gender implants, high flexion design are the modern controversies. A proper surgical technique is still the most important factor for a good clinical outcome and to prevent early revision.

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Meniscus; chondral surface injury; Unstable Patella; Tendon ruptures (quadriceps, patellar)

1 Introduction

The etymology of the term meniscus comes from the Greek, "meniskos" which means a crescent-moon shape.
The morphology of the meniscus strongly resembles this shape.
The kinematics of the menisci in humans is quite asymmetric, with the lateral meniscus being much more mobile than that of the medial meniscus.
Because the medial compartment of the knee is substantially more constrained than that of the lateral compartment, chronic ligamentous injuries – such as that of the anterior cruciate ligament which results in pathological increases in AP translation – often is associated with increased frequency of damage of the medial meniscus compared to that of the lateral meniscus.
All of the various components of the knee are important to normal functioning of this living, self-maintaining transmission system. Figure 1
A knee that has sustained a tear of the meniscus can be thought of as a transmission that has a damaged bearing.

2 Meniscus repair

2.1 Biology

Since Kohn and Siebert's study in 1989, the biomechanical basis of meniscus repair – and meniscus repair itself – has significantly evolved. Evaluation of the first-generation repair techniques with sutures showed that the biomechanical conditions of meniscal repair were dependent on the anatomy of the meniscus, the quality of this tissue and the type of suture and suture material.
Studies published in the 90s and in the current decade evaluated the second and third-generation repair devices.
While the second-generation devices represented a significant step forward with respect to the invasiveness of surgery, their biomechanical properties were generally inferior to those of the "gold standard" sutures. However, as biomechanical testing became more complex with the introduction of cyclic loading, the evaluation of meniscus repair could be extended to include criteria such as the resistance of the repair and gapping of the tear site under more physiologic loading conditions. The third-generation flexible suture anchors meet both the criteria of minimal invasiveness and biomechanical properties, which are comparable to those obtained with suture techniques.
These anchors as well as improved all-inside suture techniques will probably represent the first choice of meniscal repair techniques in the coming years.
From a scientific point of view, further studies should be performed to achieve a better understanding of the forces acting on meniscus repair under certain pathologic conditions and of the biomechanical properties of regenerated or "healed" meniscus tissue after repair.

2.2 Techniques

Saving the meniscus, especially in young patients, to decrease the risk of secondary osteoarthritis is challenging. Meniscal repair techniques are well established and allow surgeons to address tears of different complexity and location. There exists no universal technique, but rather several techniques which are adapted to different indications. Even if all-inside fourth-generation devices are now the gold standard in the majority of cases, inside-out, outside-in, and even open techniques are still indicated in selected cases. The ultimate goal is to achieve a strong repair.
In the future, the next step will be biological meniscus repair by introducing factors such as stem cells, growth factors, or cytokines at the site of the repair to enhance healing. These can be regarded as biological mediators, which regulate key processes in tissue repair (cell proliferation, directed cell migration, cell differentiation, and extracellular matrix synthesis).

2.3 Results

Menisci are no vestigial structures, but form an integral part of the 'self-maintaining transmission system' which the knee joint is.
Minimal tissue resection, which very often can be described as 'adequate', e.g. leaving the meniscal rim, should be the rule. Care should be taken to resect what has been torn and remove meniscal tissue only to avoid any further impingement that may remain sensitive to rotational painful stress and may thus produce clinical symptoms.
Arthroscopic techniques allow for repeat surgery, which may be required in case of persistent mechanical derangement. However, the fulcrum to proceed to repeat arthroscopy surgery needs to remain clinical. All too often, repeat surgery does not alter the clinical findings if it is based on – needless - imaging alone.
Therefore, potential meniscal repair is warranted in all cases where meniscal resection has been considered. Full options remain when, in addition to partial resection, suture of the meniscal remnant to the meniscal wall appears to be required.
Biomechanical investigation and testing of meniscal repair devices has received ample consideration. While tensile forces, which are of lesser importance in clinical practice, have been extensively investigated, shearing forces acting on the meniscus are of paramount clinical importance but cannot be reliably reproduced in in vitro studies.

Experience has taught us that a red-on-red tear heals spontaneously within four to six weeks, provided that the necessary immobilization is applied. Figure 2 The purpose of meniscal stabilization is to safely bridge this period in order for the scar tissue to heal and stabilize the lesion.
Because in vivo testing is not possible as yet, clinicians investigate implant material by essentially focusing on material properties, safety guidelines and ease of insertion, with convincing evidence based on physiological meniscal healing.
The implants developed in recent years allow for arthroscopic meniscal suturing all around the meniscal rim. Good stabilization is obtained in the majority of cases. Average results are defined as up to 80% of clinical healing at long-term follow-up. Failures are mainly due to improper indications or knee joint instability. Less well-documented reasons could be poor meniscal tissue, low cellularity and thus poor healing response. These findings are obviously difficult to document, but are recognized when at surgery yellowish degeneration of the meniscal core is found, which is often related to age and overload and compromises the healing response.
One of these 'degenerative' findings is the meniscal cyst. Prone to increased shearing forces at its fixation around the popliteus muscle tendon, the lateral meniscus may sustain a horizontal tear associated with cyst formation. Depending on its intra-articular 'opening', the symptomatic cyst needs to be resected and the torn meniscus repaired. Repair is mandatory at all costs in order to avoid underlying cartilage degeneration.

2.4 Rehabilitation
Although evolving continuously, concepts of postoperative rehabilitation after meniscus repair still remain controversial. Two rehabilitation protocols, applied in clinical practice, are described in the current literature: the conventional and the accelerated rehabilitation protocol.The optimum rehabilitation is yet to be identified, and the lack of scientific data in the literature does not allow us to endorse a specific rehabilitation program.
However, it is the authors' opinion that all intrinsic factors should be taken into account when designing a rehabilitation program. Individualizing the rehabilitation according to the size and type of meniscal tear, vascular supply, localization, concomitant procedure, and presence of other intra-articular disorders (ACL, cartilage lesions,...) seems to be an interesting concept. If less than two intrinsic risk factors are present, healing will occur fairly rapidly and the risk of failure is low, so that an accelerated rehabilitation protocol is recommended. However, the presence of more than two risk factors (e.g., a large tear in a red-white zone) increases the risk of meniscus failure and slow healing, and in this case a more conservative approach is probably the best garrantuee for success.
However, well-designed longitudinal studies are mandatory to determine the actual efficacy of this rehabilitative approach with regard to patient function and satisfaction.

3 Meniscus replacement
Carl Wirth and Gabriela von Lewinski investigated the basic science in meniscal transplantation. The interest taken by their German group in meniscal transplants was fueled by clinical needs.
The concept of the meniscus also being a stabilizing structure in the knee joint is not new, but they were the first to consider the meniscus as a primary stabilizer after knee ligament injury and repair. Simply removing the meniscus had proven deleterious to the long-term results after ligament repair.
In animal experiments, the authors were able to show healing after meniscal allograft implantation.
Also in human clinical studies, satisfactory healing occurred at the meniscosynovial junction, but whether this was also true for the meniscal horns remained a controversial issue.
Horn fixation is indeed mandatory for true hoop stress protection.
In addition, animal experiments showed increased cartilage degradation when the normal anatomy had not been restored. Nowadays, no clear consensus is available on whether bone fixation of meniscal allografts is mandatory for normal homeostasis.
Choosing allograft tissue such as meniscal tissue, although of limited availability, is a logical option.
Deep-freezing appears to be the most accepted method of preservation and standards of procurement have been well established.
If procured in a sterile fashion, the allografts can be used when the tissue bank has found the donor to be free of transmissible diseases. When harvesting has been done in an unsterile fashion, the issue of sterility requires appropriate attention and management. Avoiding irradiation as such is essential in order not to be detrimental to meniscal structure and thus good postoperative function.
However, national laws and regulations can interfere with good clinical practice on grounds of legal constraints based on earlier infringements and exposures.
Meniscal surgery, as it started in the 1990s, required an open approach because at that time arthroscopic meniscal fixation devices were limited and not really appropriate. In the early beginning, meniscal transplantation was very often associated with other repair surgery (mostly ligamentous).
Open surgery is also required for bone plug fixation and to obtain elementary stability.
It is only because meniscal surgery and repair indications have increased that arthroscopic transplantation has been initiated.
Without bone plug fixation the technique becomes an arthroscopic soft-tissue procedure, also with use of improved fixation and stabilization devices as applied constantly in routine meniscal repair procedures.
With growing surgical expertise and better visualization and anatomic positioning of the anterior and posterior meniscal horns, bone plug fixation has become technically less challenging.
The literature does not indicate whether one or the other technique is superior in terms of results, nor has any clinical difference in results been reported between deep-frozen, cryopreserved or viable (fresh) transplants at a 10 to 15 years' follow-up.
Obviously, clinicians are more confronted with issues dealing with partial meniscectomy and functional derangement.
In animal experiments, collagen meniscus implantation (CMI) was found to yield good results and function. The regenerated tissue appeared to be

similar to the native meniscus. The implants did not induce degenerative changes, abrasion or synovitis, and were devoid of allergic or immune responses.
Human clinical trials, which were conducted at various centres over longer periods of time, showed a lesser need for revision surgery after CMI implantation in chronic meniscectomized knees, compared to controls. Figure 3
Good alignment and stability are preoperative requirements.
Alternatives were searched for that would allow to work with stronger as well as resorbable materials.
In animal studies, long-term assessment of a polyurethane scaffold showed that transformation into meniscus- like tissue took place as the implant slowly degraded.
Another requirement is the possibility to insert and manipulate the implant into position with use of arthroscopic techniques. A first human safety and efficacy study of 52 patients demonstrated a statistically significant improvement in quality of life and clinical scores at one year, suggesting that the implant was safe and effective.
Finally, meniscal allografts seem to sustain the hypothesis that meniscal replacement after total meniscectomy is a valid alternative, more specifically in the lateral compartment. For the medial compartment, other useful options are available.
The more common knee dysfunction after partial meniscectomy does not warrant total meniscal allograft replacement.
While we are still constantly searching for useful modes of treatment, partial meniscal replacement is already a first step in the right direction

4 Ligament instability

4.1 Introduction

True ligament instability needs appropriate diagnosis and treatment.
In this presentation we will not focus on indication and techniques.
We will look into factors associated with ligament instability leading to early arthritis is not appropriately taken care of.

4.2 Sports induced OA predictors

It was formerly accepted that both higher age at the time of meniscectomy as well as longer surgical delay after meniscal rupture would be major factors in inducing osteoarthritis.
It has been shown (Neyret – Verdonk) these factors to be weak predictors for sports induced osteoarthritis.
However, early medial meniscectomy (3x) and even more dramatical medial cartilage lesion at early age (5x) will induce dramatic increase in osteoarthritis.
All these individual facts have even a worse impact in the sports induced osteoarthritis if the patient is confronted with an ACL deficient knee joint.
Stabilization of the knee joint after ACL deficiency presents with a satisfactory outcome in a large patient population.
When normal, at 11 years the intact knee remains pristine at further long-term follow-up (24 years) (Neyret – Verdonk).
In malalignment, the index compartment will present overload.
As such, literature is rather scarce in relation to osteotomies and anterior ligament instability around the knee joint. Figure 4 With respect to posterior instability only 1 paper is retained (Giffen).
Medline then presents no literature on osteotomies around the antero-posterior instabilities in the knee joint.
In the anterior instabilities with frontal imbalance will allow for closing wedge osteotomy when presenting medial narrowing of the jointline.
In case of sagital imbalance an AP closing wedge osteotomy will allow for improving biomechanics.
In case of posterior instability after chronic PCL rupture, the sagital instability will be reduced by an opening wedge osteotomy tilting the tibial plateau.

5 Patella

5.1 Introduction

Many factors, apart from sports overuse, can lead to patellar symptoms.
They are: dislocation, instability, hyperpression, cartilage lesions – more often than not associated with tendon pathology, both below in the patellar tendon as above in the quadriceps tendon -, patellar height.

5.2 Instability factors

Henri Dejour (1987) described 4 main factors inducing instability of the patella.
They are the trochleair dysplasia, the high-riding patella (>1.2), the relationship between the tuberositas tibiae and the trochlear groove (> 20mm) and the patellar tilt (> 20°).
These factors being increased will lead to patellar dislocation.
The instability factors need to be addressed individually and can possibly be combined with other "focal" treatments to eradicate the inducing factors.
The high-riding patella needs to be levelled to index 1 when pathological.
Potential patellar tilt, whether inborn or post-traumatic may need muscle plasty of the vastus medialis internus. If the medial patellar femoral ligament is ruptured because of an earlier dislocation, it needs to be reconstituted anatomically.
In case of frank trochlear dysplasia (grade B and D), a trochlear plasty may be necessitated.

In case of abnormal TT- TG it needs to be reduced to former and normal measurements.
Secondary factors such as malalignment do not need to be addressed in casu.

6 Cartilage

6.1 Introduction

Cartilage repair is physiologically non existent. Surgical approaches have been described using local regeneration using the micro-fracture technique.
Cell transplantation, both autologous as well as allotransplantation of both individual cells, cultured cells or as allografts have been used.
It appears that both in symptoms and in treatment, sizing is essential for inducing valuable results.
In addition, correct alignment is a prerequisite to support good clinical results.

6.2 Cartilage lesions

Arøen et al. (2004) and Curl (1997) have investigated the number of cartilage lesions in routine arthroscopy.
Cartilage lesions in excess of 2cm² are present in more than 66% of all cases.
However, only 20% present with a localized defect.
11% are rated grade 3 or 4 according to ICRS.
Only a very limited number of 6% present the same grade 3 – 4 ICRS in a defect that is in access of 2cm². Figure 5
It is generally accepted that only lesions in the weight bearing zone in excess of 2cm² can be symptomatic in need and are in potential need of treatment.
It is also common knowledge that degenerative lesions need an appropriate treatment that does not relate to cartilage treatment in itself.

6.3 Treatments

Nowadays small lesions tend to present with good results when treated with microfracture approach as described by Steadman.
The edges of the lesions need to be debrided until sharp.
The micro-fracture technique necessitates perforation until the subchondral lamina every 2 to 3 mm in order to expect bleeding to occur. This suggest the potential of mesenchymal stem cells to approach the lesions surface in order to generate repair cartilage tissue.
Gobbi (2005) has investigated a level 4 comparative study looking into long-term results in young athletes (38y.) retaining pain relief at 6 years, however with lower and sports activities in 80% of cases.
Gudas (2005) looked into younger sportsmen and investigated in a randomized prospective level 1 study microfracture versus mosaicplasty in a 3 year minimal follow-up study.
Lesions were grade 3 to 4. Size, 2,8 cm² and comparing microfracture versus mosaicplasty.
There was a distinct advantage in the use of the mosaicplasty treatment versus microfracture.

7 Conclusion

In painful cartilage lesions in the young athlete, the ideal candidate presents with age below 40. The lesions should be fresh (below 3 months). It is essential to have a lower end BMI (<30kg/m²) in normal axial alignment without any associated lesions. Small sizing of maximum 3cm² is prerequisite.

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FIGURES

Figure 1

All of the various components of the knee are important to normal functioning of this living self-maintaining transmission system (Sott Dye, courtesy Werner Müller)

Figure 2

The healing rate in meniscal repair is highly satisfactory when considering CT scan arthrography (courtesy Société Française d'Arthroscopie)

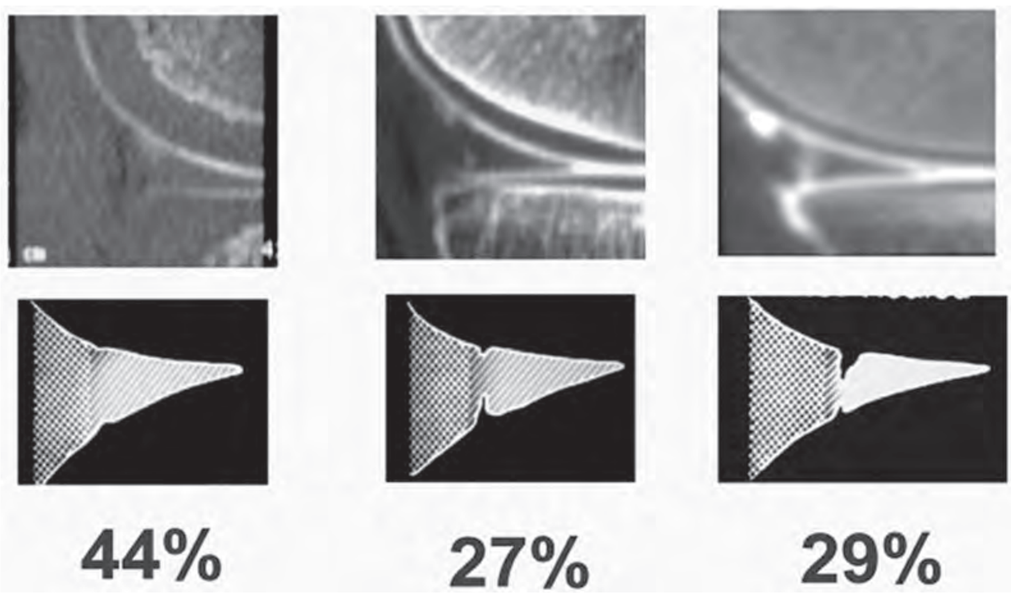
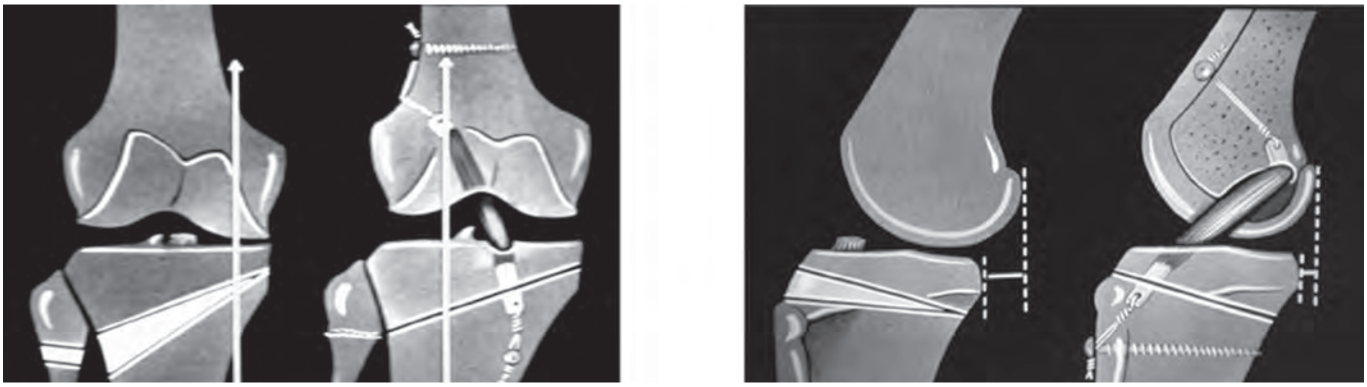


Figure 3
In case of partial meniscectomy and keeping up with a stable meniscal wall, new scaffolds may generate meniscal tissue to protect the weight bearing cartilage

Collagen scaffold

Polyurethane scaffold

Figure 4
Valgus HTO in anterior instabilities using a closing wedge osteotomy technique has a tendency to decrease the tibial slope and as such to reduce the anterior tibial translation. (courtesy Ph. Neyret)



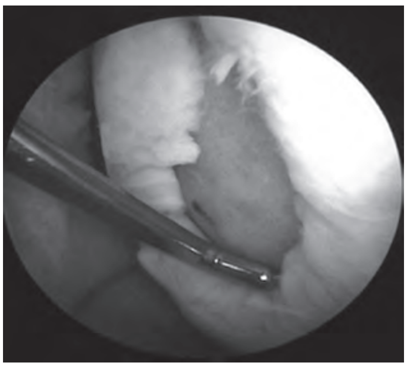


Figure 5
Limited and focal fresh cartilage lesions can be considered for surgery when limited in extent.

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Foot and ankle

Foot and Ankle surgery improved greatly in the last twenty years, improvements dues to better knowledge of physiopathology leading to more sound surgical techniques, improvements in anaesthetic techniques with reduction of pain, adaptation of postoperative cares and better understanding of reasons leading to failure, thus reducing recurrence and complications rates, and improving surgical results. This was accompanied by a huge development of orthotic, surgical devices and implants.

Anatomy

The surgical anatomy of the Foot and Ankle is all about making access to the major structures without damaging structures in the surgical field. The surface anatomy is therefore vital to planning surgical approaches. The major superficial nerves (Figure 1) are the first vital set of structures to avoid in the planning of surgical approach. These include moving from the posterior lateral side round to medially and from proximal to distal, the sural nerve, the superficial peroneal nerve, the deep peroneal nerve which becomes more superficial distally, the saphenous nerve, the dorsal proper nerve of the great toe, the terminal branches of the tibial nerve including medial and lateral calcaneal nerves and the digital nerves to the toes. Once surgical incisions are planned taking this into account further thought in certain areas needs to be given to the blood supply and terminal arteries serving skin. Incisions need to recognise the exact position of joints in relationship to the skin and general shape of the foot. Particularly coming down the medial column it is surprisingly easy to place incisions distally and access the wrong joint. As the incision deepens the major neurovascular bundles become a hazard and as do the distal insertions of tendons.

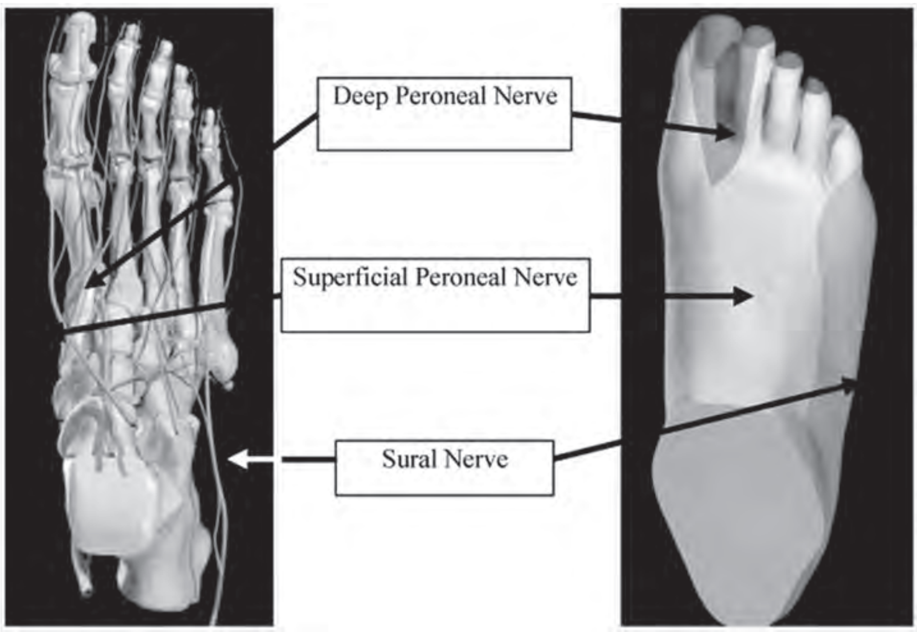

Figure 1:
Major superficial nerves of the foot.

Biomechanics

Practical biomechanics of the foot needs to recognise how the foot is maintained in a stable state during the act of standing in load bearing and propulsion. Normal gait is divided into stance (= approx 60%) and swing. The foot acts as an energy store and a stabiliser such that in midstance the foot is maximally stable and at its fl attest position this is dictated by the major ligamentous structures especially the plantar fascia, the forefoot is held stably on the floor throughout stance once the foot fl at position is obtained. This is effectively guaranteed by the reverse windlass mechanism the energy stored helps to put the foot into a propulsive mode as the body weight passes forwards and the heel rises. The windlass mechanism maintains the forefoot position while also continuing to tension the plantar fascia and in doing so the longitudinal arch of the foot raises and the heel goes into varus maximising the drive by an essentially passive mechanism. The role of the long tendons is essentially to balance the foot from side to side and cope with varying forces. In pathological situations the ability to maintain and balance the stability of the fore foot during stance is lost those intact tendons that resist increased deformity will fail, further deformity will be worsened by this and an increasing cascade of failure will occur.

Foot and ankle

History

Patients with foot pathology will usually complain of pain, loss of function and increasing deformity to varying degrees. Like in other musculoskeletal sites the presence of unremitting pain must be regarded as a red flag to the presence of significant pathology. The site nature and radiation of pain can often help identify the structures involved. The onset and the relationship to specific events can be similarly helpful. Associated symptoms such as tingling numbness and instability should be sort. Pre-existent deformity, disease and family history are all of relevance.

Examination

Examination of the foot needs to be systematised and thorough. A great deal can be learnt about the problem by observing the patient standing walking and by functional tests while standing before the patient is even touched. It is important to assess passive and active movements, motor function and neurology and particularly how these affect the balance of the foot.

Imaging

Imaging of Foot & Ankle pathologies includes: standard radiographs, US, MRI, bone scan, CT – arthrography, and Spect-CT. Standard radiographs are cheap, fast to perform, panoramic, ready available, but allow only a limited evaluation of soft tissue and do not assess bone marrow. US is a very powerful tool for tendons examination, can detect joint effusion, assess synovial hypertrophy and eventually guide a needle puncture. It can detect changes in nerve appearance and a compressive tumor in the tarsal tunnel. Teno-CT is the examination of choice if a longitudinal split or tear of one peroneal or the tibialis posterior tendon is suspected. Spiral CT-arthrography is the best imaging technique to evaluate ankle cartilages. MRI is the best modality to evaluate ankle joints because of its panoramic, multiplanar capabilities and because of its high tissue contrast. IV Gadolinium helps in the demonstration of synovial hypertrophy. Spect-CT is a relatively new and very promising technique, combining the advantages of both bone scan and Ct-scanner.

Conservative treatment

In many cases of foot pathology, conservative treatment may be the best solution and includes painkillers, steroid local injection, immobilisation, physical therapy, muscle stretching, pads, correction of shoeing, orthotic and custom made shoes or boots. Careful examination of the patient will establish the type pathology and lead to an appropriate treatment. In case of unsatisfactory result, surgery can be advocated.

Ankle

Figure 2:
Arthritis of the ankle.

Surgery for ankle arthritis (Figure 2) includes: 1. Cheilectomy either arthroscopic or open, 2. Periarticular osteotomies, 3. Arthrodesis either arthroscopic or open (Figure 3), 4) Total Ankle Replacement (TAR) (Figure 4).

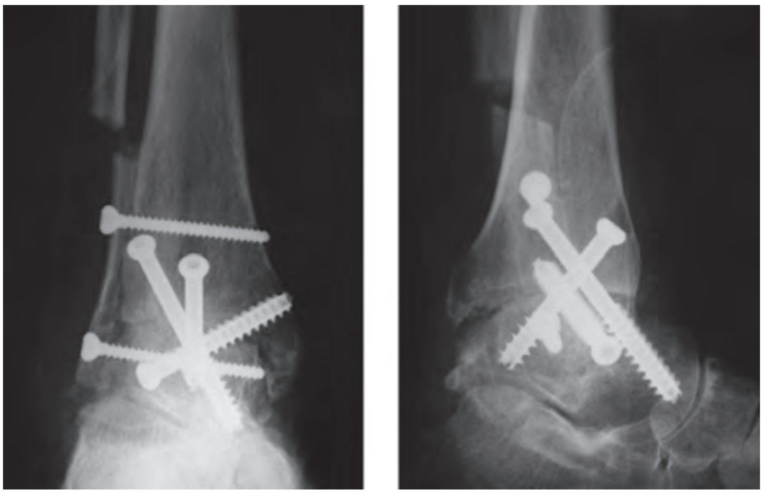

Figure 3:
Arthrodesis of the ankle.

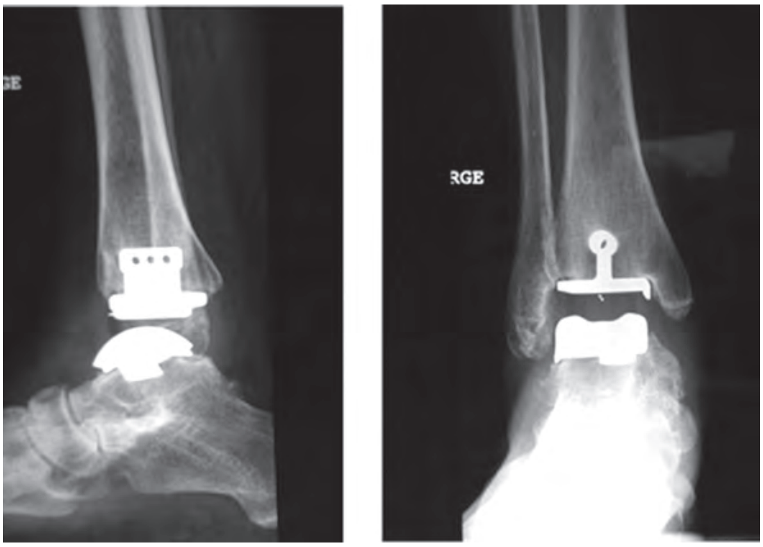

Figure 4:
Total ankle replacement (TAR).

Despite of all warnings against it, ankle arthroplasty, in comparison to ankle arthrodesis, is probably the treatment of choice in many advanced ankle arthritis, but surely not for all. Three components TAR, with mobile polyethylene spacer, are the standard in Europe. Indications: good bone stock, adequate vascular status, no immuno-suppression, good alignment of hindfoot, maintained ankle motion, sufficient medial and lateral ankle stability, contra-lateral ankle arthrodesis, low level of sports activity (bicycle, swimming, walking, golf). Relative contra-indications are: severe osteoporosis, history of osteomyelitis or septic arthritis, segmental bone defect, smoking. Absolute contra-indications: extended AVN, neuroarthropathy (Charcot), important misalignment, massive joint laxity (Marfan), highly compromised peri-articular soft tissues, neurological impairment and high level of sports activity.

Etiology of osteochondral lesions or defects (OCD) of the talar dome remains debated and their treatment is still improving. It is staged according to the extent and severity of OCD, with best results being obtained with either arthroscopic debridement and micro-fracture, or open autologous osteochondral transplant (mosaicplasty), or autologous chondrocyte culture and transplantation. Osteochondral allografts or synthetic materials are promising techniques, to be analyzed.

Chronic ankle sprains may lead to ankle instability, lateral, medial or rotational, whose treatment is surgical. Ankle sprains may also be the cause of peroneal tendons longitudinal tears, more rare complete ruptures, and tendons dislocation. All these lesions are often missed and require surgical repair.

Subtalar and Chopart
Arthrodesis of these joints remains the treatment of choice in case of advanced posttraumatic or idiopathic subtalar arthrosis, tarsal coalition and severe varus or valgus deformity of the hindfoot. Hindfoot should be placed in slight 5 degrees valgus and position secured with staples, k-wires, or, best, with screws (Figure 5). Post-operative regimen usually includes a casting period of 8 weeks.

Figure 5:
Arthrodesis of the subtalar joint.

Flatfoot
The adult acquired flatfoot is a progressive symptomatic collapse of the medial longitudinal arch of the foot. The term "acquired" implies that some structural changes cause the deformity in a foot that was structurally normal. The possible etiologies are: biomechanical disorders, neuromuscular imbalance, tendons impairment (posterior tibial tendon - PTT), a Charcot foot (neuro-arthropathy), post-traumatic sequels, degenerative arthrosis and inflammatory arthritis. Strong correlated factors are age, female patient, obesity and diabetes. The forces exceeding the static and dynamic restraints of the foot create progressive medial structures degenerative dysfunction (PTT - spring and deltoid ligaments) with progressive subluxation at subtalar and midtarsal joints.

Chronic stress cause PTT dysfunction and a hypovascular zone makes the tendon prone to degeneration. **Stage 1**: tenosynovitis\tendinosis - normal tendon length. **Stage 2**: tendon elongation – flexible hindfoot valgus. **Stage 3**: tendon elongation or disruption - fixed hindfoot valgus. **Stage 4:** rigid hindfoot with ankle involvement. Clinical signs include the "Single heel rise" test with poor or absent evidence of heel varus at heel rise and the "Too many toes" sign.
Conservative treatment is preferred as initial protocol. Stabilization and control of affected joints with orthotic can provide the patient a decreased level of pain and an increased level of function. The orthotic design should be acceptable to the patient's lifestyle to ensure compliancy. In case of symptomatic patients not controlled by conservative treatment or in case of clear progression of the pathology, surgical treatment should be advocated. Depending of the stage and severity of the deformity, most frequently bone and soft tissues procedures are associated, with tendon repair \ transfer, tendon (Achilles) lengthening and ligaments (spring, deltoid) repair, calcaneal osteotomies (Figure 6) and arthrodesis.

Figure 6:
Lengthening osteotomy (modified Evans) of the calcaneus.

Achilles tendon
Achilles tendon acute ruptures are due to chronic degeneration of the tendon, with failure of the inhibitory mechanism of the musculotendinous unit, and risk is increased by corticosteroids (local or systemic) or previous treatment with fluoroquinolone antibiotics and derivatives. Treatments options include: A. Non-operative and B. Operative – Percutaneous, Mini-invasive or Open. Non operative treatment is an adequate option but treatment is complex. Best option is the surgical mini-invasive suture for standard cases with functional post-operative care. This solution combines the advantage of both classical open and conservative modalities, without their complications.

Classification of Chronic Achilles tendinopathies includes (Marks): I. Peritendinitis, II. Pantendinitis (peritendinitis and tendinosis), III. Tendinosis, IV. Insertional (subcategories frequently coexist). After failure of conservative measures, surgical treatment can be considered and includes various techniques: Brisement, Percutaneous longitudinal tenotomy, Open debridement, Excision and repair with FHL transfer and V-Y plasty.

Heel Pain – Tarsal tunnel
The heel pain syndrome is a poorly defined entity with numerous etiologies; some of them are very rare while others are extremely frequent. This paper presents some frequent etiologies as well as the proposed treatments. We will concentrate on the two main etiologies: plantar fasciitis and entrapment of the first branch of the lateral plantar nerve. Treatment is first always conservative and carries out good results in 80 to 90% of the patients. It must however be stressed that the healing process can take a long time and both the patient and his treating physician must be aware of that. Several therapeutic modalities are necessary. Actually, surgery (Figure 7) is necessary in some 5 to 10% of the patients, all etiologies considered. If the diagnostic is carefully established, the surgical release gives favorable results in 90% of the entrapment neuropathies and recalcitrant plantar fasciitis.

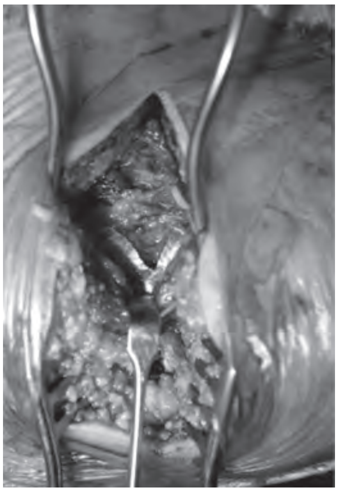

Figure 7:
Release of the first branch of the lateral plantar nerve and plantar fasciotomy

Sinus tarsi syndrome

Sinus tarsi syndrome was described by O'Connor in 1958 in the case of old ligament trauma of the ankle; it was characterized by pain on the lateral aspect of the posterior tarsus when walking on uneven ground. The pressure of the lateral aspect of the sinus tarsi provokes an important pain. The patient describes a subjective instability of the hindfoot. The examination is normal. Standard and stress X-Rays are normal. Many studies described an important quantity of mechanoreceptors (Paccini corpuscules, Golgi and Ruffini receptors, and nervous fibers) in the sinus tarsi. Electromyocinesiology studies showed dysfunction of the peroneal muscles. The normal pattern of the peronei activity is obtained after injection of local anesthetic in the sinus tarsi. Subtalar arthrography showed disappearance of the micro-recessi normally seen along of the interosseus ligament.
The treatment was conservative or surgical. Conservative therapy consists in injection of anesthetic and cortisone in the sinus tarsi, along with proprioceptive reeducation. Surgery performs curettage of the sinus tarsi. Success of both conservative and surgical treatment was uncertain. Since use of Ct-scan and MRI, many pathologies have been discovered, such as osteochondral lesions, arthritis, congenital tarsal coalition, etc., and have put suspicion on the diagnosis of sinus tarsi syndrome.
In case of painful instability of the hindfoot after a trauma, we advise to perform every possible examination (clinical, X-Rays, Ct-Scan, Bone-Scan, MRI, arthroscopy). Only if all these remain negative, consider the diagnosis of sinus tarsi syndrome.

Charcot (neuro-arthropathic) foot

Jean-Martin Charcot has described first the neuro-arthropathy of the foot in 1868, in relation with the syphilis. Nowadays, the diabetes is the leading cause of this disease, whose etiology is still largely unknown. Mean age of diagnosis is 57, with the diabetes lasting usually for more than 10 years. No difference between male and female patients. Bilateralism occurs in 6-40%. Despite the increasing number of Charcot feet, this problem is generally poorly recognized and often poorly managed, leading to a high rate of amputations. The Charcot joint probably has both a vascular and a traumatic etiology. An acute trauma or repetitive microtraumas associated with the impaired sensation caused by the neuropathy are the start point of the architectural changes and joint destruction. The presence of excellent circulation is necessary. The Charcot foot may present as a fracture, but more commonly as multiple fracture-dislocations (Figure 8).

Figure 8:
Charcot arthropathy of the Chopart joints.

Evolution: Eichenholz (1966) has described three stages of development:

1. *Stage 1 or fragmentation:* acute inflammation with bone destruction and dislocation. Clinic: hyperemia, redness, hot swollen joints
2. *Stage 2 or coalescence:* beginning of the reparative process, with bone resorption and callus formation. Clinic: diminution of edema, warmth and erythema.
3. *Stage 3 or consolidation:* bone healing, usually with residual deformity. Clinic: "cold" foot, no swelling.

Clinical evolution without treatment lead to break down of dislocated joints, with a « rocker bottom » foot deformity, plantar ulcers, infection and eventually amputation.

The principles of conservative treatment are:

1. Achieve the third stage of the bony healing with minimal deformity allowing the use of near normal shoes or easily adaptable orthopaedic shoes
2. Minimize soft tissue problems and ulcerations, avoiding the development of an osteomyelitis leading to an amputation
3. Keep the patient as mobile as possible during the healing process.
4. Long period of treatment (normal X 3)

The conservative measures include progressive stages:

1. Rest and elevation of the foot to diminish the swelling and rule out osteomyelitis
2. Total contact cast (change every 5-7 days) or CROW (Charcot Restraining Orthotic Walker)
3. Weight bearing as tolerated and if no progressive foot deformation
4. Continue the cast/walker brace as long as the patient has not reached stage 3, clinically and radiologically (usually 4-6 months, but sometimes 12 months). Monthly radiographic controls
5. After consolidation, use of an ankle brace or adapted orthopedic shoes, and regular medical supervision.

Surgical treatment is indicated in:

1. Acute - stage 1
   a. failure of conservative treatment
   b. progression of deformity or associated osteomyelitis
2. Consolidated - stage 3
   a. recurrent ulcer or joint instability

and includes various techniques depending of the problem: a. debridement only or ostectomy, b. Ilizarov external fixator, c. joint fusion with strong plates or nails (Figure 9). Complications of surgery are post-operative infection, not rare and may lead to amputation. Rate increases with co-morbidities, especially smoking and previous active infection. Non-union with rupture of implants are frequent, but it is very often well tolerated and allows walking either with a bracing (AFO) or an adapted shoeing.

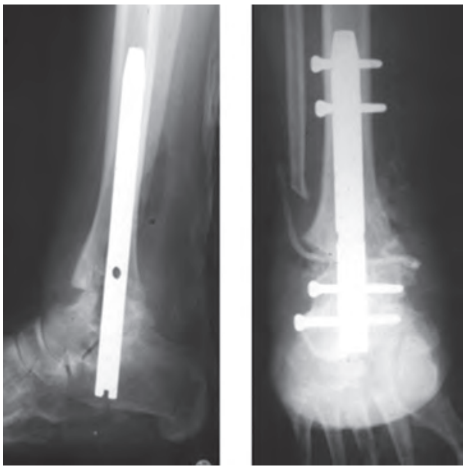

Figure 9:
Nail arthrodesis of the ankle and subtalar joints.

Hallux valgus

Hallux valgus (Figure 10) is the most common pathologic condition of the forefoot and much more often in women than in men. It is the cause of pain on the medial "bump", of transfer metarsalgia, and causes hammer toes.

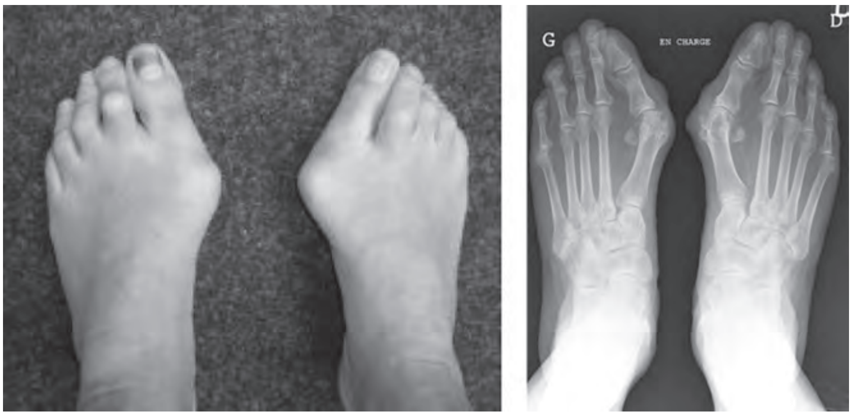

Figure 10:
Bilateral hallux valgus.

More that 150 operations have been described for hallux valgus management. They can be divided according to the localization:

1. Soft tissues
2. P1 osteotomies
   a. Akin
3. Distal MT1 osteotomies
   a. Chevron (Figure11)
   b. Reverdin
4. Mid-shaft MT1 osteotomies
   a. Scarf
5. Proximal MT1 osteotomies
   a. Crescentic
   b. Chevron
   c. Closing or opening wedge
   d. Ludloff

6. CMT1 arthrodesis (Lapidus) (Figure 12)
7. MTP1 arthrodesis
8. MTP1 arthroplasties
    a. Brandes-Keller, Valenti, Mayo
    b. Prosthesis

Or according to the technique:

A. Open
B. Minimal invasive
C. Percutaneous

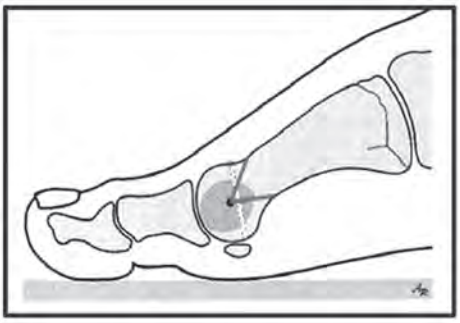

Figure 11: Distal chevron osteotomy.

Figure 12: Modified Lapidus (arthrodesis of CMT1) and Akin (P1) osteotomy.

Hallux rigidus

Arthrosis of the metatarso-phalageal joint of the big toe can be idiopathic, microtraumatic (dancers), inflammatory (rheumatoid arthritis), due to a chronic misalignment (severe hallux valgus) or due to an osteochondritis. Pain and stiffness are the main clinical signs, together with the thickening of MTP1 joint (osteophytes). NSAID drugs, steroid intra-articular injection and orthotic may relieve symptoms. In case of persistent pain, surgical options include joint preserving procedures as osteotomies of P1 (Moeberg) or MT1 (Watermann-Green, Weil), joint debridment with cheilectomy (open or percutaneous), resection arthroplasties (Valenti, Brandès-Keller), MTP1 arthrodesis and prostheses.

Arthrodesis of MTP1 joint (Figure 13) is still the gold standard in advanced, stage 3 cases and shows a 90% of satisfaction rate, but positioning is demanding and it requires stability of the internal fixation.

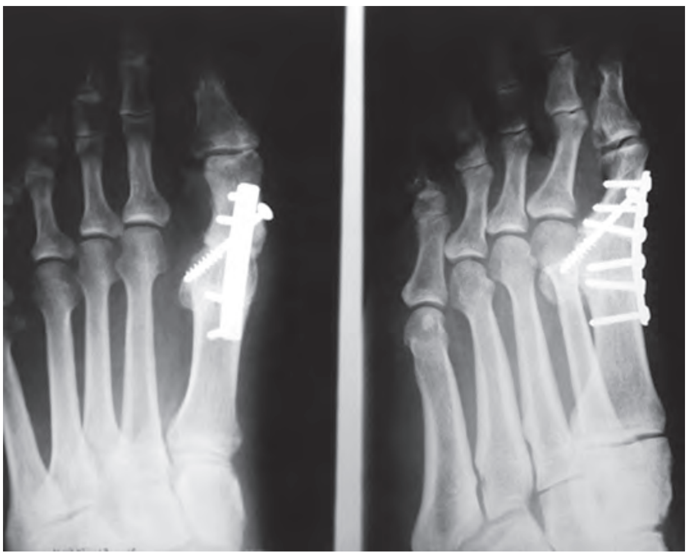

Figure 13: Arthrodesis of MTP1 joint.

Figure 14: Second hammer toe.

Hammer Toes

Surgical correction of hammer toes (Figure 14) often requires an arthrodesis of the proximal interphalangeal (PIP) joint. Most of the time, the joint is maintained with a metallic pin for weeks, with an increased risk of infection, breakage, migration and discomfort for the patient. Furthermore, fusion is not always granted after pin removal. Use of internal devices (Figure 15) could increase fusion rate, decrease complications and improve patient's comfort. Percutaneous surgery is an option to be evaluated, especially for metarsalgia.

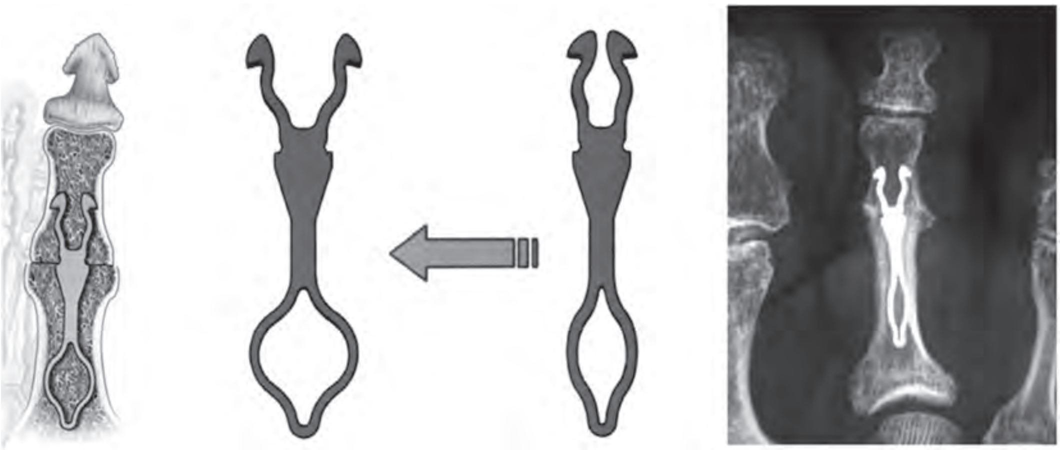

Figure 15:
Arthrodesis of PIP joint with memory alloy intramedullary device.

Morton

Morton's syndrome is a very common diagnostic, maybe too often used: its real incidence is not well known and the prolific literature is controversial. It concerns an entrapment neuropathy of an inter digital nerve under the inter metatarsal ligament. It can be isolated or, more often, combined with overload pathology of the forefoot. The diagnosis is made essentially clinically, and can be confirmed by MRI. The conservative treatment, with adequate shoes insoles, and steroid infiltration, is efficient, especially if the symptom lasts for less than one year. The aetiology must be treated. After failure of this approach, the surgical option (Figure 16) must be evaluated carefully: the relatively « easy » procedure of removal of the nerve should not obviate the potential pitfalls, leading sometimes to difficult to manage pain and re operations. Options are injection of phenol and neurolysis by cutting the intermetarsal ligament, percutaneously or endoscopically.

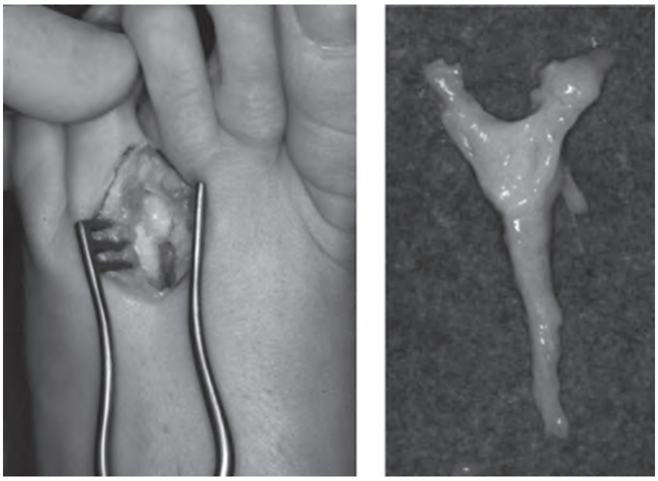

Figure 16:
Excision of Morton's neuroma through a dorsal third web space incision.

Morton's nevroma surgery seems very "simple" but is actually very difficult with many complications, bad results and "recurrences".

%	Good	Bad	Re-do	Numbness	Normal shoes
Bennett,1996	85	15	21		
Dereymaeker 1996	81	19			30
Jarde, 1995	89	11		41	75
Assmus,1994	81.5	18.5		11.1	
Ruuskanen 1994	80	20	9		
Keh, 1992	93	7			

What are the reasons for these “bad” results?

1. Differential diagnosis is wide and may lead to wrong treatment: synovitis, bursitis, MTP arthritis, Freiberg’s infarction, stress fracture, wart, mechanical hyperpressure, hyperlaxity of a MTP joint, tarsal tunnel syndrome, etc. In this situation, the so-call “recurrence” of pain is simply the consequence of the false treatment and the persistence of the etiologic problem.
   Treatment: treat the cause of the pain!
2. Excision of the nerve is followed by the formation of a stump neuroma. This is a normal process, but if this plantar neuroma is too big or too distal, it will be very painful.
   Treatment: second excision, more proximal, using the primitive dorsal approach or a plantar incision. In case of persistent problem due to a painful recurring neuroma, a redo with a tubular venous autograft could be the salvage solution.
3. Loss of sensation due to removal of the nerve is also normal, but may be the cause of bothering dysesthesia.
   Treatment: no surgery, but conservative measures including pain killer, gabapentine, clonazepam, TENS, “trigger points” desensitization, specific insoles, etc.
4. The scar itself, if plantar, is sometimes source of painful intractable plantar keratosis.
   Treatment: avoid plantar incision! Specific relief insoles. Surgery: excise the scar – plastic surgery.

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Trauma: Fractures of the wrist and hand, wrist instability

Distal Radius Fractures: Evolution in the treatment

The recent developments of many osteosynthesis and fixation devices are the reason or the consequences of the rapid changes in the treatment of distal radial fractures (DRF). From a relative conservative policy of treatment according to the expected good results of these injuries as reported by Colles and many authors we are facing now a very aggressive treatment with open reduction and internal fixation. Confusion is very often done between the different fractures types, the character of the injury and not least the patient groups, their age and activities level or expected activity levels. The use of a standardized treatment protocol may make it possible to select the patients with DRF for appropriate treatment. The chosen treatment will guarantee in each case the expected results with an almost, but not fully, normalized function at one year. All fracture types independently their severity will reach the same good results. There is no evidence based reason, with the actual knowledge in 2009 to apply a standardized treatment with volar locking plate to all patients and/or type of DRF. Further studies on this subject are needed and might change the actual standard of care in the future. We always have to be aware of the morbidity of the applied.

Wrist Instability: To recognize a pathology

In order to recognize pathology, the physical examination of the wrist remains the primary tool to be used. A careful assessment, including inspection, observation of use, motion and abnormalities, palpation with eventually reproduction of pain, comparison with the contra lateral side is an absolute requirement. The clinical examination can of course not be dissociated of the patient history and both together lead to hypothesis of eventual pathology. The pathology can than after be confirmed or denied by the help of other more or less invasive investigation procedures like radiographs, CT, MRI or arthroscopy. Beside the experience of the physician the absolute knowledge of the anatomy is the key point of the diagnosis. Instability of the wrist can only be defined in relation with the stability concept and be in relation with the normal kinematic of the wrist in motion understanding the change of the scaphoid position in relation with the lunate with the so called VISI and DISI deformations

Hand Fractures: A challenge of treatment, a goal for the treatment.

Stability of a fracture during healing is a prerequisite to obtain a good anatomical result. On the other hand mobilization is a necessity to avoid stiffness. Immobilization reduces pain and the risk of fracture dislocation but increase edema, stiffness and adhences. For these reasons the hand surgeon is often in front of the dilemma which opposed stable fixation and early mobilization. Further on the goal of eventual surgery is not only to reduce the fracture but also to stabilize it enough in order to allow early mobilization. Dealing with multiple fractures the necessity of early mobilization can by itself argue for internal stable fixation.

Dorsal fracture-dislocations of the proximal interphalangeal joint (PIP) can be taken as an example of this challenge of treatment. It is a common injurie especially among young active individuals. The mechanism of injury is often a longitudinally transmitted compressive force, combined with hyper-extension. In the classification of these fractures the size of the fractured articular surface of the base of middle phalanx is measured to predict the potential instability of the PIP joint throughout the full arc of motion. Treating these injuries one has to a) maintain articular congruity by reconstruction of the "cup shaped geometry" of the base of middle phalanx, b) maintain the stability of the PIP joint, mainly by restoring the buttress of the volar lip of the middle phalanx, c) achieve early functional range of motion and d) avoid post-traumatic arthritis of the PIP joint. In non comminuted fractures: Excellent or good results, with active ROM of PIP joint reaching or even exceeding 80o, can be expected in acute cases with only one large volar lip fragment. In comminuted fractures: an extreme fragmentation of the volar lip makes anatomical reconstruction of the articular surface impossible by open reduction and mini screw fixation. Indirect reduction and minimally invasive fixation with cerclage/tension wire have been used, sometimes with good results. External fixation devices distracting the joint surfaces to unload have been used. a promising but technically demanding method of PIP reconstruction. The anatomical similarity noticed between the volar lip of the base of the middle phalanx and the dorsal part of the hamate articulating with the base of the forth and fifth metacarpal make an anatomical and physiologic modality of fracture reconstruction.

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Trauma: Acute & Late Flexor Tendon Reconstruction

Summary

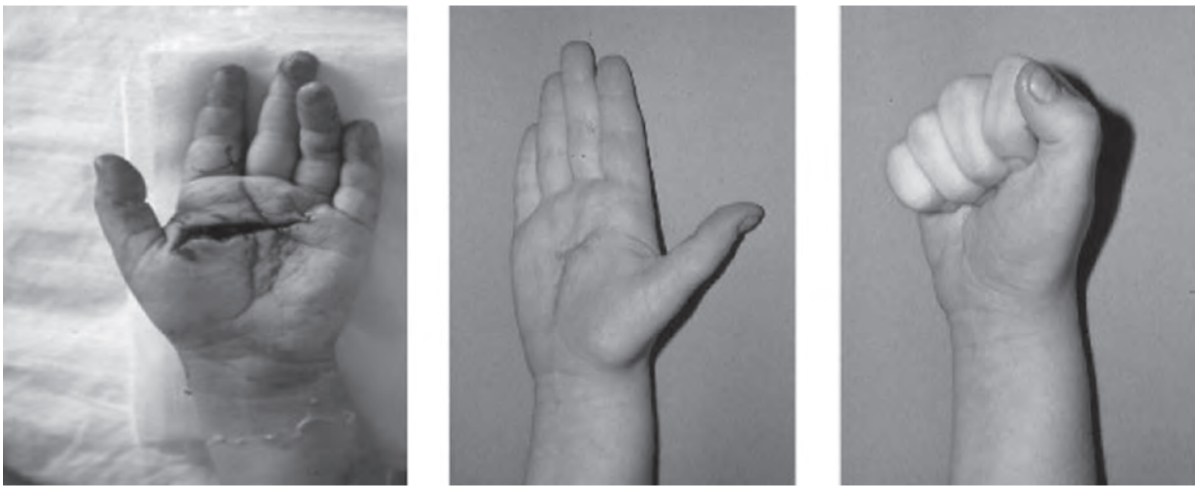
Treatment and prognosis of flexor tendon injuries has been facilitated by dividing the flexor tendon system into zones. Flexor tendon grafting may be indicated after a few days in zone I, if the injury was not repaired primarily. Zone II is considered by all hand surgeons the most difficult area to restore good gliding function. Secondary procedures commonly applied to zone II, include one and two-staged flexor tendon grafting. In cases where both tendons have been lacerated and primary repair could not be formed, then secondary single-stage graft can be used. In severely mutilated hands where extensive damage to the flexor tendon sheaths has occurred two-stage flexor tendon reconstruction using silicone rods is indicated. This restores the gliding mechanism of the tendon within the fibro-osseous canal and reconstructs the pulleys with good results. Paneva's modification of Hunter's two-stage flexor tendon reconstruction, is based on forming a loop between the FDP and the FDS so that a pedicle graft is formed and passed through a tendon sheath. Secondary procedures suited for zone III injuries include, transfer of the adjacent superficialis to the severed profundus, bridging of the gap with an interpositioned tendon graft and end-to-side profundus reconstruction using an interweaving technique. The secondary procedures best suited for zone IV and V injuries are similar to those describe for zone III injuries.

Introduction

- Progress in the understanding of the functional anatomy & mechanics of the hand has been pivotal for the recent advances in repair and reconstruction of the flexor tendons.
- The flexor tendon system is part of the fibrous framework which is comprised of the ligamentous structures, the aponeuroses, and the fibrous sheaths attached to the bones and dermis.
- The fibrous system complements the osseous skeleton and acts to reinforce, provide flexibility and maintain the functional integrity of the hand.

Timing of Repair

- The timing of flexor tendon repair is closely associated with the type of injury.
- Primary Repair
  - In a clean-cut "guillotine" injuries, some tendons of the hand may be repaired primarily.
  - Primary tendon repair takes place acutely (when wound is initially cleaned & debrided).



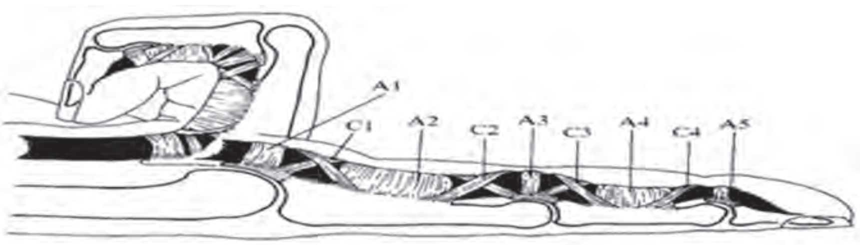
  - This occurs within the first 6 hrs to at most, 24 hrs after injury.

- Delayed Primary Repair
  - When the initial wound has been irrigated & debrided, but the tendons are not repaired until 24 hrs or up to 10 to 14 days after injury, it is referred to as a delayed primary repair.
  - Primary repair is used for clean-cut tendon injuries alone or in conjunction with injury to the neurovascular bundle.
  - In the presence of bone fracture, primary flexor tendon repair can be performed only when the bone has been stabilized.

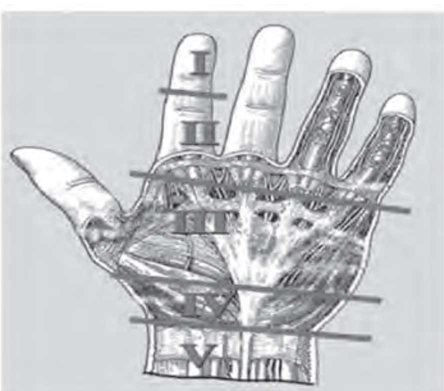
- Secondary repairs
  - procedures performed after about 14 days.
  - Between 14 days to 4 weeks, the repair is referred to as early secondary.
  - After 4 weeks, the repair is considered late secondary repair.
  - Direct suture at the site of severance, tendon grafts & tendon transfers are all used in secondary repair.
  - Indications:
    - clean-cut tendon injuries with bone fractures in cases where the bone can not be fixed and adequately stabilized.
    - extensive crushing injuries with bony comminution near the level of tendon injury
    - injuries associated with extensive neurovascular injury & severe joint injury
    - injuries with extensive skin loss which require coverage with skin graft or free flap.
  - After 4 weeks, repair of the flexor tendon is difficult because of the scarring & destruction of the tendon sheath which obstructs pulling the tendon through the fibroosseous sheath & pulleys. At this point, single-stage tendon grafting may be done.
  - When injury to the sheath and pulley system is extensive and joint contractures and nerve injury are present, two-stage tendon grafting should be considered.

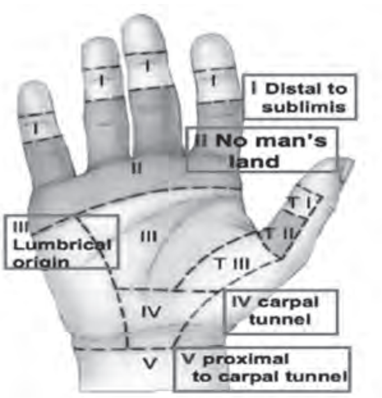
Selection Criteria: General Considerations:

- 2ndary repair of the flexor tendons, regardless of the zone of injury, requires:
  - minimal swelling in the area
  - adequate skin coverage
  - minimal scarring of the gliding mechanism
  - good bone stabilization
  - adequate passive motion of joints
  - satisfactory sensation of the digit.
- In cases of severely damaged digits, reconstruction of the critical pulleys, A2 and A4, may precede 2ndary two-stage flexor tendon reconstruction.



- Treatment & prognosis of flexor tendon injuries has been facilitated by dividing the flexor tendon system into zones which have specific anatomic characteristics.





- Zone II is considered by all hand surgeons the most difficult area to restore good gliding function. This is because both tendons lay close together within the fibrous retinaculum in this area.

Zone I

- Extends from the midpoint of the middle phalanx to the base of the distal phalanx.
- Only the flexor digitorum profundus is present (thus, the superficialis remains intact).
- The flexor retinacular system is reinforced by the A5 pulley & C3 cruciform ligament.
- Usually treated primarily with end-to-end suturing of the profundus, before the tendon retracts into the palm and avulsion of the vincula occurs.
- If the tendon has been cut closed to its point of insertion, it can be advanced to its bony insertion.
- Flexor tendon grafting may be indicated after a few days, if the injury was not repaired primarily. This is considered only in younger patients (less than 20 years).
- Two-stage flexor tendon reconstruction has also been successfully used.

2ndary Procedures in Zone I Flexor Tendon Injuries:

- Indicated when the injury is older than 4 wks & primary repair can not be performed. Particularly, when the short & long vincula are not intact and the flexor profundus has retracted into the palm.
- 2ndary procedures: tenodesis, arthrodesis and one or two staged-tendon grafting

Zone II

- Extends from the proximal edge of zone I (the midpoint of the middle phalanx) to the neck of the metacarpal.
- Both the flexor digitorum profundus & superficialis (sublimis) are usually damaged.
- The flexor retinacular system is reinforced by the A1, A2, A3 &A4 pulleys, the C1 & C2 cruciform ligaments, as well as the short and long vinvula.
- When only sublimis tendon has been lacerated, 2ndary repair is not performed because the profundus allows for adequate function.
  - If a hyperextension deformity of the proximal interphalangeal joint occurs, it can be managed by tenodesis.
- The profundus tendon in the presence of an intact sublimis tendon can undergo delayed primary repair with satisfactory results.
- After 4 weeks then tenodesis or arthrodesis should be considered for the middle or index fingers.
- When both tendons have been lacerated & primary repair could not be formed, then 2ndary single-stage graft can be used.
- In severely mutilated hands with excessive scarring & fibrosis, primary flexor tendon suture or one-stage palm-to-distal phalanx tendon grafting are not indicated because of adhesion formation that prevents active finger flexion. Two-stage flexor tendon reconstruction using silicone rods is indicated.
  - This restores the gliding mechanism of the tendon within the fibro-osseous canal & reconstructs the pulleys with and good results.

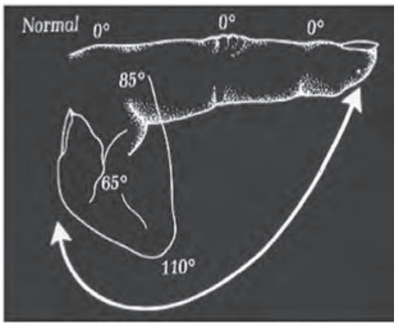
Secondary Procedures in Zone II Flexor Tendon Injuries:

One-Stage Flexor Tendon Reconstruction using Tendon Graft:

- Because of advances in primary tendon repair, free flexor tendon grafts are performed less frequently.
- Indicated for tendon injuries in zones I and II, when primary or delayed primary repair can not be performed and when the tendon bed is minimally injured.
- Used to reconstruct the profundus tendon only.
- Palmaris longus is most frequently used. It has good length & diameter. It does not produce donor site deformity & allows for one palm-to-fingertip tendon graft.
- The plantaris tendon or the long-toe extensors from the lower extremity are also suitable in cases where the palmaris longus is absent or does not have adequate length.

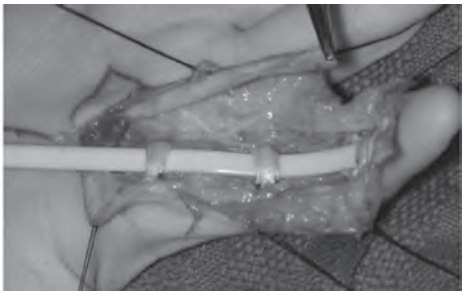
Two-Stage Flexor Tendon Reconstruction Using Silicone Rods:

- Ability to rebuild pulleys over the tendon implant is a major advantage of the two-stage tendon reconstruction over the single stage free tendon graft.
- The implantation of a Silicone-Dacron tendon prosthesis leds to the formation of a pseudo-tendon sheath with a gliding surface through which a secondary tendon graft could be inserted, thus, restoring active finger flexion.
- Indications:
  - patients with extensive scarring of the tendon bed (Boye's categories II-V) where primary suture or immediate tendon grafting are contra-indicated
  - replantation patients with multiple digital amputations & extensive damage of the fibro-osseous canal
  - cases where primary suture & grafting techniques have failed.
  - all digits require a total passive motion of no less than 220o compared to the 260o achieved in normal motion or that the tip of the finger could be passively bent to less than 2 cm from the distal palmer crease.

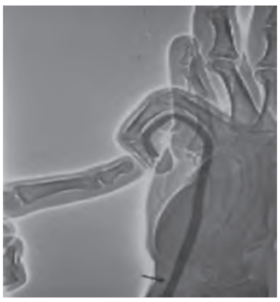


- Surgical Technique:
  - Stage I - (Pulley Reconstruction and Rod Insertion):
  - Reconstruction of the pulley system is a key factor in restoration of the gliding mechanism of the tendon, where 3 - 4 pulleys can usually be restored; one proximal to the axis of the each finger joint and one at the base of the proximal phalanx using portions of the undamaged retinaculum sheath or segments of the superficialis tendon.
    - excision of scarred tendon remnants
    - release of joint contractures
    - nerve repair
    - the insertion of flexible silicone-Dacron reinforced tendon implant along with pully reconstruction.

- Pulley reconstruction is usually required in two-stage reconstruction, and may also be required during acute repair, one-stage grafting and tenolysis. A pulley can be repaired using the residual base of an annular ligament, along with the underlying periosteum and a long strip of tendon.
- Three to four pulleys should usually be restored; one proximal to the axis of the each finger joint and one at the base of the proximal phalanx using portions of the undamaged retinaculum sheath or segments of the superficialis tendon. By reconstructing proximal to the axis of motion of each joint, normal gliding of the tendon can be restored.



- Stage II
  - Follows after an interval of three to five months.
  - Tendon graft is used to replace the implant with minimal disturbance to the newly formed sheath.
  - Graft is attached distally to the base of the distal phalanx and proximally to the profundus motor.
  - A xerogram prior to surgery for the Stage II is useful for determining the exact position of the distal end of the rod.



- Postoperative Management.
  - Stage I: Standard postoperative hand dressing is applied following closure. The wrist and metacarpophalangeal joints should be in moderate flexion (40-50 degrees) with the interphalangeal joints in slight flexion (20-30 degrees). Passive motion should be initiated at about 3 weeks. Dynamic splitting may be needed to prevent joint contracture.
  - Stage II: Post-operative treatment is similar to that for Stage I and is initiated on the first day postoperatively. By 8 weeks, full activity is allowed and by 12 weeks the patient can perform a full-power grip.
- Good Results

Case 1

Case 2

Complications in two-stage treatment of flexor tendon ruptures:

- Complications using either silicone or Hunter rods are serious, and may jeopardize the final functional outcome of the repaired tendons.
- Stage I complications include,
  - skin necrosis
  - rod buckling

  - rupture of the distal end of the silicone rod or Hunter implant

  - rod migration
  - synovitis
  - infection,
- Stage II complications include:
  - distal or proximal disruption of the graft juncture

- grafts which are too loose or too tight

- bowstringing

- impingement of the proximal suture in the sheath at the level of the wrist
- flexion deformities of the PIP and/or DIP joints and infection

- The most common complication is a flexion deformity of the PIP and/or DIP joint which is related to the surgical procedure.

Zone III

- Extends from the neck of the metacarpals distally (distal palmar crease) to the distal edge of the transverse carpal ligament.
- One or both tendons can be injured at this level which is proximal to the finger flexor retinaculum & distal to the carpal ligament.
- Since there are no retinacular structures, direct repair is usually effective.

Secondary Procedures in Zone III Flexor Tendon Injuries:

- Although direct suturing of the flexor tendons usually gives satisfactory results, end-to-end coaptation can not be effectively performed after more than 4 weeks have passed since the time of injury when a tendon gap of 2-6 cm is frequently present, because of tendon retraction.
- The common digital nerves, superficial arch, motor branch of the median nerve and lumbrical muscles are also usually injured in Zone III injuries.
- Rule of thumb- only the flexor digitorum profundus is reconstructed in zone III. (reconstruction of both tendons after a period of 4 to 6 weeks has a high risk of excessive adhesion & scar formation.)
- Best suited for zone III injuries
  - transfer of the adjacent flexor digitorum superficialis to the severed profundus
  - Bridging of the gap with an interpositioned tendon graft or end-to-side flexor digitorum profundus reconstruction using an interweaving technique.
  - End-to-side flexor digitorum profundus reconstruction is prefered in zones IV and V where there is no risk of impinging on the A1 pulley. End-to-side reconstruction is done using the Pulvertaft interweaving technique.

Zone IV

- Defined by the carpal canal and the distal & proximal edges of the transverse carpal ligament.
- The flexor tendons are enclosed in synovial sheaths & contained within a tight compartment under the transverse carpal ligament.
- Landmarks include the pisiform and trapizium, distally, and the hamate hook and the scaphoid tuberosity, proximally.

- The median nerve is vulnerable to injury.
- 2ndary procedures best suited for zone IV injuries (similar to those describe for zone III) include:
  - transfer of the adjacent flexor digitorum superficialis to the severed profundus
  - bridging of the gap with an interpositioned tendon graft
  - end-to-side flexor digitorum profundus reconstruction using an interweaving technique

Zone V

- Extends distally to the proximal edge of the transverse carpal ligament & proximally to the musculotendinous juncture of the flexor tendons.
- Tendons are surrounded by loose areolar tissue & are less constrained.
- Injury includes the flexors of the digits, thumb & wrist is frequently associated with injury to the major nerves, medial and ulnar nerve, as well as the major vessels, radial and ulnar artery.
- 2ndary procedures best suited for zone V injuries (similar to those describe for zone III) include:
  - transfer of the adjacent flexor digitorum superficialis to the severed profundus
  - end-to-side flexor digitorum profundus reconstruction using an interweaving technique

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Trauma: Digital Replantation: Indications and Management

Summary

Even though today replantation surgery has become a routine procedure, it still remains a delicate and demanding surgery that requires that the orthopaedic, plastic or hand surgeons involved have adequate training, experience and expertise in microsurgical techniques. The surgeons must also have at their disposal all of the necessary microsurgical armamentarium in order for digital replantation surgery to be possible. The indications, as well as the priorities for replantation procedures have been well established and documented, including formulated guidelines for thumb, single digit, multiple digit and mid palm amputations. For cases that face more complex problems, the surgeon should be aware of other alternative techniques, such as transpositional microsurgery and various other secondary reconstructive procedures. Although, replantation procedures have been simplified, a second surgical team should be present in the operating room to assist and facilitate the chief surgeon. The assisting team, in this two-team system, saves valuable surgical time by harvesting microvenous grafts, performing bone fixation or tendon repair among other things, while the chief surgeon focuses on revascularization. In addition, a well-trained anesthesia team familiar with replantation procedures should always be on standby to monitor a number of parameters related to either the type of anesthesia administered (general anesthesia, regional or combination) or other factors, such as drugs, room temperature, patient's body temperature, etc., all of which are closely related to the success of the replantation effort. A number of sophisticated post-operative measures are now available to follow the replanted digit and are invaluable in the patient's post-operative care. A plethora of methods are available for early identification of complications before they rapidly turn to an irreversible state and thus, allow for their immediate management. None-the-less, the presence of a member of the replantation team with the assistance of a nurse on a 24-hour basis is still widely accepted as the most beneficial means for avoiding an undesirable post-operative course of the replanted digit. Overall, the most significant guideline, which underlines the philosophy and trends of digital replantation today, reflects the current aim of not only ensuring the survival of the finger, but its functional use, as well. Experience dictates that this can be achieved only if the basic principles, indications and selection criteria, which have been described above, are adhered to.

Introduction

- 1968, Komatsu & Tamai – 1st successful replantation of an amputated thumb.
- Today, accumulated experience has made revascularization & replantation surgery a fairly routine procedure, provided that surgeons are well-trained in microsurgical techniques.
- Goal of all replantation efforts is targeted not only towards the survival of the amputated part, but mainly towards producing as close as possible normal functional ability.
- Well-defined selection criteria enable the surgeon to avoid procedures which lead to a surviving, but non-functioning digit on the one hand, and a plethora of secondary reconstructive procedures on the other hand.
- Fundamental to the success in replantation of a digit is not only a solid microsurgical technique for vascular microanastomosis, nerve coaptation and tendon repair, but also a clear understanding of the selection criteria.

Selection Criteria

- Well documented selection criteria have been established to assist the surgeon in screening patient eligibility for replantation.
- The functional outcome should be superior to that of a prosthesis or revision of the amputation. The criteria which aid the surgeon in predicting outcome can be divided into:
  1. those factors related to the type of amputation and its characteristics;
  2. general factors related to the patient.

Classification of Amputations (based on the viability of the digit)

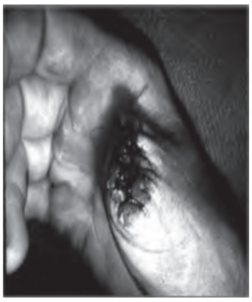
- *Complete Digital Amputations:* amputated part is completely detached from the proximal stump; there is no tissue part interposed between the distal amputated part and the proximal stump.

- *Incomplete Nonviable Digital Amputations:* both neurovascular bundles & entire or most of the venous network system are severed or severely damaged. The distal segment is connected to the proximal stump with either an islet of skin or a small segment of tendon or nerve. None of these tissue components are capable of ensuring the viability of the distal part.

- *Incomplete Viable Digital Amputations:* assessed only after visualization under the operating microscope. Usually one digital artery and 1 or 2 dorsal veins remain intact.

Indications & Contraindications According to Type of Amputation

Thumb: High priority; When successful, results are better than any reconstructive procedure.




Single Digit: 3 major indications.

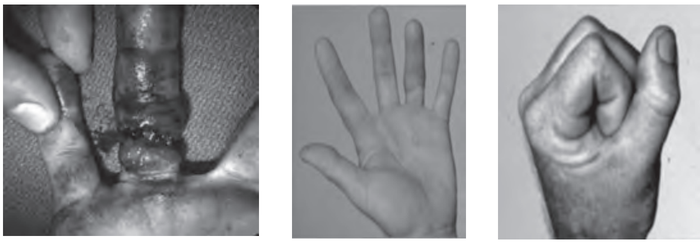
- level of the amputation - distal to the insertion of the flexor digitorum sublimis (superficialis). The digit immediately becomes functional as flexion of the middle phalanx by the intact superficialis tendon is possible.



- level of amputation at or distal of DIP joint. Replantation achieved with the anastomosis of one artery, while venous drainage can be provided by provoked bleeding or with the application of leeches.


- ring avulsion injuries Type II or IIIa. The flexor digitorum superficialis tendon remains intact & outcome almost always has good function.

Type II



Type IIIa.

Contraindications

- amputation at the level of the proximal phalanx or PIP joint, particularly avulsion or crush injuries. Almost always results in a nonfunctioning digit.

Multiple Digits: High priority. Most important consideration is the overall function of the hand.

- When amputated segments are severely mutilated and damaged, then efforts are aimed at replanting the least damaged digit segment to the most useful stump.
- When all of the digits are not replantable & thumb remains intact, the aim is to restore width of palm by replanting or transposing digits to the ulnar side. This augments grasp power of the hand and maintains light pinch.

- *Transpositional Microsurgery*: transpostion & replantation of any digit to another stump which plays a more significant role in the function of the hand. 5 major indications
  - Multiple Digit Amputations Including the Thumb: when thumb is not replantable either because it is too short or is extensively damage, the least damaged digit is replanted in the place of the mutilated thumb.

  - Bilateral Thumb Amputations: the thumb of the non-dominant hand which is less damaged or the least damaged digit is transposed to the thumb stump of the dominant hand for the sake of maintaining dexterity in that hand.
  - Bilateral, Symmetrical Digital Amputations: replantation effort is directed towards increasing the dexterity of the dominant hand by transposing digits over from the non-dominant hand.
  - Multiple Digital Amputations with the Thumb Intact: digits are replanted towards the ulnar side of the hand, so as to preserve the width of the palm and consequently increase the power grasp of the hand.
  - Amputation of All Five Digits: 2 goals:
    1. replant & create a useful and functional thumb.
    2. transpose the digits towards the ulnar side, to preserve width of the palm & power grip.

Mid Palm: ideal candidates for replantation & constitute an absolute indication. If replantation efforts are successful, hand functional ability is superior to any prosthetic device. Success is directly related to the level of the amputation. Greater success rate when amputation located at the level of the superficial or deep palmar arch, compared to those at the level of the common digital arteries.

General Indications & Contraindications:

Age:

- Children- an attempt should be made to replant almost any amputated digit. If the reattached part survives, useful function can be predicted.
- Elderly- poor nerve regeneration & joint stiffness poses problems for good functional outcome. Good sensibility, strength and coordination is rarely achieved.

Mechanism of Injury:

- Clean-cut "guillotine" type amputations are good candidates for replantation.
- Minor crush or avulsion amputations with minimal vascular injury are good candidates.
- Severely crushed or avulsed digits have extensive vascular, nerve and soft tissue damage and the predicted outcome is usually poor.

Time of Ischemia:

- Warm ischemia or anoxia at 20o to 25oC produces irreversible necrotic changes to the muscle and soft tissues.
- Because digits lack muscle, the time allowed for warm ischemia is about 8 hours. By cooling the amputated part to 4oC, ischemia time for digits can be extended to up to 30 hours.

General Health of the Patient:

- With major life-threatening injuries at the time of trauma, then replantation of digits may need to be postponed or even canceled.
- Certain diseases which adversely affect peripheral circulation (diabetes mellitus, autoimmune diseases, collagen vascular diseases, etc) often a contraindication.

Pre-operative Care of the Patient & Amputated Part

- After stabilization of other major injuries, bleeding from the stump is controlled using pressure. The patient is transported with a pressure dressing & no attempt to ligate or clamp vessels should be made. In cases where bleeding is persistent, a pneumatic tourniquet or cuff can be used.
- The amputated part, if contaminated, is gently rinsed in normal saline & wrapped with gauze, moistened in normal saline or Ringer's lactate. The wrapped part should then be immersed in normal saline in a plastic bag and the bag placed on ice.
- In incomplete amputations, the amputated part should be left attached to the stump with care taken to avoid rotation or pinching of the soft tissues which might further compromise any remaining flood flow.

Surgical Sequelae & Techniques in Replantation

- The entire sequelae that comprises a single digital replantation procedure is a series of complex & delicate operations for vessels, bone, tendons, nerve and skin.
- Surgical sequelae may vary somewhat according to level of the amputation & type of injury.
- 1st thorough cleansing & debridement, so that structures are identified
- Structures are repaired serially from the skeletal plane outwards, so that the deeper structures are repaired first, avoiding the sites of vascular anastomosis. In most cases, the repair of digits follows the following operative sequence:

  1. neurovascular identification and labeling in the amputated part and stump;
  2. tissue debridement;
  3. bone shortening and stabilization;
  4. extensor tendon repair;
  5. arterial anastomoses; Survival is directly related to the successful anastomosis of both of the digital arteries, and two dorsal veins per patent digital artery.
  6. venous anastomoses;
  7. flexor tendon repair;
  8. nerve repair;
  9. soft-tissue and skin coverage.

- All of the structures are repaired primarily, including nerves unless a large nerve gap is present which necessitates a secondary nerve grafting procedure. Secondary reconstruction of structures would entail operating through repaired structures of the replanted part.

Surgical Preparation of Amputated Part and Patient for Replantation

- Two surgical teams: One team prepares the amputated part, while the other prepares the patient & the amputated stump.
- The amputated part is cleaned with normal saline & kept cool by placing it on a bed of ice.
- Debridement should be performed using the operating microscope or magnifying loupes. It is important to excise all necrotic and potentially necrotic tissue, as well as foreign bodies.
- The amputated part is carefully debrided & dissected to expose arteries, veins, nerves, tendons, joint capsule, periosteum and soft tissues which will save considerable time during replantation later. Digital vessels & nerves are identified & traced for 1.5 to 2 cm and tagged with 8/0 or 9/0 nylon sutures for later vascular and nerve repair.
- Most replantations can be performed under axillary brachial plexus block with bupivacaine, a long-acting local anesthetic. Regional anesthesia is preferred because of the increased vasodilation and peripheral blood flow due to the peripheral autonomic block.
- The stump is first cleansed with an antiseptic, such as povidone-iodine solution and irrigated with normal saline. Then the stump is debrided and neurovascular structures are identified and labeled with 8-0 or 9-0 nylon under magnification and tourniquet ischemia.
- Subcutaneous veins on the stump are often very difficult to locate, but to avoid venous congestion, it is critical that an adequate number of veins are identified for later patent anastomosis.

Bone Shortening and Fixation:

- Bone shortening almost always proceeds osteosynthesis & vessel anastomosis.
- Shortening of the digital skeletal framework before replantation appears to be one of the best alternatives in achieving good end-to-end vessel anastomoses on healthy tissue and without tension. This also applies for digital nerve repair.
- The amount of bone removed ranges from 0.5 - 1 cm and varies according to the type of injury and the level of the amputation
- preferable to remove bone from the amputated part, so that if the replantation fails, length of the digit stump has not been sacrificied.
- Bone resection is followed by osteosynthesis, which allows for the healing of microvascular anastomoses and nerve sutures, as well as repaired tendons.
- Mini plates with screws, single lag screws, crossed Kirschner wires, a combination of intraosseous circlage wires and Kirschner wires, as well as intramedullary Kirschner wires are examples of the materials and techniques suitable for bone fixation.

Tendon Repair

Extensor Tendons:

- The extensor tendons are always repaired with an end-to-end suture technique directly after bone shortening and fixation.
- Suturing of the extensor tendons provides additional stability for the replanted digit
- Repair of the extensor tendons is always done primarily.

Flexor Tendons:

- Rule of thumb: tendon repair is done directly only in very selected clean-cut amputations. In all other cases, repair is done as a secondary operation either with tendon grafts or using a two-stage flexor tendon reconstruction procedure.
- Care must be taken in retrieving the proximal flexor tendon stump, so as not to induce spasm or damage to the proximal arteries.
- If tenolysis is required, it should not be performed until 3-6 months after replantation, while secondary flexor tendon reconstruction using the two-stage silicone rod method can be performed about 3 months after replantation.

Digital Artery Repair:

It is preferable to repair both digital arteries.

- Critical for successful microvascular anastomosis are
  1. solid microsurgical technique, and
  2. anastomosis on normal intima with no tension.
- The artery should be dissected until normal intima is visualized under high-power magnification. If normal intima can not be approximated without tension, then the surgeon must consider either further bone shortening, or preferably the use of a vein graft.
- If the ends can not be anastomosed without tension, then an interpositional vein graft obtained from the palmar forearm should be used.
- With a patent anastomosis, the fingertip will begin to turn pink in a few minutes. Capillary refill and pulp turgor should be inspected.

Digital Vein Repair:

- In order to repair two veins for each artery, veins may need to be mobilized or harvested.
- The most common error is anastomosis under tension or to waste time trying to repair very small veins. Only the largest veins should be anastomosed.

Digital Nerve Repair:

- Repair of the digital nerves adheres to the same guidelines as with the repair of the flexor tendons within the tendon sheath.
- With clean-cut injury, direct end-to-end digital nerve coaptation is indicated.

- In all other situations, such as crush or avulsion type injuries, secondary procedures using a nerve graft or if the nerve gap is less than 2 cm, using a nerve conduit, are recommended.

Skin Coverage:

- Once all of the structures have been repaired, hemostasis is imperative.
- The skin be loosely approximated with a few interrupted nylon sutures.
- Potentially necrotic skin is excised and the skin is closed with out tension.
- A local flap, split thickness graft, z-plasty, two-stage pedicle flap or free flap may be required to ensure coverage of the anastomosis site, as well as area of nerve and tendon repair.
- Fasciotomies are indicated if pressure or constriction occurs.

Dressing:

- The wounds should be covered with strips of gauze moistened with antibacterial grease or petrolatum.
- It is essential that the strips are not placed in a continuous or circumferential manner which can potential constrict the replanted digit.
- A bulky dressing is applied, with the fingertips remaining exposed for clinical observation and temperature probes.

Postoperative Management and Rehabilitation

- Careful postoperative management is essential for a successful outcome.
- The room should be warm, as cooling can lead to cold-induced vasospasm.
- Cigarette smoking by the patients and visitors is strictly forbidden, as nicotine is a potent inducer of vasospasm. Cold drinks, as well as those with caffeine are restricted.
- Broad spectrum antibiotic (cephalosporins) are generally indicated for 5 to 10 days for patients with open injuries.
- High energy crush or avulsion injuries with extensive vessel damage depend upon adequate anticoagulant therapy for better patency. Among the agents commonly used are heparin, aspirin and low molecular weight dextran.
- Clinical evaluation should include color, capillary refill, temperature and turgor. Clinical evaluation should be performed continuously for the first three 24 hours postoperatively.

Complications

Acute complications:

- Inadequate perfusion is responsible for acute complications.
- Decreased skin temperature, loss of capillary refill, diminished turgor, or abnormal color in the immediate postoperative period indicate that the replanted digit is in jeopardy.
- When the area is cyanotic, congested and turgid, then venous insufficiency is present. If the problem is minor, it sometimes can be managed without having to reoperate. Congestion can be efectively relieved with the use of medicinal leeches..
- If normal perfusion does not return, the patient must be returned to the operating room within 4 to 6 hours after the appearance of inadequate perfusion. If the patient is returned with the first 12-48 hours, some failures can be salvaged by redoing the vein graft, removing the thrombus and grafting a previously unrecognized damaged vessel segment.

Subacute and Chronic Complications:

- Subacute complications due to infection are fairly frequent in digital replantations, they rarely result in the loss of the replanted part.
- Pin tract infections are the most common and occur about four weeks after surgery. They can be managed by pin removal and administration of antibiotics.
- The most common chronic complications include cold intolerance, tendon adhesions and malunion. Cold intolerance improves over time.
- Tendon adhesions are frequent, resulting in limited motion. In severe cases, tenolysis can be performed after three months.

Conclusions

- Even though today replantation surgery has become a routine, it still remains a delicate and demanding surgery that requires adequate expertise in microsurgical techniques.
- Indications are well established with formulated guidelines for thumb, single digit, multiple digit and mid palm amputations.
- Although replantation procedures have been simplified, a second surgical team can save valuable surgical time by harvesting microvenous grafts, performing bone fixation or tendon repair among other things, while the chief surgeon focuses on revascularization.
- The current aim which underlines the philosophy in digital replantation today is ensuring not only the survival of the finger, but more importantly its functional use as well.
- Experience dictates that this can be achieved only if the basic principles and indications which have been described above are adhered to.

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Congenital Anomalies: Classification & Management

Summary

Reconstructive microsurgery in the management of congenital anomalies is aimed at providing the ability to control placement of the hand in space, good skin cover with adequate sensibility and satisfactory power grasp and precision handling. Early correction of skeletal alignment is vital. As such, extra bones, malpositioned bones, and fusions between adjacent bones should be dealt with in order to allow normal growth and development. Although several congenital upper extremity anomalies may be treated using various microsurgical techniques, microvascular autotransplantation in reconstructive surgery of congenital anomalies brings versatility to reconstruction of the upper limb that has previously not been available. These procedures allow for transplantation of skin flaps in one stage, and the transplantation of vascularised joints and/or growth centers. In addition, they offer the opportunity to reconstruct digits by transplantation of homologues from the foot. Long-term studies have shown the usefulness of microvascular toe transfer in the treatment of adactyly with the incorporation of the transferred digit into grasp-and-pinch function. Morbidity to the donor site is almost negligible, and the functional improvement to the hand is reasonably good considering the young age of the patients. Functional results are limited by the lack of full motion, soft-tissue contractures, sensory recovery, and the delay in cortical reeducation. The use of free fibular transfer for long bone deformities of the forearm has been shown to provide bony union as well as growth. In selecting a reconstructive procedure, surgeons must consider various factors such as, patient age, vessel availability, and lack of other possible reconstructive options. In reconstruction of congenital hand anomalies, the importance of digit positioning to provide prehensile pinch and grasp as the ultimate goal needs to be emphasized so that opposing fingers rather than cosmetic fingers result in effective hand use. In the selection process among reconstructive alternatives the surgeon must consider factors related to both aesthetic improvement of the hand, as well as long-term functional return.

Introduction

- Embryology
  - Bud appears – 25th day
  - Full development – 56th day
- Tissue element development
  - Skeletal elements – 5 wks
  - Joints & tendons – 6 wks
  - Ligaments – 8 wks
  - Ossification – 9 wks
  - Synovial tissue – 11 wks
- Normal Development
  - Age 1 yr – Hand fully integrated. Good grasp & pinch control
  - Age 3 yrs – Prehension accuracy, coordination refinement & increased strength
- Congenital deformities = structural abnormality present at birth
  - Anomalies of musculoskeletal system = broad spectrum. Single vs multiple. Major vs minor clinical significance.
  - Incidence: 1 of 626 newborns (0.16%). Of which 90% have no functional impairment, and 10% have functional impairment. (Finland incidence 0.18%. Study by Vilkki; Greece incidence 0.19%. Study by Soucacos)
  - 10-15% are associated with anomalies to organ systems (cardiovascular, craniofacial, genitourinary.

Classification

- There are numerous systems for classification of upper-extremity anomalies. Based on embryology, anatomy, etc.
- Based on Swanson (1968), IFFSH and ASSH propose: Eliminates confusion from Greek & Latin terms. Defines anomalies according to embryonic failure during development and uses clinical diagnosis for categorization. 7 Categories
  - Failure of formation
  - Failure of differentiation
  - Duplication
  - Overgrowth
  - Undergrowth
  - Constriction ring syndrome
  - Generalized abnormalities & syndromes

Hand and wrist

Failure of formation

- Arrest of development
- Complete or incomplete
- Transverse (congenital amputation) Can be at any level
  - Absent limb or absent finger
  - Common levels of arrest are upper third of forearm, wrist, metacarpal, phalangeal
  - Absence of hand = acheria; absence of finger = adactyly. Often difficult to distinguish from constriction band syndrome. Nail remnant disqualifies patiens from this category.

- Longitudinal arrest
  - Preaxial – varying degrees of hypoplasia of thumb or radius
  - Central
    - divided into typical & atypical types of cleft hand

  - Postaxial – varying degrees of ulnar hypolasia to hypothenar hypoplasia
  - Intercalcate longitudinal arrest – various types of phocomelia
  - Includes:
    - Missing ray (eg thumb aplasia)
    - nubbins
    - phocomelia – the functional terminal element is present. Various types:
      - hand attaches to shoulder (forearm & arm deficient)
      - forearm attaches to shoulder (arm deficient)
      - hand attaches to arm (forearm deficient)
    - Radial club hand
    - Ulnar club hand

Failure of Differentiation

- Failure of separation of parts
- Soft tissue involvement – syndactyly, trigger thumb, Poland syndrome, camptodactyly
- Skeletal involvement – various synostoses & carpal coalitions
- Congenital tumorous conditions – include all vascular & neurological malformations. (eg radio-ulnar synostosis, symphalangism [stiff proximal interphalangeal joints with short phalanges] camptodactyly, arthrogryposis, syndactyly
- Basic anatomic units are developed
  - Shoulder
    - Undescended scapula
  - Arm
    - Proximal radio-ulnar synostosis
  - Forearm
    - Distal radio-ulnar synostosis
  - Hand
    - Syndactyly – one of the most common anomalies in the hand. Classified according to completeness (complete, incomplete) and presence of bony union.

· Clinodactyly – deviation of finger as a result of an abnormally shaped middle phalanx.



· Camptodactyly – almost exclusive to Caucasians. Presents either in infancy or adolescence. Usually bilateral and affects little finger.

Duplication

- Splitting of embryonic parts
- Ulnar or radial side
  - Polydactyly



  - Mirror hand – classic presentation is duplication of ulna, with no radius, 7-8 digits with no thumb.


Overgrowth

- Gigantism, hyperplasia
- Limb or part (finger, hand or arm)
- Involves skeleton or soft tissue
- Macrodactyly, megalodactyly

- Hemihypertrophy

Undergrowth

- Incomplete development
- Hypoplasia
- Brachysyndactyly
- Brachydactyly, Brachyphalagia
- Short metacarpals

- Madelung's deformity (abnormal distal radial growth)

Constriction Ring Syndrome

- Represents a disruption of deformation sequence subsequent to annular bands of chorionic tissue encircling the limb. It has a low incidence of associated anomalies.
- Clubfoot is the most common association
- Limbs or digits
- Streeter hypoplasia – occurs with or without lymphedema; involves amputation at any level

Generalized skeletal abnormalities

- Unclassified category
- Syndromes with skeletal malformations
- Dwarf, Marfan

Management

- Surgical targets
  - Good power grasp
  - Precision handling
  - Good skin cover
  - Hand placement control
- Timing of surgery. Early surgery is performed by definition with the 1st 2 yrs. Advantages include full potential for development & growth, less scarring, easier & early incorporation of reconstructed part, anatomic adaptation, and reduced psychologic consequences.
  - Disadvantage: technical difficulty.
- Conservative management (90% of congenital anomalies require no surgery!)
  - Night splints

- Physiotherapy
- Prostheses
  - Functional
  - Cosmetic

Failure of Formation

- Transverse
  - Cosmetic prostheses
  - Toe-to-thumb
  - Digital lengthening



  - If metacarpal elements are present, objective is to create a basic hand:
    - Mobile ray on radial side
    - A cleft
    - A post on ulnar side or at least one ray on the opposite side
- Longitudinal
  - Phocomelia – best treated with prosthesis.. Radial or ulnar deviation of the hand may need centralization.
  - Toe-to-thumb
  - Polisization
    - For thumb aplasia
    - Good grasp & pinch function

Failure of Differentiation

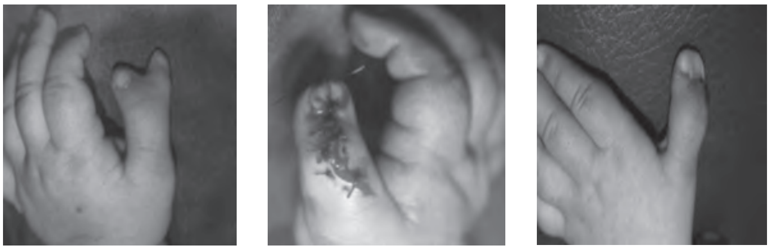


- Syndactyly
  - Separation of digits, provision of a lined commissure, avoidance of scars

Duplication



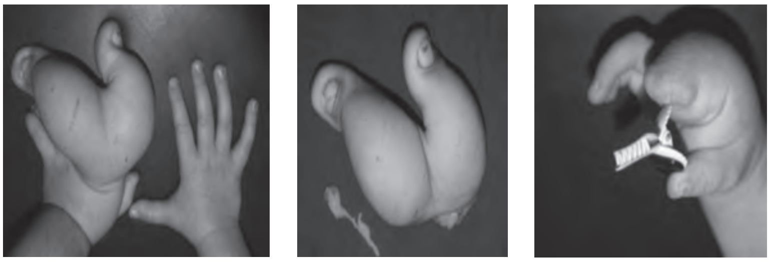
- Polydactyly
  - Excision
- Mirror hand



- Correction begins proximally with correction of elbow. Excision of one of the ulnar heads. Wrist extension is restored by tendon transfer or the wrist can be arthrodesed. In the hand, resection of the accessory preaxial middle & little fingers and then using the accessory ring digit as a thumb with a modified pollicization procedure.

Overgrowth

- Macrodactyly
  - Objective is to diminish length & bulk without compromising sensation or vascularity.
  - Includes: staged debulking, epiphysiodesis or total physeal resection, shortening procedures, partial amputation or ray amputation.

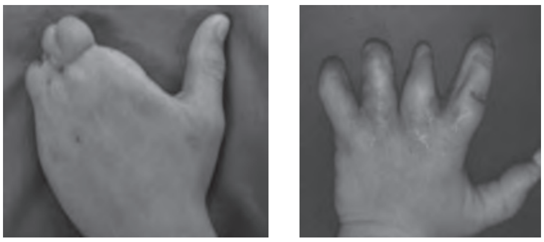


Undergrowth

- Brachyphalangia
  - Digital lengthening

Constriction Ring Syndrome

- Toe-to-hand



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Elbow and forearm

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Upper Limp Trauma: Elbow and forearm

Introduction

The most authoritative and comprehensive textbook about the elbow is certainly *The Elbow and Its Disorders, 4th Edition, Elsevier 2008 by Bernard F. Morrey, MD.* In it, the student will find a compilation of the most recent knowledge of all aspects of elbow pathology.
For the latest in fracture fixation techniques the reader is invited to visit the *AO surgery reference site: AO surgery reference: http://www.aofoundation.org.* Another most useful publication containing pertinent facts related to orthopaedics and musculoskeletal in general trauma is the *AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.*

Facts about the elbow

The distal humerus is an arch subtended by two columns of equal importance. The trochlea is a pulley like structure covered by cartilage in a 300° arc. The articular portion of the distal humerus in the lateral plane is inclined 30° anterior with respect to the axis of the humerus, the frontal plane is tilted 6° into valgus, and in the transverse plane is rotated medially about 5°. The capitellum is a half sphere covered anteriorly with cartilage. The radial head is asymmetric and has two articular interactions: The proximal ulno-radial joint and the radio-humeral joint. It has approximately a 240° of articular cartilage coverage which leaves 120° of non cartilage covered area amenable to hardware fixation. The head and neck have an angle of 15° in valgus. The proximal ulna has a coronoid process that has an area equivalent to the radial head. There is no cartilage in the middle of the sigmoid notch. The joint is angled 30° posteriorly in the lateral plane; 1° to 6° in the frontal plane. The carrying angle is the angle between the humerus and the ulna with the elbow extended fully and it varies between 11°-14° in men and 13°-16° in women. The capsule attaches anteriorly above the coronoid and radial fossae and just distal to the coronoid. Posteriorly it attaches above the olecranon fossa, follows the columns and distally attaches along the articular margins of the sigmoid notch. The normal elbow has a range from 0° or slightly hyperextended to 150° of flexion, pronation is 75° and supination is 85°. A 3° to 4° varus-valgus laxity has been measured during F/E. The rotation of the forearm is around an oblique axis passing through the proximal and distal radio-ulnar joints. The primary static stabilizers of the elbow are the ulno-humeral articulation and the collateral ligaments. The secondary static stabilizers are the capsule, the radiohumeral articulation and the common flexor and extensor tendon origins. The dynamic stabilizers are all the muscles that cross the elbow (Anconeus, triceps, brachialis). Finally all forces that cross the elbow joint are directed posterior and this has implications in surgical procedures around the elbow, in the design of elbow prosthesis, and in rehabilitation programmes.
The Elbow and Its Disorders, Editor BF Morrey, 4th Edition, Elsevier 2008.

Approaches to the elbow

Lateral approach

Kocher (radial head fracture, lat collat reconstruction)

Interval between the anconeus and extensor carpi ulnaris

Column (Stiff elbow)

Extensor carpi radialis longus and distal fibers of the brachial radialis elevated from the lateral column and epicondyle. Brachialis muscle separated from the anterior capsule; safe if the joint penetrated at the radiocapitellar articulation. Triceps may be elevated posterior giving access to the olecranon fossa.

Anterior approach

Henry (PIN, proximal radius, tumors)

After an appropriately curving incision to avoid the flexor crease, brachioradialis and brachialis are gently separated to find the radial nerve. Follow the nerve to the arcade of Frohse where the motor branch plunges into the supinator to course dorsally in the forearm then elevate supinator from its radial insertion laterally thus protecting motor branch in the supinator mass.

Medial approach

Over the top Hotchkiss approach

(Coronoid fracture type 1: transolecranon suture)

50:50 split in the flexor-pronator mass anterior to the ulnar nerve.

Natural split : Taylor and Scham

(Coronoid fracture type 2-3 with plate fixation).

Elevation of the entire flexor-pronator mass, from the dorsal aspect to the volar aspect.

Boyd Posterolateral Exposure (Radial head, proximal radius)
The ulnar insertion of the anconeus and the origin of the supinator muscles are elevated subperiosteally. More distally, the subperiosteal reflection includes the abductor pollicis longus, the extensor carpi ulnaris, and the extensor pollicis longus muscles. The origin of the supinator at the crista supinatorus of the ulna is released, and the entire muscle flap is retracted radially, exposing the radiohumeral joint. The posterior interosseous nerve is protected in the substance of the supinator, which must be gently retracted

Posterior approach (Fractures distal humerus, arthroplasty, stiff elbow)
- Posterior approach with extensile exposure of the distal humerus:
  - Bilaterotricipital approach (Alonso-Llames) with lateral and medial retraction of the triceps.
  - Triceps Splitting (Campbell)
  - Olecranon osteotomy: Extra-articular, chevron or straight.
  - Triceps sparing elevation of triceps according to Gschwend (osseous) or Morrey-Bryan (subperiosteal).
  - Triceps reflecting anconeus pedicle approach (TRAP) O'Driscoll.

The Elbow and Its Disorders, 4th Ed, Elsevier 2008 Ed. Morrey BF.
Fracture of the Anteromedial Facet of the Coronoid Process. Surgical Technique. Ring D, Doornberg JN. J Bone Joint Surg Am. 2007;89:267-283.
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Fractures and dislocations
Fractures of the distal humerus
These fractures are relatively rare and constitute about 2% of all fractures, but represent a ⅓ of all elbow fractures. They most commonly occur in patients in the 6th decade and above and are frequently associated with osteoporosis. These fractures are frequently comminuted and operative fixation is therefore technically difficult. Fractures of the distal humerus are articular fractures characteristically **unstable** and prone to displacement. Only in exceptional circumstances is non-operative treatment warranted. For the best results **operative intervention** providing accurate reduction and stable fixation is therefore indicated in these complex fractures. Before intervening careful physical examination is necessary and specifically ascertaining the neurovascular status of the involved extremity. **Compartment syndromes**, a menacing complication with a devastating outcome must be diagnosed early and aggressively treated with fasciotomy. The goal of the treatment is to obtain a stable construct restoring the anatomy and allowing for early motion so as to restore function and strength to the elbow joint.

The anatomy of the distal humerus is complex and for practical purposes the **two column concept** is the best suited. It may be described as two columns, the lateral and the medial, providing the stable structure upon which the articular epiphysis, trochlea and capitellum, is anchored.

Many **classifications** exist; the one best suited being the AO classification which includes type A or extra-articular fracture patterns, type B or partial intra-articular fractures and type C, the most complex, with intra-articular separations and comminution involving the whole joint.
To aid in classification it may be useful to obtain x-rays of the contralateral elbow, to perform CT scanning and perhaps most helpful to obtain traction X-rays. Certain fractures such as capitellum fractures are difficult to diagnose and therefore all imaging modalities must be obtained in case of doubt. All these modalities will aid in the diagnosis of the fracture pattern and influence the approach and fixation modalities.
AO surgery reference: http://www.aofoundation.org.

Once the decision to operate is taken, it must be decided on how the patient should be **positioned** during the intervention. This will depend on the fracture pattern and on the patient's condition. The decision should be made in accordance with the anaesthesiologists. For fractures involving the lateral column only a supine approach will be chosen while for fractures involving the medial column or both columns a decubitus lateral position or a ventral position may be necessary to perform a posterior approach, it must be noted that in these positions it will be nigh impossible to access to the front of the elbow, however having to do so is very rare. Also, the surgeon must be very careful of the positioning of the contralateral limb, head and neck, to avoid injury due to compression.

The use of a **tourniquet** is debatable, if the fracture is uncomplicated and the operation is anticipated to be short, a tourniquet will provide a bloodless field and will be useful. In case of a complex fracture, paradoxically, I tend not to use a tourniquet which might have to be inflated for too long a time and I prefer instead to perform careful haemostasis during the approach and operate in the driest field possible.

The **lateral approach** will be directly on the lateral column dissecting off sharply the insertions of the brachioradialis and the extensor carpi radialis longus and brevis from the lateral supracondylar ridge in front and the triceps in the back. The common extensor origin is then sharply lifted off of the epicondyle anteriorly and if necessary the anconeus posteriorly. Proximal extension must be done with caution because of the radial nerve. The joint capsule is incised and elevated to view the capitellum and the radial head.

The **medial approach** is useful for fractures of the epitrochlea and the ulnar nerve must be carefully identified before inserting screws.

The **posterior approach** will be useful for fractures involving the medial or both columns and with intra-articular fractures of the trochlea. The incision will be midline, swerving laterally around the olecranon and in line with ulnar shaft. In all cases the **ulnar nerve** must be visualized and protected. The nerve is easy to find, lying almost subcutaneously at the medial edge of the triceps three finger breadths above the olecranon, once identified it is followed over the epitrochlea into the common flexor mass avoiding injury to the motor branch of the flexor carpi ulnaris that it penetrates between its ulnar (posterior) and humeral (anterior) heads. At the end of the operation it must be decided whether to transpose the nerve anteriorly into a subcutaneous pocket or not. Personally, I avoid this if possible because it renders redo surgery extremely difficult if the whereabouts of the transposed nerve are not exactly described. The next difficulty is exposing the fracture. If there is widespread comminution of the trochlea it is wise to proceed to an **osteotomy of the olecranon** which may be chevron shaped or transverse. The near cortex is cut with an oscillating saw for precision but the articular cortex should be broken off with an osteotome allowing for perfect reposition. At the end of the intervention the olecranon must be repositioned and fixed using a tension band with K-wires or a single 6.5 mm spongiosa screw. In the case the hole may be drilled before osteotomy ensuring a good reposition. In cases where the fracture of the trochlea is sagittal with no comminution a **bilateral tricipital reflecting approach** as described by Alonso-LLames may be used or alternatively a **triceps reflecting anconeus pedicle approach** (TRAP) as described by O'Driscoll may be used. It is best to avoid triceps cutting (V-Y) approaches for they tend to weaken the extensor mechanism without really being efficacious for exposure.

Isolated fractures of the **capitellum** are approached laterally and must be repositioned and fixed with two posterior to anterior small fragment 3.5 mm lag screws or with Herbert type screws.

Isolated fractures of the **epitrochlea** are approached medially and fixed in place with a lag screw after careful reposition. The ulnar nerve must be protected.

Fractures of the **lateral column** are approached through a direct lateral approach. Plate fixation will be needed to augment the screw fixation, usually small fragment implants placed on the posterior aspect of the lateral column will provide adequate fixation.

Both column fractures without articular involvement need a posterior approach and can be addressed through a bilaterotricipital Alonso-LLames or TRAP approach. Both columns are identified and fixed to the articular epiphysis using a lateral 1/3 tubular plate for the medial column and a posterior 3.5 reconstruction plate for the lateral column. Newer anatomically contoured plates have now reached the marketplace and may also be used.

Both column fractures with articular involvement are the most difficult fracture patterns and need an extensive posterior approach with an accompanying olecranon osteotomy for visualisation. It is necessary to reconstruct the distal epiphysis first. Most of the time the fracture is sagittal line and adequate reduction is easily obtained and held with a lag screw placed in such a way as not to interfere with the ulnar nerve. Sometimes in case of comminution it is necessary to place an intercalary bone graft so as not to squeeze and narrow the epiphysis which renders the joint incongruent. One the joint surface has been reconstructed it is then possible using various types of implants to fix both columns. In general a 1/3 tubular plate placed medially on the trochlear column and a posterior 3,5 mm reconstruction plate on the lateral side will provide sufficient fixation. Both plates should be at right angles to each other, the medial plate lying in the sagittal plane and the lateral plate in the frontal plane. Other options include multiple small plates (2.7 mm) or more recently the use of contoured anatomic plates some equipped with locking holes which provide angularly fixed screws. As a general rule it is wise to avoid provisional reduction with too many K-wires as these will interfere with the placement of the definitive implants and reduction will be lost when these are put in place while having to remove the provisional fixation. These fractures tax the anatomical and biomechanical knowledge of the surgeon, as well as his imagination and skill and are amongst the most challenging of articular fractures to undertake.

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Surgical Exposures in Orthopaedics: The Anatomic Approach. Hoppenfeld S, deBoer P,Buckley R. Lippincott Williams & Wilkins; Fourth Edition edition 2009.

Comminuted intra-articular fractures in osteoporotic bone. In cases of comminuted fractures of the distal humerus occurring in elderly, osteoporotic, low demand patients it is now a recommended option to place a cemented **Total Elbow Arthroplasty.** Because the epicondyles and their ligamentous attachments are cannot be reconstructed, the chosen prosthesis must provide intrinsic stability. Excision of the radial head must be performed if it impinges upon the prosthesis. Contra-indications include open fractures or a high infectious risk because of extensive soft tissue damage. The technique is demanding and the surgeon must be experienced in TEA for elective procedures before embarking on this intervention.

The results are reported to be satisfactory in the literature; however the complication rate is high for this type of operation.
Gambirasio R, Riand N, Stern R, Hoffmeyer P. Total elbow replacement for complex fractures of the distal humerus. An option for the elderly patient. J Bone Joint Surg Br. 2001 Sep;83(7):974-8.

Comminuted open fractures of the distal humerus. In rare instances one is confronted with a major soft tissue injury with an underlying fracture. In case of Gustilo I and II open fractures the treatment is to debride and wash out the wound and proceed with internal fixation as if it were a closed injury. Whenever possible the opening should be incorporated in the approach and the wound closed over suction drainage at the end of the procedure. Appropriate antibiotic prophylaxis should be started after swabs are obtained for microbiological investigations including culture and sensitivity. In the face of Gustilo III open fractures a **humero-ulnar external fixateur** bridging the fracture zone and immobilising temporarily the joint is a reasonable and useful option. Beware of the radial nerve crossing the humeral diaphysis laterally approximately 7cm above the elbow joint. It is recommended to insert the pins of the external fixateur through a small open incision after having visualized and protected the radial nerve. The fixateur pins, usually a half frame, should be placed as far from the fracture zone as possible so that the pin tracts will not interfere with future osteosynthesis. Once the elbow is bridged, the priority is restoring the integrity of the soft tissue envelope with the help of a plastic surgeon if deemed necessary. Once the soft tissue envelope is restored it may be advisable to remove the fixateur and to proceed with a stable reconstruction of the joint surfaces so as to begin motion and avoid a stiff and painful elbow.

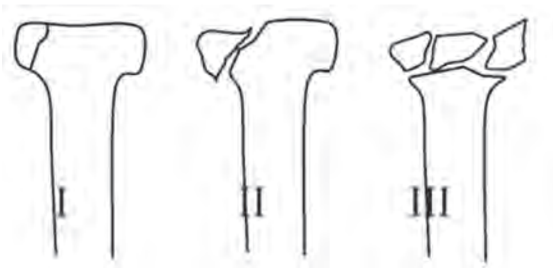
Rehabilitation consists in splinting to protect the soft tissues but with immediate assisted *active* motion. After 6 to 8 weeks the soft tissues are less swollen the splint may be removed and careful use with non weight carrying may be tolerated.

Fractures of the radial head
Fractures of the radial head represent around 2 % of all fractures and 33% of all elbow fractures. They usually occur after a fall on the slightly flexed outstretched elbow with the hand in supination. The patient complains of immediate pain in the lateral region of the elbow after a fall. There is often a palpable fluctuation outwardly bulging over the radio-humeral joint due to haemorrhagic effusion and active prono-supination is painful or impossible. To assess the amount of displacement the humero-radial joint is aspirated and lidocaïne is injected into the joint. If smooth, non-grating, active or passive prono-supination is possible this is a reliable sign that the fracture is minimally displaced and that non-operative will lead to a satisfactory outcome, otherwise surgical treatment is mandatory if painless motion is to be restored.

Anatomically and biomechanically, the radial head is part of the **forearm articular complex** including the proximal radio-ulnar joint, the interosseous membrane and the distal radio-ulnar joint that allows prono-supination of the forearm. The **radiohumeral joint** also participates in the flexion/extension mobility of the elbow joint. Furthermore the radial head is involved in the stability of the elbow joint and plays the role of a **secondary stabilizer**. If the ulnar collateral ligaments and the distal radioulnar joint are intact, the radial head plays no role in the stability of the elbow and may therefore safely be removed if necessary. However, in the absence of the radial head and disruption of the distal radioulnar ligaments (Essex-Lopresti lesion), the radius will migrate proximally and more so when there is an associated tear of the interosseous membrane. In these circumstances a relative over-lengthening of the ulna will occur at the wrist entailing painful dysfunction. Also, in the absence of the radial head, valgus instability will occur at the elbow if the ulnar collateral ligament is torn or elongated.

Fracture classification of radial head fractures:
Various classification schemes have been proposed:
Mason Classification:
- Type I: Non-displaced
- Type II: Displaced marginal fractures
- Type III: Comminuted fractures
- Type IV: Associated with elbow dislocation

Hotchkiss modification
- Type I: No surgery
- Type II: Displaced but fixable
- Type III: Displaced and unfixable



As a general rule displaced fractures need surgical intervention, minimal displacement may benefit from Open Reduction and Internal Fixation (ORIF) and highly displaced or comminuted fractures may necessitate excision in case of a stable Distal Radio-Ulnar Joint and intact interosseous membrane and prosthetic replacement if these conditions are not met.

Approach
The approach is basically lateral starting obliquely from the supracondylar ridge over the radio-humeral joint and trough the Kocher interval between the anconeus and the extensor carpi ulnaris. This protects the motor branch of the radial nerve (Avoid placing a Hohmann type retractor over the anterior neck of the radius) and the approach is sufficiently anterior to spare the ulnar collateral ligament which will not be inadvertently severed. The capsule is revealed and an arthrotomy is performed exposing the radial head. The annular ligament is spared.

Technique

Reconstructible fractures: After assessment they are fixed using small fragment 2.0 or 2.7 AO or Herbert type screws. Sometimes the use of a mini blade plate type of implant may be necessary.

Radial head excision: If excision is necessary be sure that all fragments are excised by reconstructing the head on the instrument table. The head should be removed at the level of the annular ligament. The elbow and wrist should be closely assessed for stability and the lateral collateral reconstructed if necessary.

Prosthetic replacement: It is necessary to provide stability by inserting a radial head prosthesis in cases of fracture dislocations with either frontal plane instability such as with extensive tearing of the lateral collateral ligaments or with longitudinal instability with tearing of the interosseous membrane or DRUJ. Today, the accepted prosthesis is metallic with or without a moving or floating (bipolar) head and a stem that may be cemented or non-cemented. In some cases the prosthesis may be left permanently in place while in other instances such as in very young patients it may be useful to remove the prosthetic head used as a temporary spacer once healing of the ligamentous complex has occurred. Silastic implants once in vogue are now generally abandoned because of the risk of a destructive synovial inflammatory response due to fragmentation of the prosthesis leading to the accumulation of irritative particulate matter. Furthermore biomechanical studies have shown that these prostheses are not stiff enough to allow anatomic healing of torn ligaments.

Rehabilitation

As general rule rehabilitation must be begun early and motion should be started within days of the intervention in case of operative treatment or diagnosis in case of conservative treatment. After a few days of rest start by gentle *active* flexion exercises going from 90° to 110° then progress with *active* extension exercises ranging from 120° to 30° as tolerated. After two to three weeks gentle *active* prono-supination exercises are begun. An articulated brace is useful for protection in cases of instability

The ESSEX LOPRESTI injury

This injury was described in 1951 by Essex-Lopresti and associates as a severely comminuted fracture of the radial head with tearing of the interosseous membrane and disrupting the DRUJ. The diagnosis is clinical and radiological. X-rays of the whole forearm are necessary. The radial head must imperatively be fixed or replaced with a prosthesis and the DRUJ has to be stabilized with a cross pin left in situ for 4 to 6 weeks. (See below).

Frankle MA, Koval KJ, Sanders RW, Zuckerman JD: Radial head fractures with dislocations treated by immediate stabilization and early motion J Shoulder Elbow Surg 1999;8:355-356.

Cooney WP. Radial head fractures and the role of radial head prosthetic replacement: current update. Am J Orthop. 2008;37(8 Suppl 1):21-5.

Fractures of the olecranon

Fractures of the olecranon usually occur after falls directly on the elbow point. They are frequently seen in the osteoporotic patient.

There are various classifications; the most popular are the Mayo classification:

Type I: Undisplaced

Type II: Displaced but stable elbow (Noncomminuted: A /Comminuted: B)

Type III: Displaced and unstable elbow (Noncomminuted: A / Comminuted: B)

The AO classification (Complex: includes the proximal forearm segment: radius and ulna):

A: Extra-articular fractures

B: Intra-articular fractures

C: Fractures of both olecranon and radius

A treatment plan must be elaborated. The great majority of these fractures are displaced and the question arises as to what is the best suited technique.

Approach

The surgical approach is straightforward. The ulna is subcutaneous; the patient may be in a supine or lateral decubitus position with the arm resting on a support. A tourniquet may be used. The incision follows the shaft of the ulna and some recommend arcing the incision radially to avoid the tip of the olecranon and also to avoid a scar over the ulnar nerve.

Technique

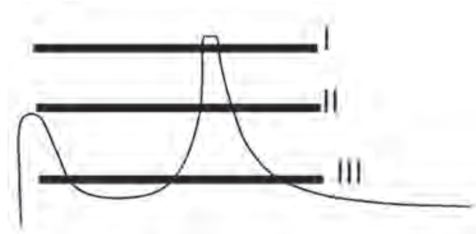
Clearly transverse fractures are best treated by a technique associating K-wires and tension band cerclage such as described by the AO Group. The technique must be meticulously followed and especially the placement of the K-wires must be parallel, 5 to 6 cm long, and the tip should be into the opposite cortex distally to the coronoid and the ends must be bent at 180° and deeply buried into the triceps and olecranon. Comminuted fractures will require a plating technique (3.5 LCP or DCP plates) augmented by longitudinal screws (so-called homerun screws). If the fracture is oblique and is near the coronoid a compression screw will be most useful. The main drawbacks of these techniques lie in the high reoperation rate that all authors mention. K-wires tend to back out and must be carefully followed and plates usually present some degree of discomfort and are best removed after adequate consolidation. A more recently described complication is the interference of K-wires or screws placed in the proximal ulna with the proximal radius. Some implants are too long and either impinge or are screwed into the radial head or bicipital tuberosity. This is not an easy diagnosis post-operatively and freedom of prono-supination must be carefully ascertained at the end of the surgical reconstruction.

Rehabilitation

The patient is placed into a backslab at 80° of flexion and gentle active flexion and extension exercises are started as tolerated. The olecranon is protected for 6 to 8 weeks before any weight bearing exercises are started.

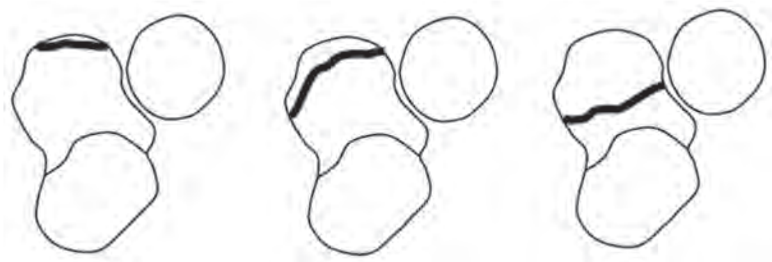
Fractures of the coronoid

This is usually associated with dislocations of the elbow. Regan and Morrey have classified these injuries into:
Type I: Fracture of the tip
Type II: Less than 50% of the height of the coronoid
Type III: More than 50%
A and B types signify no or associated dislocation.
Some have added a:
Type IV: Fracture of the sublime tubercle.



Type I fractures are generally stable and do not need fixation if the elbow is stable. Types III and IV need surgery to insure stability of the elbow because the medial collateral ligament attaches to the medial coronoid and instability will occur if the bony fragments are not fixed.
More recently O'Driscoll has modified this classification: into
In this classification all types 2 and 3 need fixation and especially if associated with a dislocation or a radial head fracture. Plain x-rays and preferably a CT scan should be used for making the diagnosis and classifying the lesions. Small lesions can be fixed by transolecranon sutures. The fragment is approached from a medial incision in an "Over the top" as approach described by Hotchkiss Large fragments are approached by a posteromedial route.
In very unstable elbows a hinged external fixateur device will provide stability while allowing early motion.
Regan W, Morrey B. Fractures of the coronoid process of the ulna. J Bone Joint Surg Am 1989;71:1348–1354.)
O'Driscoll SW, Jupiter JB, Cohen MS, Ring D, McKee MD. Difficult elbow fractures: pearls and pitfalls. Instr Course Lect 2003;52:113–134.
Hotchkiss RN. Fractures and dislocations of the elbow. In: Rockwood CA, Green DP, eds. Rockwood and Green's fractures in adults. Vol 1. 4th ed. Philadelphia, PA: Lippincott Williams & Wilkins; 1996:929–1024.

Type 1: Tip fractures
Type 2 : Anteromedial fractures
Type 3 : Base of coronoid fractures



Dislocation of the elbow

The mechanism is usually a fall on the outstretched hand with the elbow in a varus position. The primary lesion is a tear of the lateral collateral ligament from the lateral humeral insertion and as the mechanism of dislocation the capsule is then torn anteriorly , the coronoid may be damaged by the ram effect of the trochlea and finally the medially collateral may be torn also, leading to a very unstable position. In 5 to 10% of cases a fracture of the radial head may be associated as well as more rarely a fracture of the capitellum. Neurovascular injuries occur infrequently but must be looked for. The median nerve may be stretched by the front riding humerus, and this is the most frequent neurological injury, however the radial nerve and the ulnar nerve may also be damaged. The brachial artery may suffer an intimal tear or a rupture while it is stretched out over the protruding distal humerus and very rarely the skin may split leading to an open injury. A compartment syndrome is always a possibility and the patient must be monitored.
Dislocations of the elbow are classified as anterior (rare), posterior (most common) and divergent (very rare the radial head will be separated from the ulna and the annular ligament is torn).
The elbow, after proper radiographic and clinical assessment should be reduced, general anaesthesia may be necessary, and tested for stability: varus, valgus and postero-lateral. Postero-lateral rotatory instability occurs when the ulno-radial bloc dislocates off of the humerus laterally in supination and upon reduction in pronation a clunk is heard and felt. The elbow is then flexed to past 90° and held in a splint in pronation. An X-ray is then taken to determine that the reduction is adequate. After 5 to 7 days the elbow is moved, first in flexion then extended as tolerated in an active-assisted mode. A hinged splint may be worn and after 3 to 6 weeks all immobilisation if motion has returned and the patient feels stable all splints are removed.
Indications for surgery range from incarceration of a bony fragment in the joint space, to vascular impairment or gross instability usually associated with a coronoid fracture (see above). Late contracture or heterotopic bone may also lead to surgery at a later stage if mobility is severely limited (>30° of flexion deformity). Late instability may also necessitate surgery and the use of a hinged fixator allowing stable distraction of the joint surfaces and concomitant mobilisation.
O'Driscoll SW, Morrey BF, Korinek S, An KN. Elbow subluxation and dislocation: A spectrum of instability. Clin. Orthop. Relat. Res. 280:186, 1992

Medial instability of the elbow
Throwing athletes may develop medial instability due to medial ulnar collateral ligament (MUCL) stretching out or tearing. The patient may experience a pop or a tearing sensation during a throw. Physical examination includes looking for ulnar neuritis and Tinel's sign. The elbow is stressed in valgus at 25° of flexion and the MUCL is palpated for taughtness. Further diagnostic imaging using plain stress-test x-rays, dynamic ultrasound or Arthro-MRI will fine tune the diagnosis. MUCL reconstruction using a figure of eight tendon graft as described originally by F Jobe and refined and modified more recently may then be performed.
Safran M, Ahmad CS, El Attrache NS. Ulnar collateral ligament of the elbow. Arthroscopy 21:1381, 2005.

Postero-lateral rotatory instability of the elbow
After injury or dislocation of the elbow the patient may develop a condition where recurrently he has the impression of the elbow popping or giving way or even dislocating. The symptoms are on the lateral side where the patient often has pain and discomfort. Clinical testing will reproduce the sensation of pain and instability when the elbow is stressed in valgus and supination. An audible pop can occur during this manoeuvre. It signifies that the radius and the ulna although firmly attached by the annular ligament, slip out laterally as a unit from the capitellum because of a tear of the ulnar lateral collateral ligament that laterally unites the humerus to the supinator crista of the lateral ulna. Repair may be accomplished by a tendon graft uniting the humerus to the supinator crista of the ulna and passing under the radial head.
Nestor BJ, O'Driscoll SW, Morrey BF. Ligamentous reconstruction for posterolateral rotatory instability of the elbow: J Bone Joint Surg Am. 1992;74(8):1235-41.

The stiff elbow
The normal elbow has a range from 0° or slightly hyperextended to 150° of flexion, pronation is 75° and supination is 85°. The stiff elbow becomes a clinical problem when the functional arc accepted in flexion/extension diminishes beyond 130°-30°- 0. Very severe stiffness occurs when the total arc is less than 30°, severe stiffness is when the arc is between 31° and 61°, moderate between 61° and 90° and minimal when the arc is greater than 90°. A 100° range of pron/supination (50° pronation and 50° of supination) is necessary for normal function although as a rule lack of pronation is in general less tolerated than lack of supination.
If no bony abnormalities are present the lateral column procedure, where the anterior and posterior contracted capsule is excised from a lateral approach after detaching the distal fibers of the brachioradialis and the extensor carpi radialis longus is recommended. Medial release detaching the flexor-pronator mass is performed in case of arthritic osteophytes, caring for the ulnar nerve. It may be combined with the lateral column procedure. For the rehabilitation it is important to immobilize during night-time the elbow in the position of greatest motion loss. If extension is to be gained the elbow should be immobilized in extension during night-time and flexion during the day.
For more complex conditions with bony deformity, ectopic bone, major osteophytes overgrowth or posttraumatic conditions a posterior approach with of sculpturing of deformed bony surfaces, excision of new bone formation and sectioning of restraining tissues will have to be performed. In some of these cases a hinged uni or bilateral humero-ulnar external fixator allowing controlled motion will need to be used. The ulnar nerve will need special care and transposition may be indicated in some cases. The radial nerve may be at risk when external fixation is used.
Some authors in cases of minimal or moderate stiffness have used arthroscopic release techniques
Ball CM, Meunier M, Galatz LM, Calfee R, Yamaguchi K. Arthroscopic treatment of post-traumatic elbow contracture. J Shoulder Elbow Surg 2002;11:624-629.
Mansat P, Morrey BF. The column procedure: A limited lateral approach for extrinsic contracture of the elbow. J Bone Joint Surg Am 1998;80:1603-1615.
Morrey BF. The posttraumatic stiff elbow. Clin Orthop Relat Res 2005;26-35.

Tendon ruptures and athletic injuries
Distal Biceps Tendon Ruptures
The distal biceps is the most commonly ruptured tendon around the elbow. This usually occurs with heavy lifting. The patient reports hearing a pop or a crack in the anterior region of his elbow. In the hours that follow the injury an ecchymosis may discolour the antecubital fold. The biceps muscle belly does not retract immediately because it is held down by the lacertosus fibrosus. The patient will have near normal flexion extension strength but will complain of weakness in supination. In an active population the treatment is usually surgical and a two incision reattachment technique as described by Morrey yields satisfactory results. When using this technique care must be taken not to come into contact with the proximal ulna when bringing the distal biceps through the ulno-radial space so as to avoid an osseous synostosis. Gentle flexion-extension exercises follow the surgery and at 6 weeks a full return to activity is permitted.
Rupture of the brachialis and of the triceps tendons have been reported. These are rare injuries and the best surgical treatment consists in suturing the ruptured tendons.
Papandrea RF: Two-incision distal biceps tendon repair, in Yamaguchi K, King GJW, McKee O'Driscoll SW : Advanced Reconstruction Elbow. Rosemont, IL, American Academy of Orthopaedic Surgeons, 2006, pp 121-128.

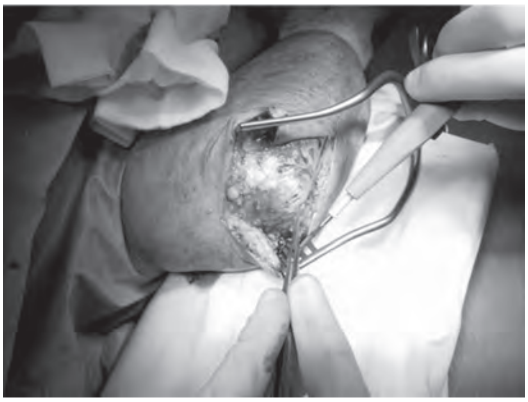
Lateral Epicondylitis (Tennis Elbow)
The most comprehensive description of the pathoanatomy of epicondylitis is Nirschl's. The essentially this is an overuse lesion causing tearing of the extensor carpi radialis brevis tendon at its distal humerus insertion. Diagnosis is made by eliciting pain on palpation of the lateral epicondyle, wrist extension against resistance as long finger extension against resistance will also produce pain at the elbow in case of epicondylitis. All oth-

er conditions leading to elbow pain such as carpal tunnel, radial nerve entrapment under the arcade of Frohse or radiohumeral arthritis should be eliminated. Adjunct imaging such as plain x-rays will not be specific and MRI may be used to image a tear or an edematous area in the region of insertion. Treatment consists of modifying activity, steroidal infiltration, adapted physiotherapy and in case of a long duration of symptoms surgical excision of the ECRB tendon, situated under the Extensor Carpi Radialis Longus tendon. Most authors recommend open procedures although success has been reported using arthroscopic techniques. A characteristic angiofibroblastic hyperplasia-tendinosis has been described by Nirschl which characteristically demonstrates little inflammatory cells. Postoperative treatment consists of a protective splint followed by gentle motion as tolerated with full function possible 6 to 8 weeks postoperatively.
Kraushaar BS, Nirschl RP. Tendinosis of the elbow (tennis elbow). Clinical features and findings of histological, immunohistochemical, and electron microscopy studies. J Bone Joint Surg Am 1999;81:259-278.
Nirschl RP, Pettrone F. Tennis elbow: The surgical treatment of lateral epicondylitis. J. Bone Joint Surg Am. 1979; 61:832.

Medial Epicondylitis
Rarely, in the competitive athlete pain will develop following overuse of the flexor-pronator complex. Again the treatment should first be conservative. If symptoms persist surgical excision of the diseased part of the medial conjoint tendon of the flexor-pronator complex may be considered. In some cases a transposition of the ulnar nerve completes the procedure.
Vangsness CT, Jobe FW. Surgical treatment of medial epicondylitis. Results in 35 elbows. J Bone Joint Surg Br. 1991;73(3):409-11.

Osteochondritis Dissecans
Rare condition affecting mostly skeletally immature patients involved in receptive throwing sports. Symptoms include pain, flexum deformity or catching and locking. This should be differentiated from Panner disease which is an osteochondrosis not requiring treatment. A classification has been evolved that spans from the simple cartilage fissures (I) to the detachment of a large fragment (IV) of cartilage. Treatment is at first conservative with activity modification and if not successful can go, depending on severity, from simple drilling of the lesion to complex mosaicplasty.
Baumgarten TE, Andrews JR, Satterwhite YE: The arthroscopic classification and treatment of osteochondritis dissecans of the capitellum. Am J Sports Med 1998;26:520-523.

Septic olecranon bursitis
This is a potentially life threatening condition caused by a septicaemia originating from an infected bursa under tension. Generally seen in debilitated patients but can arise without a clear cause or after minor trauma in an otherwise healthy individual. Diagnosis is clinical with standard laboratory findings such as high white cell count, left shift of white blood cells, high sedimentation rate and elevated C-reactive protein levels. Organisms found are generally staphylococcus or streptococcus. In mild cases treatment may be antibiotics and splinting. In more severe cases it is mandatory to incise the bursa and leave open, to immobilise in a splint and after a few days to perform a closure secondarily. During the treatment period appropriate IV and oral antibiotics are administered.
Pien FD, Ching D, Kim E. Septic bursitis: Experience in a community practice. Orthopaedics 1991; 14:981
Infectious olecranon and patellar bursitis: short-course adjuvant antibiotic therapy is not a risk factor for recurrence in adult hospitalized patients. Perez C, Huttner A, Assal M, Bernard L, Lew D, Hoffmeyer P, Uçkay I. J Antimicrob Chemother. 2010 Mar 1. [Epub ahead of print]



Forearm

In the AO manual that covers all important fixation techniques the reader will fact pertinent facts related to the topic at hand: *AO Principles of Fracture Management. Second expanded edition, TP Rüedi, RE Buckley, CG Moran. Georg Thieme Verlag; 2 Har/Dvdr edition (2007).* For the latest in fracture fixation techniques the reader is also invited to visit the AO surgery reference site: *AO surgery reference: http://www.aofoundation.org.* Another most useful publication containing pertinent facts related to orthopaedics and musculoskeletal in general trauma is the *AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.* For surgical approaches the most useful reference is without doubt: *Surgical Exposures in Orthopaedics: The Anatomic Approach. Hoppenfeld S, deBoer P, Buckley R. Lippincott Williams & Wilkins; Fourth Edition 2009.*

Introduction forearm

The forearm must be considered as a whole functioning joint allowing pronation of 75° and supination of 85°. The interosseous membrane plays a major stabilising role.

AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.

Classification of forearm fractures

The AO classification is popular. It classifies the fracture patterns of radial and ulnar shafts as type A (simple, transverse or spiral) type B (wedge with a butterfly fragment) and type C (segmental or comminuted fragments). Open fractures are classified according to Gustilo and Anderson: Type I inside-out (< 1 cm), Type II outside-in (> 1cm), Type III A (open but osseous coverage possible), type III B (open necessitating a local or free flap), Type III C any open fracture with vascular injury.

Specific to the forearm are the **Monteggia** fracture pattern (Fracture of the ulna with dislocation of the radial head).

Bado classification:

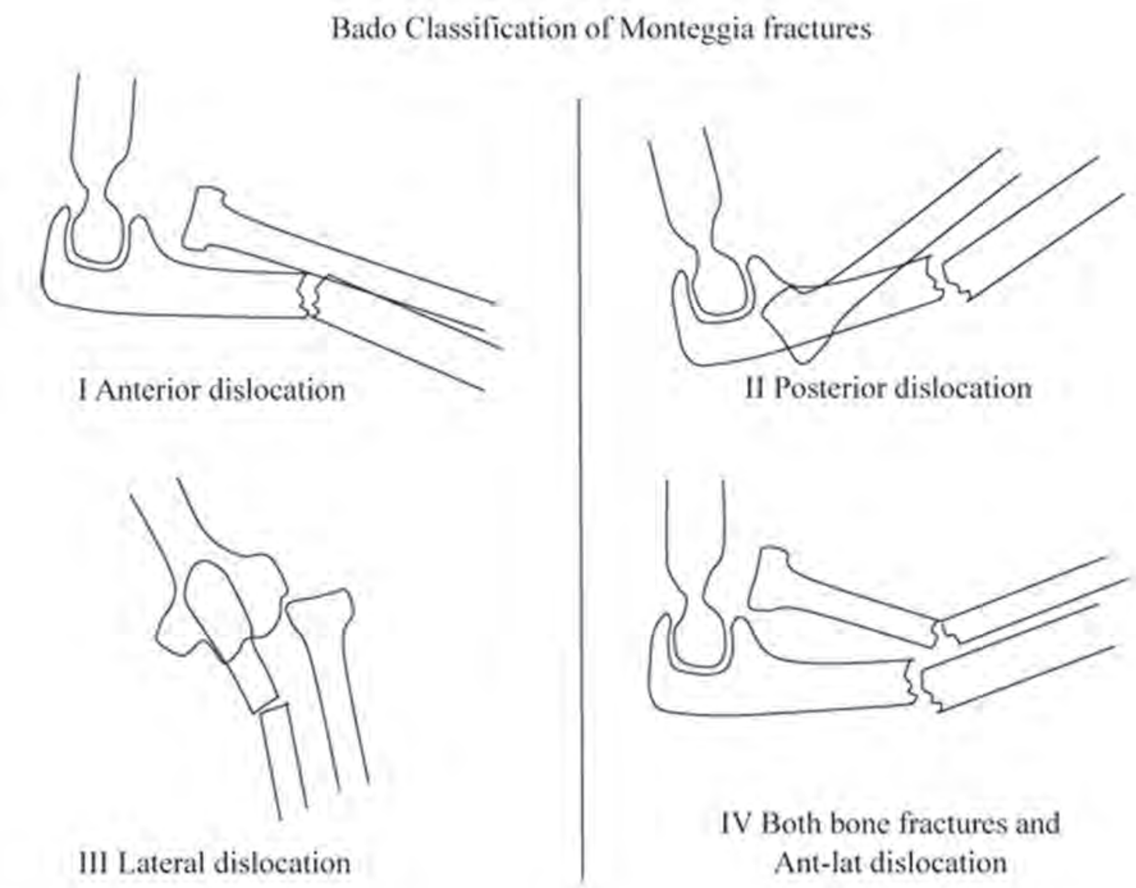
I Anterior radial head dislocation and proximal ulnar shaft fracture (apex anterior)

II Posterior or postero-lateral radial head dislocation and proximal ulnar shaft fracture (apex posterior)

III Lateral radial head dislocation and proximal ulnar shaft fracture (apex posterior)

IV Anterior radial head dislocation and proximal ulnar and radial shaft fracture (apex posterior)

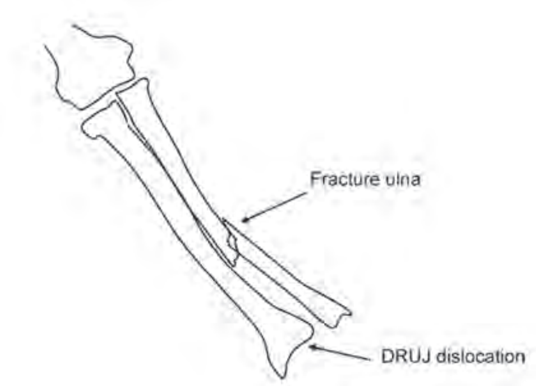
Konrad GG, Kundel K, Kreuz PC, Oberst M, Sudkamp NP. Monteggia fractures in adults: long-term results and prognostic factors. J Bone Joint Surg Br. 2007;89(3):354-60.



Also specific to the forearm is the **Galeazzi** fracture pattern where the radius shaft is fractured along with a dislocation of the distal radio-ulnar joint (DRUJ). Suture of the triangular ligament or pin fixation of the DRUJ are indicated if after fixation of the radial shaft gross instability is still present.

Rettig ME, Raskin KB. Galeazzi fracture-dislocation: a new treatment-oriented classification. J Hand Surg Am. 2001;26(2):228-35.

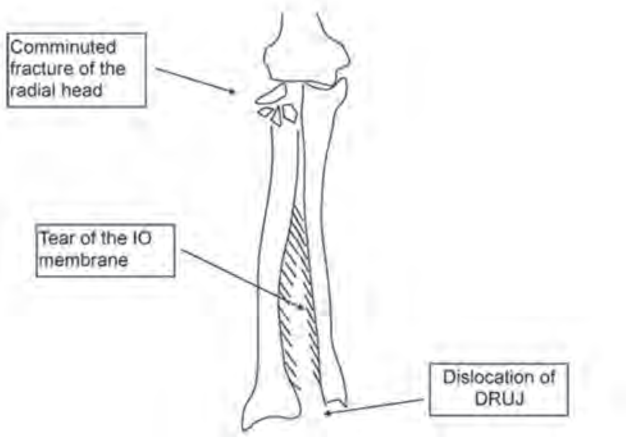
Galeazzi fracture-dislocation



The **Essex-Lopresti** lesion combines a comminuted fracture of the radial head along with disruption of the interosseous membrane causing a relative overlengthening of the ulna at the wrist. (see Elbow section).

Perron AD, Hersh RE, Brady WJ, Keats TE. Orthopedic pitfalls in the ED: Galeazzi and Monteggia fracture-dislocation. Am J Emerg Med. 2001 May;19(3):225-8.
AO Principles of Fracture Management. Second expanded edition, TP Rüedi, RE Buckley, CG Moran. Georg Thieme Verlag; 2 Har/Dvdr edition (2007).
Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III (severe) open fractures. A new classification of type III fractures. J Trauma 1984, 24:742-746.
Gustilo RB, Anderson J. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: Retrospective and prospective analys

Essex-Lopresti fracture-dislocation



Clinical presentation of forearm fractures

A deformed extremity is present. Look for neurovascular injuries (radial nerve) carefully before any manipulation of the injured extremity. Plain X-rays including the shoulder and elbow are generally sufficient in acute traumatic cases. MRI, CT, Bone scintigraphy are useful in special situations such as chronic infection, metastatic or primary tumors.

Conservative treatment

There is practically no place for conservative treatment in adult both bone forearm fractures. Isolated fractures of the ulnar shaft may be treated by functional bracing but the rate of non-union remains high and many authors recommend immediate plate fixation

Mackay D, Wood L, Rangan A. The treatment of isolated ulnar fractures in adults: a systematic review. Injury. 2000;31(8):565-70.

Surgical Approaches

- Anterior (Henry) approach
  Anatomic approach but with some soft tissue stripping. Allows exposure of the whole radius.

- Dorsal Thompson approach
  Danger to the Posterior Interosseous Nerve (PIN).
  http://www.wheelessonline.com/ortho/dorsal_approach_thompson
- Direct approach
  The direct approach is best suited for the ulna.

Mekhail AO, Ebraheim NA, Jackson WT, Yeasting RA. Vulnerability of the posterior interosseous nerve during proximal radius exposures. Clin Orthop Relat Res. 1995 Jun;(315):199-208.Erratum in: Clin Orthop 1997;(334):386.

Operative treatment indications: *The forearm constitutes a joint and in the adult the treatment is anatomical reduction and fixation*

- IM Nailing
  Difficult to guarantee stable fixation and anatomic fixation with these devices.
  - Anterograde
    Nails for the ulna are in use and being developed
  - Retrograde
    Nails for the radius may be used
- Plating
  3,5 mm plates should be used and never semi or third tubular type plates. 6 cortices on each side of the fracture should be used. Some authors

Both bones fracture of the forearm fixed anatomically with rigid compression plating

External fixation

In case of open fractures an external fixation may be applied. For the ulna the pins may be applied closed but for the proximal radius an open approach allowing to identify the pertinent neurovascular structures should be performed.

Hertel R, Pisan M, Lambert S, Ballmer FT. Plate osteosynthesis of diaphyseal fractures of the radius and ulna. Injury. 1996;27(8):545-8.

Chapman MW, Gordon JE, Zissimos AG. Compression-plate fixation of acute fractures of the diaphyses of the radius and ulna. J Bone Joint Surg Am. 1989;71(2):159-69.

Lindvall EM, Sagi HC. Selective screw placement in forearm compression plating: results of 75 consecutive fractures stabilized with 4 cortices of screw fixation on either side
of the fracture. J Orthop Trauma. 2006;20(3):157-62; discussion 162-3.

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Degenerative arthritis

Osteoarthritis of the Elbow

Primary osteoarthritis (OA) of the elbow is relatively rare, affecting 2% of the population. The average age of the patient at initial presentation is 50 years old, and the male-to-female ratio is 4:1. The etiology is unclear, but primary elbow OA is usually associated with a history of heavy use of the arm, such as is the case with manual workers. Although the elbow is a non-weight-bearing joint, studies have reported forces up to 2 times body weight during motions commonly seen in occupational duties such as lifting, moving, and placing 2kg weights. Therefore, individuals who perform strenuous activities, or who require the use of a wheelchair, may be expected to produce large loads across the elbow. Secondary causes of elbow OA include trauma, osteochondritis dissecans, synovial chondromatosis, and valgus extension overload. Patients under the age of forty often have a history of traumatic event.

The symptoms include loss of terminal extension of the dominant elbow, painful catching or clicking, or locking of the elbow. Pain is typically noted at the end range of both flexion and extension. Patients report that it is painful to carry heavy objects at the side of the body with the elbow in extension. The arc of motion is restricted by the presence of osteophytes, as well as secondary to capsular contracture. Night pain is not typical, and forearm rotation is relatively well-preserved. Ulnar neuropathy is present in up to 50% of patients. The degree of pain and disability varies among patients and is affected by functional demand.

Radiographs (Figure 1) show osteophytes involving the coronoid process, coronoid fossa, olecranon, and olecranon fossa. Preservation of the joint space at the ulnohumeral and radiocapitellar joints is common. Loose bodies may be seen, but up to 30% of them are not detected on plain X-Rays.

Conservative treatment includes rest, activity modification, and non-steroidal anti-inflammatory medication (NSAID). Surgery is indicated for those patients who fail to respond to conservative treatment, particularly when loss of motion interferes with activities of daily living (loss of extension >30°), when there is painful locking or clicking, or ulnar nerve symptoms are present. Current treatment options include (1) classic open procedure, (2) ulnohumeral arthroplasty, (3) arthroscopic osteocapsular arthroplasty, and rarely (4) total elbow replacement. The classic Outerbridge-Kashiwagi (OK) procedure includes a posterior approach to the elbow with a triceps split, removal of the tip of the olecranon, and osteophyte removal through olecranon fossa trephination. Limitations of this procedure are incomplete anterior release and inability for osteophyte removal anteriorly. Any flexion contracture can be more reliably addressed via an ulnohumeral arthroplasty, which is a modification of the OK procedure including triceps elevation rather than splitting, and a lateral column procedure to perform an anterior capsule release. Ulnar nerve decompression is advocated if preoperative symptoms are present, when preoperative flexion is <100°, or when a gain of 30°-40° of flexion is expected. Postoperative complications include ulnar neuropathy, and recurrence of a flexion contracture or osteophytes. Arthroscopic débridement appears to give good results, although currently there is a lack of long term follow-up. Total elbow arthroplasty (Figure 2) is only indicated for patients older than 65 years for whom other interventions have failed, and who are willing to accept low activity levels in regard to the surgical elbow.

The Rheumatoid Elbow

Rheumatoid arthritis affects 1-2% of the population and involves the elbow joint in 20-50% of the patients. The great majority of patients also have wrist and shoulder involvement. Initially, patients present with a painful stiff elbow. Secondary changes may develop over time, leading to a fixed flexion contracture, pain throughout the range of motion, instability due to soft tissue deterioration, and ulnar and radial nerve neuropathies.

Anteroposterior and lateral radiographs of the elbow are needed to stage the disease according to the classification of Larsen or the Mayo Clinic, which are based upon the radiographic degree of joint involvement as well as clinical symptoms. Radiographic signs include periarticular erosions, symmetric joint space narrowing, osteopenia, subchondral plate erosions, and finally gross destruction of most or all articular architecture.
Nonsurgical management is appropriate for patients with early disease, and includes physical therapy, resting splints, NSAID, and occasional corticosteroid injections. Surgical options include synovectomy (Larsen stages 1 to 2), radial head excision, and total elbow arthroplasty (Larsen stages 3 to 4). Open synovectomy is usually performed via a lateral approach. The most common complication is recurrence of pain over time. Arthroscopic synovectomy is less invasive but technically demanding and carries the risk of neurovascular injury. Radial head excision is controversial. Rheumatoid arthritis is the primary indication for total elbow arthroplasty. Due to bone loss and soft tissue involvement, semi-constrained implants are the prostheses of choice. Complication rates may be as high as 50% and patient selection is very critical. Age less than 65 years old is only a relative contraindication and total elbow arthroplasty can be performed in low-demand patients with severe disease.

Synovial chondromatosis

Synovial chondromatosis is a rare benign pathology of the synovium in which cartilaginous material is formed within synovial tissue. The cartilaginous nodules may become intraarticular loose bodies or undergo ossification, described as osteochondromatosis. The symptoms are non-specific, and include pain on exertion, swelling, locking symptoms, and flexion/extension deficit. It is a monoarticular process most often occurring in middle-aged men, with the knee being the most frequently affected joint. Using standard radiographs to diagnose intraarticular chondromatosis can be difficult when there is no calcification of the cartilage nodules, and magnetic resonance imaging (MRI) or computed tomography (CT) may be helpful. Treatment consists of open or arthroscopic removal of loose bodies and partial synovectomy. Additional procedures may be necessary according to the local status of the elbow, such as removal of osteophytes, anterior capsulotomy, etc. Recurrence rates between 3-22% have been reported after surgery. Chondromatosis of the elbow frequently leads to secondary osteoarthritis.

Septic olecranon bursitis

This is a common condition that requires prompt recognition and treatment in order to avoid potentially life threatening complications. Septic bursitis generally arises after blunt trauma or a superficial wound (Figure 3). Clinically there is local tenderness over the bursa, but the range of motion of the elbow is usually full and pain-free. The diagnosis is based upon clinical evaluation, with standard laboratory findings including elevated white cell count, and high C-reactive protein levels. The organisms that are found are generally staphylococci or streptococci. Treatment consists in incision and drainage with removal of the bursa, and the wound is left open. After several days secondary closure can be performed. During the treatment period appropriate antibiotics are administered intravenously.

FIGURES

Figure 1

Figure 2

Figure 3

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Degenerative disorders

Basic anatomy

The shoulder consists of four joints, the sterno-claviclular, the acromio-clavicular, the gleno-humeral and the thoraco-scapular joint. The latter is not a proper joint but assists in the total range of motion corresponding to 30° of flexion-extension. Motion in the sterno- and acromionclavicular joints is small and consists of rotation. Most of the shoulder motion occurs in the gleno-humaral joint and consists of both flexion-extension and rotation inwards and outwards. The shoulder is the most mobile joint in the body. The normal motion is flexion 160°, abduction 160°, adduction to reach the opposite shoulder, external rotation 75° and internal rotation to Th 5-6.

The gleno-humeral joint has a large head articulating with a small and flat socket that does not cover the head. The surface of the glenoid is just 1/5 of the surface of the humeral head. This means that the stability of the joint is totally dependent of the function of the surrounding soft tissues: the glenoid labrum, the rotator cuff, the long head of the biceps muscle and to low pressure in the joint cavity. Also the scapula stabilising muscles, trapezius, rhomboids, levator scapule and serratus anterior contribute to shoulder stability and function. The most important muscle for shoulder function is the deltoid that provides strength and endurance in motion of the arm.

Approaches to the shoulder

Deltopectoral approach

The deltopectoral approach is used for most open shoulder procedures. The incision is from the clavicle to the insertion of the deltoid on the humerus just lateral to the coracoid process following the interval between the deltoid and the pectoralis major. It may be used in its full length but usually one only needs the proximal part or less. After opening of the skin and subcutaneous tissue the cephalic vein is held laterally together with the deltoid muscle and the pectoral muscle medially. The subscapular muscle is transacted close to its insertion and the joint capsule opened. When closing the incision a careful repair of the subscapularis is important.

Lateral, transdeltoid approach

The lateral, transdeltoid incision is mainly used for surgery on the acromio-clavicular joint, open acromioplasty and rotator cuff repair. The skin incision follows the Langer lines along the acromion. Underneath the anterior and middle deltoid bellies are separated and freed subperiosteally from the acromion. Care must be taken not to split the muscle too far distally (> 4-5 cm) in which case the axillary nerve may be injured. The subacromial space is entered and the acromion, a-c-joint and rotator cuff can be addressed. When closing a good repair of the deltoid on the acromion is of great importance.

Posterior approach

The posterior approach is not so commonly used but is practical for posterior instability, most scapular fractures and can be used for arthroplasty. The incision frees the deltoid from the scapular spine and then the infraspinatus muscle is separated from the teres minor. The tendon of the infraspinatus is transacted close to the insertion on the humerus and the posterior joint capsule opened.

Clinical diagnosis

The diagnosis of degenerative conditions of the shoulder is based upon a good clinical examination evaluating motion, strength and weakness of the shoulder muscles, instability of the sterno-claviclular, the acromio-clavicular and the gleno-humeral joints and certain clinical tests. The routine examination should include the Neer or Hawkins's test for impingement, Jobe's test for supraspinatus strength, the lift off test for subscapularis weakness and the apprehension test for instability. In addition tenderness and adduction pain in a-c-joint should be tested.

Radiology

Conventional x-rays with AP- and lateral films and special a-c-joint views are the basis for diagnosis of shoulder disorders. Ultrasound examination by an experienced examiner is good for rotator cuff pathology. MRI should always be preceded by conventional x-ray and is primarily a study of the soft tissues. For detailed diagnosis of the skeleton CT gives the best information.

Arthroscopy

Today arthroscopy is primarily a therapeutic technique and pure diagnostic arthroscopies are rarely indicated. MRI usually provides sufficient and similar information in a non-invasive way.

The degenerative shoulder

Primary osteoarthritis

This entity is not uncommon in the shoulder. Its most often affects the a-c-joint and less common the gleno-humeral joint. Arthritic changes in the a-c-joint are common findings on x-ray examination but need not be symptomatic. Radiological arthritis in the gleno-humeral joint is usually symptomatic. Patients complain of pain and limited motion. X-ray films show a decreased joint space and typical inferior osteophyte formation. Treatment modalities are initially conservative (NSAIDS, physiotherapy). When conservative treatment fails in a-c-joint arthritis operation with resection of the most lateral 0.5-1 cm of the clavicle is indicated. This procedure gives pain relief but does not affect shoulder function.
For gleno-humeral arthritis arthroplasty is the optimal procedure. Both hemiarthroplasty and total joint replacement are used although the latter is preferred when rotator cuff function is intact and glenoid bone stock is preserved enough to permit fixation of a component.

Cuff tear arthropathy

A special form of osteoarthritis in the shoulder, cuff tear arthropathy is seen in combination with massive rotator cuff tears. It is characterized by advanced arthritic changes, superior migration of the humeral head and absence of cuff function. Without the rotator cuff there is an increased risk of glenoid loosening so hemiarthroplasty with or without an extended head is usually preferred. Alternatively prosthesis with so called reversed design can give a good function. This prosthesis has the head fixed to the glenoid and the cup in the humerus thus medialising the centre of rotation which facilitates arm elevation by the deltoid muscle alone. The lack of rotator cuff function is thus overcome.

Inflammatory arthritis

Rheumatoid disease often affects the shoulder. Modern pharmacological treatment is usually successful and recent progress with anti-TNF drugs have very much slowed down the destructive process. Synovectomy and arthrodesis were used earlier but today arthroplasty is the procedure of choice when the drug treatment fails. The choice between hemi- and total shoulder replacement is decided by the degree of glenoid destruction and rotator cuff function. With an intact rotator cuff total replacement is preferred. When the humeral head is structurally intact a resurfacing prosthesis on the humerus can be a good alternative to avoid a stem down the diaphysis in case an elbow prosthesis is in place or indicated later.

Septic arthritis in the shoulder

This is most common in patients with a compromised immune system such as rheumatoid arthritis, post organ transplantation or during chemotherapy. It can be a potentially life threatening condition caused by a septicaemia and should be treated as such. Diagnosis is clinical with standard laboratory findings such as high white cell count, left shift of white blood cells, high sedimentation rate and elevated C-reactive protein levels. Joint aspiration reveals the causing bacteria. Organisms found are generally staphylococcus or streptococcus. In mild cases treatment may be antibiotics but in more severe cases it is mandatory to clean out the joint arthroscopically or by open surgery. Appropriate i.v. and oral antibiotics are then administered.

Adhesive capsulitis

Adhesive capsulitis is also called frozen shoulder. It is an idiopathic disease characterized by pain and progressive contracture of the gleno-humeral joint. The disease affects the joint capsule but the underlying cause is not known.
The disease starts insidiously with slowly increasing shoulder pain especially at night. After 2-6 months increasing stiffness of the gleno-humeral joint is noted. Both active and passive motions are reduced and may progress until the joint is completely stiff. This phase takes 3-9 months. The pain then starts to decrease slowly and the mobility of the shoulder comes back over a period of 3-12 months. Adhesive capsulitis thus takes 12-24 months from start to end. Full recovery is usually achieved. The treatment is symptomatic with analgesics and physiotherapy aiming at preserving the motion. Arthroscopic release of the joint capsule may be indicated when the diagnosis is clear in order to improve motion and shorten the natural history.

Impingement syndrome

Impingement syndrome is a pain condition in the shoulder. The name was introduced by Neer who believed the cause to be a conflict between the acromion and coraco-acromial ligament and the subacromial bursa and the rotator cuff on arm elevation. Bigliani-Morrison defined three types of acromial shapes where impingement is most common with the most curved acromion. This etiology has later been challenged. Impingement syndrome is characterized by pain on raising the arm and when doing overhead work. Night pain and difficulties sleeping on the affected side is typical. It exists on its own or in connection with rotator cuff tears. The diagnosis can be established by the patient's history and a clinical examination. Special clinical test are the Neer test and the Hawkins' test which when positive produce the impingement pain. Injection of a local anaesthetic subacromially should take away the pain and make the impingement test negative. Standard x-rays may be normal or show a curved acromion, sometimes with osteophytes at the tip, and/or arthritic changes in the a-c-joint with inferior osteophytes. MRI may show impression on the rotator cuff by the skeletal changes.
Initially impingement syndrome is treated with pain medication, subacromial injection of steroids and physical therapy. If non-surgical therapy fails an acromioplasty is indicated. This means increasing the subacromial space by resection of the tip and bottom surface of the acromion changing the form from curved to flat. Any inferior osteophytes in the a-c-joint are also resected. In Neer's original description of the operation the coraco-acromial ligament was also resected but later studies have shown that this is not necessary. An acromioplasty may be combined with lateral clavicle resection and with rotator cuff repair. Acromioplasty can be performed arthroscopically or open and today the former technique is dominating. Rehabilitation after the operation consists of a structured training programme and the outcome may take up to six months to achieve.

Rotator cuff tears

With normal ageing the rotator cuff becomes thinner and weaker. The tendon tissue degenerates and tendinosis and partial tears occur. This degenerative process can progress to full thickness ruptures without symptoms but more common is that it is associated with pain and weakness on elevation and external rotation. Rotator cuff tears are more common with increasing age. A trivial trauma or load can change a partial tear into a total rupture. Cuff tears also occur in younger individuals but then usually after a significant trauma. Dislocation of the shoulder is associated with cuff rupture in patients over 40 years of age.

Typical clinical symptoms are pain which aggravates with overhead activities and often disturbs sleep. Weakness on elevation and external rotation and sometimes loss of these motions are also typical. Jobe´s test (Empty can test) for loss of supraspinatus strength. On the other hand full range of motion is possible even with massive total ruptures.

Diagnosis is made by the history and clinical examination. Plain x-rays may show cranial displacement of the humeral head relative to the glenoid. MRI is diagnostic for the size of the rupture and which tendons are involved. It also shows the condition of the muscle bellies which atrophy with long standing rupture. The muscle is infiltrated by fat and becomes non-functional.

Non-surgical therapy consists of physiotherapy aiming at strengthening the shoulder muscles and anti-inflammatory drugs. Subacromial steroids injections may give temporary pain relief. When this therapy fails to give sufficient pain decrease surgery is indicated. For patients with no pain but reduced motion and strength surgery is usually not indicated since the outcome regarding these parameters is less predictable.

Surgery aims at repairing the torn tendons and reattaches them to the humerus. The repair can be made arthroscopically for minor tears or mini-open (a combination of arthroscopic debridement and mobilization and open suture through a small transdeltoid incision. Larger tears demand an open repair. If the rupture is massive cuff and the cuff can't be repaired a tenotomy of an intact long head biceps tendon may reduce pain. Acromioplasty is usually performed to increase the subacromial space and remove impingement on the repaired cuff.

For patients in whom the loss of motion is a big problem improvement can be achieved with latissimus dorsi transfer or with a reversed shoulder prosthesis.

Rehabilitation after cuff repair consist of a structured training programme initially focused on gaining motion and after six to eight weeks strengthening exercises are added. The final outcome may take six to twelve months to achieve.

Recommended reading

The following text books can be recommended:

Rockwood-Matsen-Wirth-Lippitt: The Shoulder. 4th ed., 2 vol., Saunders, 2009

Iannotti-Williams: Disorders of the Shoulder. 2nd ed., 2 vol. Lippincott Williams & Wilkins, 2006

Matsen-Lippitt: Shoulder Surgery: Principles and Procedures. 1st ed., Saunders, 2004.

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Upper Limp Trauma: Shoulder Girdle Trauma

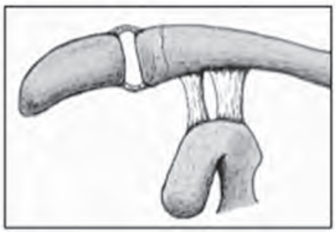
For shoulder pathology the major reference is: *The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier.* In the AO manual that covers all important fixation techniques the reader will fact pertinent facts related to the topic at hand: *AO Principles of Fracture Management. Second expanded edition, TP Rüedi, RE Buckley, CG Moran. 2007, Georg Thieme Verlag.* For the latest in fracture fixation techniques the reader is also invited to visit the AO surgery reference site: *AO surgery reference: http://www.aofoundation.org.* Another most useful publication containing pertinent facts related to orthopaedics and musculoskeletal trauma is the *AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.* For surgical approaches the most useful reference is without doubt: *Surgical Exposures in Orthopaedics: The Anatomic Approach. Hoppenfeld S, deBoer P, Buckley R. Lippincott Williams & Wilkins; 2009, Fourth Edition.*

Clavicle fractures
Clavicular fractures are some of the most common fractures accounting for 5% to 10% of all fractures and 35% to 45% of shoulder girdle injuries.
The clavicle struts the shoulder girdle.
Clavicular fractures are the result of falls, rarely direct trauma and rarely secondary to metastatic disease.
Clinical examination shows deformity of the shoulder girdle; a careful neurovascular examination must be performed due to the vicinity of fragile structures deep to this unprotected and subcutaneous bone.
Diagnosis necessitates an AP X-ray of the clavicle and often an AP view of the whole shoulder girdle will be of help to comparatively determine the amount of displacement. In some rare cases a CT will define the fracture.

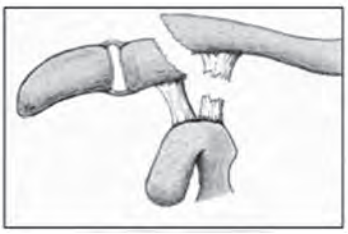
Fractures of the clavicle are divided **into proximal third, mid-third and distal third.**

- **Proximal third fractures**
  Usually conservative treatment will be sufficient, if displaced will benefit from fracture fixation, preferably with a plate. Beware of free pins that tend to migrate.
- **Mid-third fractures**
  If little displacement is present conservative treatment with a sling will be sufficient. In cases of displacement >100% or > 2 cm of shortening, fixation is indicated. Flail chest, scapulothoracic dissociation, fractures menacing the integrity of the skin or open fractures are also indications for operative fixation. Activities such as professional cycling cannot tolerate unequal clavicular lengths and in these cases reconstruction is indicated.
  Fixation may be accomplished with a 3.5 mm reconstruction or dynamic compression with or without locked screws. Nails of different types have been advocated and reported to be successful by many authors.

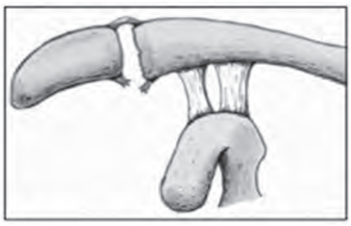
Robertson C, Celestre P, Mahar A, Schwartz A. Reconstruction plates for stabilization of mid-shaft clavicle fractures: differences between nonlocked and locked plates in two different positions. J Shoulder Elbow Surg. 2009;18(2):204-9.
Lee YS, Lin CC, Huang CR, Chen CN, Liao WY. Operative treatment of midclavicular fractures in 62 elderly patients: Knowles pin versus plate. Orthopedics. 2007;30(11):959-64.
Canadian Orthopaedic Trauma Society Trial. Midshaft Clavicular Fractures. A Multicenter, Randomized Clinical Nonoperative Treatment Compared with Plate Fixation of Displaced.
J Bone Joint Surg Am.2007;89:1-10.



Neer Type 1



Neer Type 2



Neer Type 3

- **Distal third fractures**
  In case of displacement > 100%, skin menace or open fracture fixation is indicated. Depending on the size of the distal fragment the surgical intervention can vary from simple excision, to figure of 8 wiring with pins, to heavy sutures to specific plates or hook plates. If the coracoclavicular ligaments are compromised (Neer type II fractures) coracoclavicular fixation (sutures or screws) may be indicated.

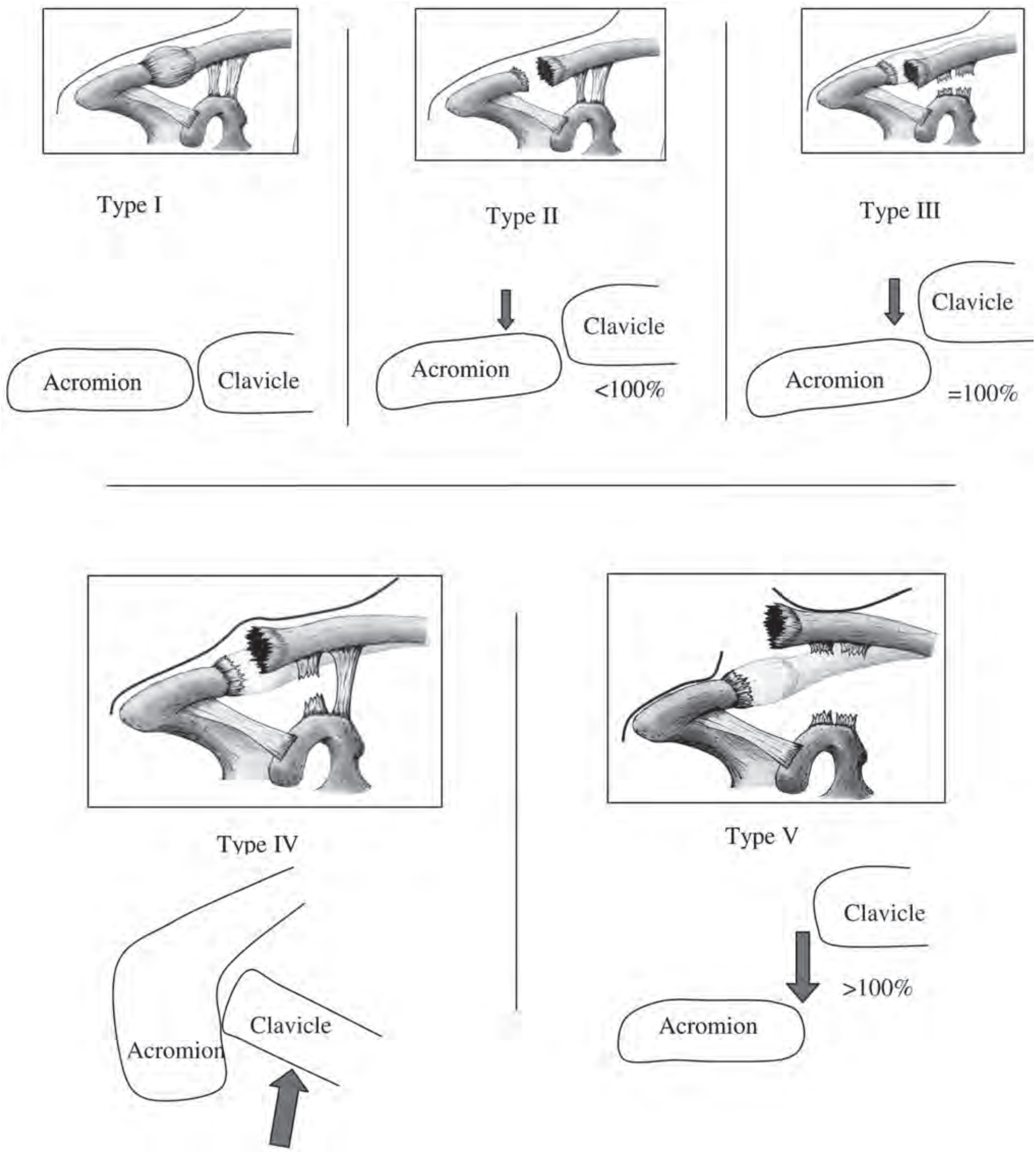
Khan LA, Bradnock TJ, Scott C, Robinson CM. Fractures of the clavicle. J Bone Joint Surg Am. 2009;91(2):447-60.
Neer CS II. Fractures of the distal third of the clavicle. Clin Orthop. 1968;58:43–50.
Fann CY, Chiu FY, Chuang TY, Chen CM, Chen TH. Transacromial Knowles pin in the treatment of Neer type 2 distal clavicle.fracturesA prospective evaluation of 32 cases.
J Trauma. 2004;56(5):1102-5; discussion 1105-6.
Goldberg JA, Bruce WJ, Sonnabend DH, Walsh WR. J Shoulder Elbow Surg. Type 2 fractures of the distal clavicle: a new surgical technique. 1997;6(4):380-2.
The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier.
Muramatsu K, Shigetomi M, Matsunaga T, Murata Y, Taguchi T. Use of the AO hook-plate for treatment of unstable fractures of the distal clavicle. Arch Orthop Trauma Surg. 2007;127(3):191-4.

Complications
Infections, nonunions or neurovascular compromise dominate the scene.
The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier.
Endrizzi DP, White RR, Babikian GM, Old AB. Nonunion of the clavicle treated with plate fixation: a review of forty-seven consecutive cases. J Shoulder Elbow Surg. 2008;17(6):951-3.

Sternoclavicular dislocations
- **Anatomy**
  With relatively no osseous constraints, stability is provided by the anterior capsular ligament, the posterior capsular ligament, and a joint meniscus. The costoclavicular and interclavicular ligaments provide adjunct stability.
- **Antero-superior dislocation**
  Unstable and needs surgical intervention for stability. Usually reassurance and conservative treatment will suffice however.
- **Postero-inferior dislocation**
  This is potentially a life threatening situation. Symptoms are related to the posterior structures under compression (dyspnea, dysphagia, vascular compromise or thrombosis). CT is helpful to make the diagnosis. Reduction under anaesthesia with a bolster under the dorsal spine and simultaneously pulling the arm in extension while grabbing the clavicle end with a towel clip will usually reduce the clavicle that will stay stable.
  Beware of fractures passing trough the proximal growth plate, which is the last to ossify at age 25.

Jaggard MK, Gupte CM, Gulati V, Reilly P. A comprehensive review of trauma and disruption to the sternoclavicular joint with the proposal of a new classification system. J Trauma. 2009;66(2):576-84.

Acromioclavicular dislocations
Usually a consequence of a fall on the tip of the shoulder in a young to middle-aged male athlete, the acromion is pushed downwards and the coraco- and acriomio-clavicular ligaments are damaged to varying degrees along with a displacement of the clavicle with respect to the shoulder girdle.
The patient presents with a deformity due to the antero-inferior position of the shoulder girdle. Check for instability in the frontal and transverse planes. Inspect the skin to rule out abrasions.
AP X-rays of the shoulder, Zanca views (10°-15° cephalic tilt) and axillary views are necessary and sufficient. An AP X-ray view of the shoulder girdle is a useful adjunct. Stress views are not necessary.
AC dislocations are classified according to Rockwood:
Type I: Strain without tear, Type II tearing of AC ligaments, Type III: Tearing of AC and CC ligaments (Trapezoid and conoid), Type IV: posterior displacement of the clavicle in relation to the acromion. Type V: More than 100% displacement with tearing of AC and CC ligaments and overlying trapezius muscle.
Types I and II need conservative treatment.
Surgery is usually recommended in types IV and V. Type III is controversial in frail patients in may be recommended. The techniques may involve coraco-clavicular screws, CC and AC heavy sutures or tapes or transarticular pinning.
In long standing cases the Weaver-Dunn procedure is recommended, with removal of 1 cm of the distal clavicle and using the coraco-acromial ligament as a substitute inserted into the hollowed out distal clavicle. Hook plates are used by some authors but will require reoperation for their removal.



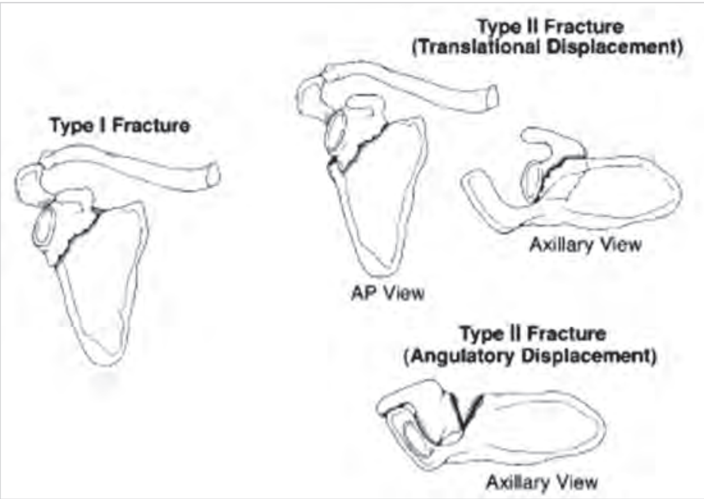
The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier.
AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons

Scapular fractures

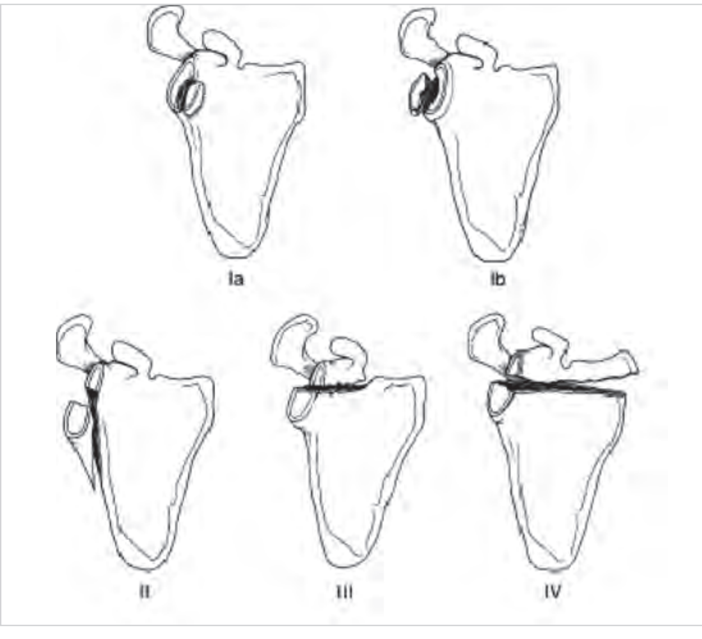
Fractures of the scapula result from high energy trauma with 80 to 95% incidence of associated trauma 50% of which are thoracic trauma. Mortality is 10% to 15% principally due to associated thoracic and cranial injuries. Thorough clinical examination is mandatory and CT with 3D reconstruction is of great help in determining the exact extent of the fracture.

- **Scapulothoracic dissociation**
  This is the equivalent of an internal amputation entailing serious neurovascular damages. This injury is associated with a traumatic break or dislocation of the shoulder girdle (AC, clavicle, SC) and a lateral displacement of the scapula as seen on AP chest X-Ray. Consequences are dire and in many cases lead to loss of the upper extremity or death from major thoracic injury or massive haemorrage.
  Ebraheim NA, An HS, Jackson WT, Pearlstein SR, Burgess A, Tscherne H, Hass N, Kellam J, Wipperman BU. Scapulothoracic dissociation. J Bone Joint Surgery Am, 1988;70,428-432,

- **Body Fractures**
  Most of these fractures may be treated conservatively, the scapula being well protected and surrounded by muscles. The most popular classification is the Ideberg classification.
  Ideberg R, Grevsten S, Larsson S. Epidemiology of scapular fractures. Incidence and classification of 338 fractures. Acta Orthop Scand. 1995;66(5):395-7.
  Schofer MD, Sehrt AC, Timmesfeld N, Störmer S, Kortmann HR. Fractures of the scapula: long-term results after conservative treatment. Arch Orthop Trauma Surg. 2009.
  Lapner PC, Uhthoff HK, Papp S. Scapula fractures. Orthop Clin North Am. 2008 ;39(4):459-74, vi.
  Lantry JM, Roberts CS, Giannoudis PV. Operative treatment of scapular fractures: a systematic review. Injury. 2008;39(3):271-83..
- **Glenoid Fractures**
  Fractures of the glenoid surface and rim must be reduced and fixed if they are accompanied by instability or subluxation of the glenohumeral joint. If the humeral head does not appear centered in AP and axillary views and in CT cuts then the indication is absolute. When the joint remains centered, the indication for fixation becomes relative.
  Goss TP. Fractures of the glenoid cavity. J Bone Joint Surg Am. 1992;74-A:299-305.
  Schandelmaier P, Blauth M, Schneider C, Krettek C. Fractures of the glenoid treated by operation. A 5- to 23-year follow-up of 22 cases. J Bone Joint Surg Br. 2002;84(2):173-7
  Maquieira GJ, Espinosa N, Gerber C, Eid K. Non-operative treatment of large anterior glenoid rim fractures after traumatic anterior dislocation of the shoulder. J Bone Joint Surg Br. 2007;89(10):1347-51.
- **Acromion and Spine Fractures**
  Displaced fractures of the acromion or the spine of the scapula need plate fixation or tension band fixation. Constant pull of the deltoid will displace the fragments and lead to a secondary impingement that may be difficult to treat.
  Ogawa K, Naniwa T. Fractures of the acromion and the lateral scapular spine. J Shoulder Elbow Surg. 1997;6(6):544-8.



Classification of fractures of the scapular neck: TP Goss. J Am Acad Orthop Surg 1995;3:22-33



Classification of the scapular body : Ideberg R, Grevsten S, Larsson S. Epidemiology of scapular fractures. Incidence and classification of 338 fractures. Acta Orthop Scand. 1995;66(5):395-7.

Glenohumeral dislocation

For shoulder pathology the major reference is: *The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier.* In the AO manual that covers all important fixation techniques the reader will fact pertinent facts related to the topic at hand: *AO Principles of Fracture Management. Second expanded edition, TP Rüedi, RE Buckley, CG Moran. 2007, Georg Thieme Verlag.* For the latest in fracture fixation techniques the reader is also invited to visit the AO surgery reference site: *AO surgery reference: http://www.aofoundation.org.* Another most useful publication containing pertinent facts related to orthopaedics and musculoskeletal trauma is the *AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.* For surgical approaches the most useful reference is without doubt: *Surgical Exposures in Orthopaedics: The Anatomic Approach. Hoppenfeld S, deBoer P, Buckley R. Lippincott Williams & Wilkins; 2009, Fourth Edition.*

Introduction

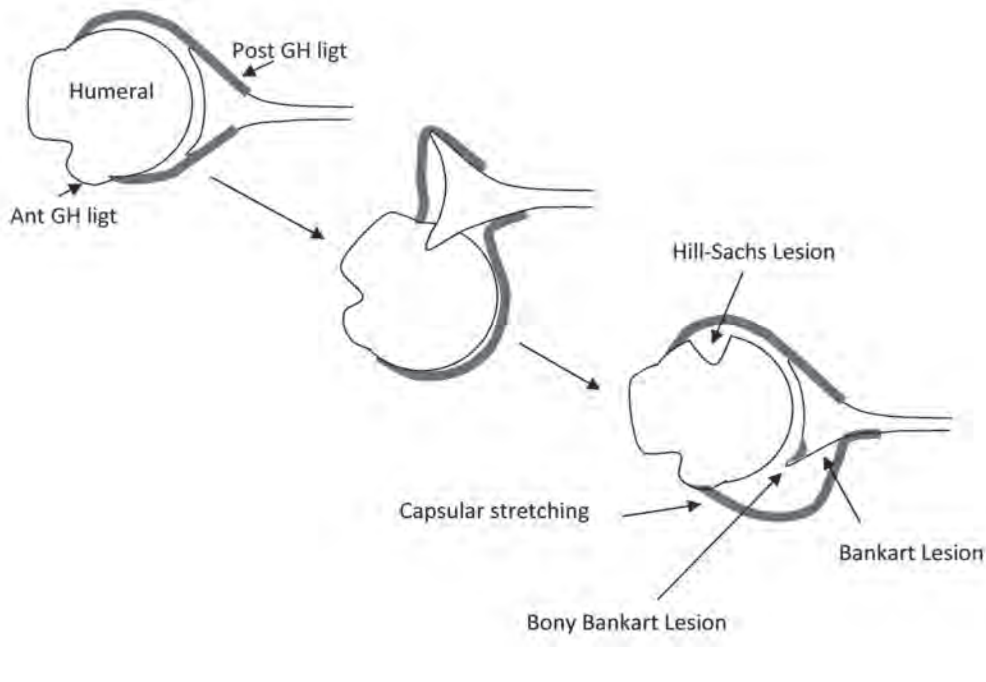
Dislocation applies to a complete loss of contact between two joint surfaces. Subluxation implies partial loss of contact. Laxity is the result of a clinical examination showing more than "normal" passive motion or translation. Instability is a subjective sensation described by the patient that includes subluxation up to dislocation.
Glenohumeral instability is a spectrum that includes hyperlaxity and traumatic dislocation whether anterior or posterior or multidirectional.
Classification of the different types of instability include:

- Traumatic anterior dislocation: Accidental fall
- Traumatic posterior dislocation: Accidental fall
- Atraumatic instability due to capsular stretching because repeated "micro-trauma"
- Multidirectional instability due to capsular laxity

Pathoanatomy

- **Traumatic anterior instability**
  Generally accompanied by a tear of the capsulo-labral complex that sometimes includes osseous fragments off from the glenoid rim:
  The **Bankart** lesion.
  Anterior capsular stretching.
  In many cases a bony trough in the posterior-superior region of the head will be caused by impaction against the glenoid rim sometimes leading up to a fracture of the greater tuberosity: **The Hill-Sachs** lesion.
- **Traumatic posterior instability**
  The inferior glenohumeral ligament is the main restraint in abduction/external rotation and found to be torn or detached in all cases of traumatic dislocation.
  Generally accompanied by detachment and stretching of the posterior capsulo-ligamentous complex, rarely with osseous lesions involving the glenoid rim: The **reverse Bankart** lesion.
  Posterior capsular stretching. Impaction of the anterior region of the head just medial to the lesser tuberosity leading up to a head-split fracture: The **reverse Hill-Sachs** lesion.

Anterior dislocation injuries



Hill-Sachs impression; Bankart bony and labral; capsular stretching.

Dislocation and instability types

Anterior dislocation

Usually related to sports activities (soccer, skiing etc.) or falls.

Recurrence rates are high in patients below 20 yrs (up to 90%), between 20 and 40 yrs 60% recurrence rates, above 40 yrs 10%. These numbers vary depending on authors but trends remain.

Clinical examination is dominated by apprehension in abduction and external rotation.

Signs of generalized laxity are often present: Antero-posterior drawer, inferior sulcus sign, joint hyperlaxity (fingers, thumb, elbow).

In acute cases axillary nerve injury occurs in 5% of patients.

Imaging involves AP and axillary views. Arthro-CT scans delineate precisely bony morphology of fractures; Hill-Sachs lesions, glenoid brim fractures or rounding are well visualized. MRI may be helpful but bony lesions are poorly demonstrated.

- Treatment for acute dislocations

  AFTER diagnostic X-Rays: Reduction techniques include, after neurovascular testing, *Stimson* (Patient prone, arm hanging with 1 to 3 kg weights attached to the wrist), *Saha* (slow elevation in the plane of the scapula), *Kocher* (Adduction in internal rot followed by abduction in ext rotation), Traction after intra-articular injection of lidocaïne or equivalent, Davos (Patient to cross his fingers around his flexed knee and with elbows extended is instructed to slowly bend backwards), *Hippocrates technique* (anesthetized, traction on the arm and with foot in the axilla which should be replaced by a towel) should only be performed when the non traumatic techniques have failed.

  Postreduction treatment includes, after neurovascular testing, immobilisation in internal rotation or in an **external** rotation splint. (The rationale for the external rotation immobilisation is to force the Bankart lesion to stay fixed to the anterior glenoid rim pressured by the subscapularis). Immobilisation should be 2 to 4 weeks followed by strengthening exercises.

- Treatment for recurrent dislocations

  Surgical indications for stabilisation include one episode of dislocation too many, or severe apprehension.

  Techniques include capsulorraphy, Bankart lesion refixation, bony augmentation if severe rounding or fracture of the rim.

  Open or arthroscopic techniques are both suitable. Closed arthroscopic techniques are advocated in traumatic Bankart lesions, open techniques are recommended in cases of capsular stretching or large Hill-Sachs lesions. Recurrence rates range between 5% and 30% depending on technique used, strength of reconstruction and patient compliance.

  Patients are immobilized from 3 to 6 weeks in internal rotation; rehabilitation emphasizes muscular strengthening in the first weeks followed by range of motion exercises. Patients are advised to avoid contact sports for a year following stabilisation.

Posterior dislocation

Fall on outstretched hand, seizures or electrical shocks are the main causes. AP and axillary X-rays for diagnosis. Relatively rare; less than 5% of all instabilities. Beware of the diagnosis: The cardinal sign is active and passive limitation of external rotation. On the AP X-ray, the joint space is not visible and the axillary is always diagnostic. In doubt a CT will solve the issue.

- Treatment for acute dislocations

  If a small i.e. less than 10% reverse Hill-Sachs is present, gentle traction will generally reduce the shoulder which should then be immobilized in an external rotation splint for three to 6 weeks with a rehabilitation programme to follow.

  If a large Hill-Sachs lesion is present, reduction under anaesthesia may be necessary followed by the McLaughlin procedure where through an anterior deltopectoral incision the head is gently levered out and the subscapularis or the osteotomized lesser tuberosity is sutured or screwed into the bony defect. External rotation immobilisation 4 to 6 weeks followed by a rehabilitation programme.

- Treatment for recurrent dislocations

  If no major Hill-Sachs lesion is present a posterior approach with a cruciate capsulorraphy and fixation of the reverse Bankart lesion is performed. A bone graft from the spine of the scapula or the iliac crest may be necessary if a bony defect is present.

  If a major Hill-Sachs lesion is present a McLaughlin procedure will be necessary and if insufficient an adjunct posterior procedure may be necessary.

Multidirectional dislocation

This applies to young patients with laxity and instability in more than in one direction, i.e. anterior and posterior or posterior and inferior or all three. Cardinal signs are hyperlaxity, sulcus sign and anterior and posterior drawer signs all causing discomfort or apprehension.

Standard X-rays, arthro-CT or MRI will delineate the existing lesions. Surgery is indicated only after one year of serious muscle strengthening physiotherapy and exercises.

The most commonly accepted operation is Neer's capsular shift which may be performed through an anterior deltopectoral approach but in certain cases may need an adjunct posterior approach. The axillary nerve must be protected during this demanding and complex intervention. 6 weeks of immobilisation in neutral (handshake) position is necessary follwed by a muscle strengthening programme.

Chronic dislocation

Usually seen in debilitated patients. The best option may be no treatment. In cases of chroni pain and discomfort shoulder fusion may be another option. Some authors advocate the reverse prosthesis but the danger of dislocation is great.

Recurrent dislocation in the elderly patient

Often these dislocations are associated with minor trauma. A massive rotator cuff tear is the usual cause. If repairable the supra and infraspinatus lesions should be repaired. If not repairable the reverse prosthesis may be an option and if not fusion may have to be performed.

The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier.
AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.
Shoulder Reconstruction. CS Neer. W.B. Saunders Company (January 1990)

Proximal humerus fractures

For shoulder pathology the major reference is: *The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier.* In the AO manual that covers all important fixation techniques the reader will fact pertinent facts related to the topic at hand: *AO Principles of Fracture Management. Second expanded edition, TP Rüedi, RE Buckley, CG Moran. 2007, Georg Thieme Verlag.* For the latest in fracture fixation techniques the reader is also invited to visit the AO surgery reference site: AO surgery reference: http://www.aofoundation.org. Another most useful publication containing pertinent facts related to orthopaedics and musculoskeletal trauma is the *AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.* For surgical approaches the most useful reference is without doubt: Surgical Exposures in Orthopaedics: The Anatomic Approach. *Hoppenfeld S, deBoer P, Buckley R.Lippincott Williams & Wilkins; 2009, Fourth Edition.*

Introduction

Proximal humerus fractures constitute 5% of all fractures. High energy fractures occur in young males and low energy fractures in elderly females. They are intra-articular fractures and treatment modalities should attempt to reconstruct the anatomy so that function may be best restored. 80% of all these fractures need conservative treatment. Avascular necrosis, mal or non unions, stiffness and postoperative sepsis plague the treatment results.

Biomechanics

The quasi sphericity of the humeral head allows smooth articulation on the glenoid. The subacromial arch must be preserved; any bony fragments or overgrowth will lead to impingement inhibiting motion. The rotator cuff plays the roles of transmission belt, spacer and shock absorber. Translation of the humeral head is limited by the glenoid geometry, the labrum, the glenohumeral ligaments and the coaptation force of the cuff muscles. The deltoid muscle provides power in elevation and abduction, the rotator cuff centers the humeral head and provides power in external (infraspinatus) and internal rotation (subscapularis). The supraspinatus fine tunes practically all glenohumeral movements. The pectoral plays a role in adduction and internal rotation.
The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier

Anatomy

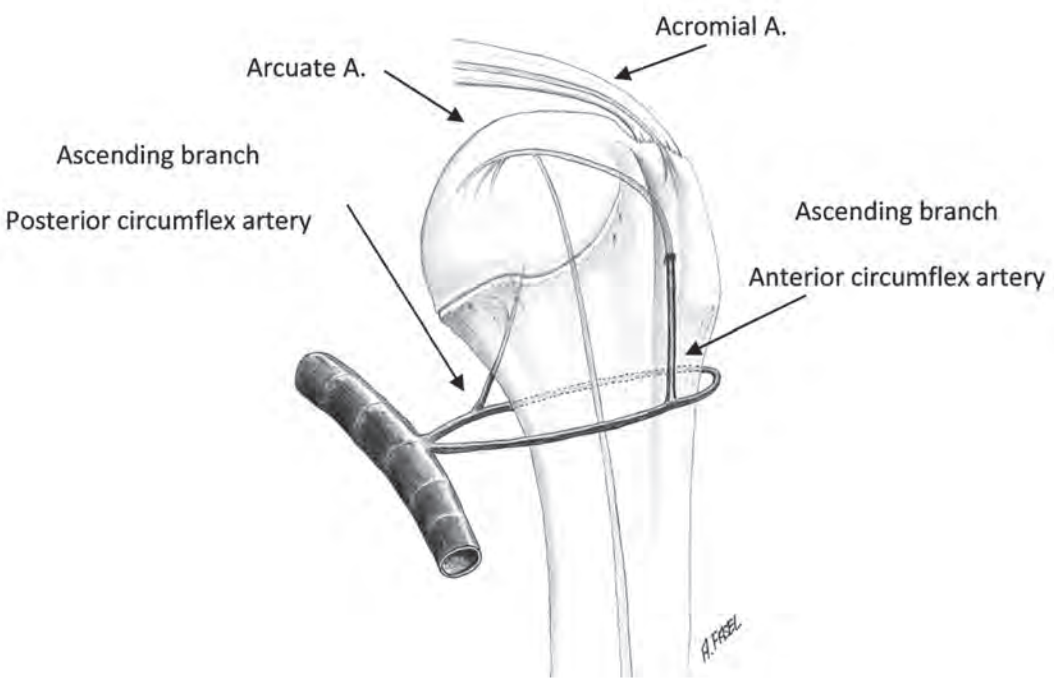
The humeral head is a half sphere with a diameter between 37 to 57 mm, inclined at 130°, retroverted at 30°. The axillary artery is divided into three segments by the pectoralis minor muscle. The first part is medial to the pectoralis minor muscle, the second part is deep to the pectoralis minor muscle and the third part lateral to the pectoralis minor has three branches: the subscapular artery (the circumflex scapular branch runs through the triangular space), the anterior humeral circumflex artery and the posterior humeral circumflex artery accompanies the axillary nerve and exits posteriorly through the quadrilateral space (medial: long head of triceps, lateral: humeral shaft, superior: teres minor, inferior: teres major). The blood supply of the humeral head is provided by the anterolateral ascending branch of the anterior circumflex artery terminating into the arcuate artery in the humeral head, the rotator cuff arterial supply, the central metaphyseal artery and the posterior circumflex artery. Innervation of the deltoid and teres minor muscles arises from the axillary nerve along with a sensory component in the lateral shoulder. Innervation of supra and infraspinatus depends on the suprascapular nerve passing through the scapular notch giving off branches to the supraspinatus and then passing around the spinoglenoid notch to innervate the infraspinatus. The subscapularis is innervated by the subscapularis nerve, a direct branch off of the posterior trunk of the brachial plexus. The pectoralis muscle nerve stems off the medial trunk.
AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.
Hertel R, Hempfing A, Stiehler M, et al. Predictors of humeral head ischemia after intracapsular fracture of the proximal humerus. J Shoulder Elbow Surg 2004; 13(4):427–433.
The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier

Clinical Presentation

Deformity and functional impairment are the presenting signs and symptoms. The neurovascular status must be explored namely the status of the axillary nerve. In undisplaced fractures a tell-tale ecchymosis appearing two to three days after a fall will sign an underlying fracture. Diagnosis will be made with well-centered x-rays AP and axillary views. If operative treatment is entertained a CT with 3D reconstruction will give invaluable information. MRI may be occasionally useful for assessment of the rotator cuff or to ascertain the existence of a fracture. Excellent imaging is the only way to accurately classify the fracture and establish a prognosis as to the occurrence of avascular necrosis.
The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier

Classification of Proximal Humeral Fractures
Many classification schemes exist: Neer classification into two, three and four part fractures, a fracture is deemed displaced if there is more than 1 cm of displacement or 45° of angulation. The AO-OTA classification is based on the scheme of the overall AO classification. The "Lego" classification of Hertel is interesting because it allows to combine the different fracture patterns and the Duparc classification which has an anatomic and functional determinant. However although helpful, none of these classifications has perfect inter or intra-observer reliability.
Neer CS II: Displaced proximal humeral fractures: Part I. Classification and evaluation. J Bone Joint Surg Am 1970;52:1077-1089
AO Principles of Fracture Management. Second expanded edition, TP Rüedi, RE Buckley, CG Moran. Georg Thieme Verlag; 2 Har/Dvdr edition (2007).
Hertel R. Fractures of the proximal humerus in osteoporotic bone. Osteoporos Int. 2005;16 Suppl 2:S65-72.
Duparc J. Classification of articular fractures of the upper extremity of the humerus. Acta Orthop Belg. 1995;61 Suppl 1:65-70.

Conservative Treatment
Most fractures will not be greatly displaced; immobilisation for three to six weeks in a shoulder immobilizer or a Velpeau type bandage will be indicated. Rarely an abduction splint will be needed to hold the fracture pattern in an acceptable position. Appropriate analgesic medications should be prescribed and personal hygiene measures with removal of the Velpeau every five days should be organized in the first weeks. After 3 to 6 weeks depending on the fracture type gentle physiotherapeutic exercises, emphasising on isometric exercises should be instituted. The fracture will heal in 12 weeks.

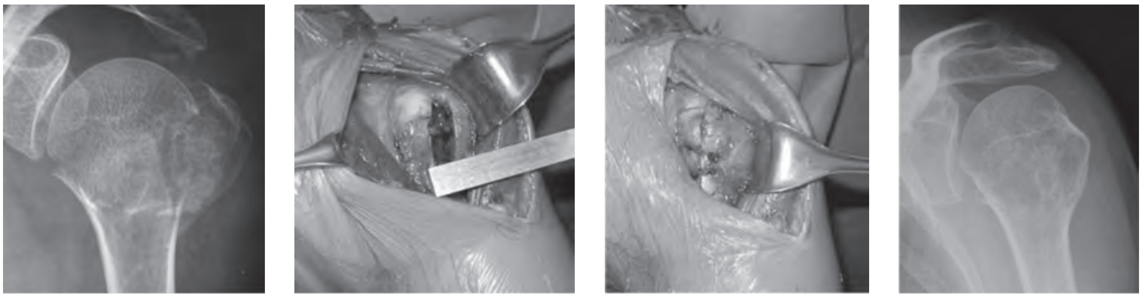


Vascular anatomy of the Humeral Head

Surgical Approaches
- **Delto-pectoral approach**
  The cephalic vein should if possible be preserved. The axillary nerve must be palpated in front of the subscapularis. If the long biceps tendon is not anatomically replaced a tenodesis is in order.
- **Trans-deltoid approach**
  The deltoid should not be split further than 5 cm distal to the acromion to protect the axillary nerve.
- **Posterior approach**
  A deltoid split will lead to the unfraspinatus which may have to be detached to access the capsule for arthrotomy. Rarely used approach in the trauma setting.

The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier
AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.

Operative techniques
- **Isolated greater tuberosity fractures**
  Displacement of more than 0,5 to 1cm warrants operative treatment. Usually a trans-deltoid approach with suture fixation, sometimes aug-

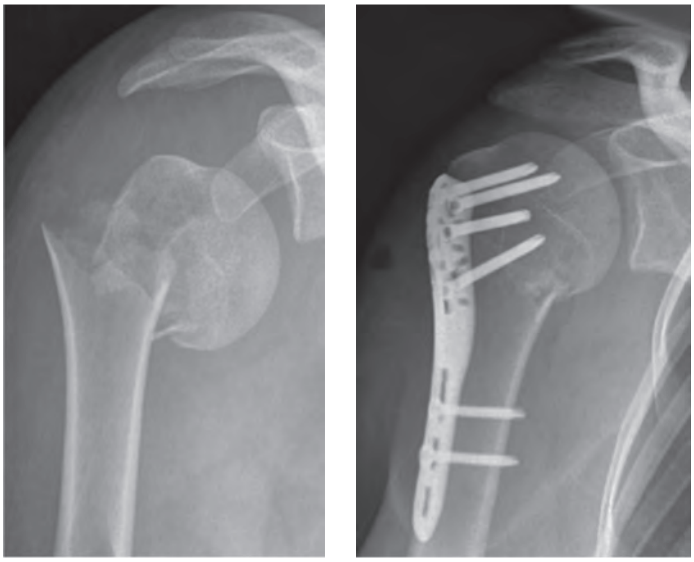


mented by isolated screws or perhaps a plate in case of a large fragment.

Transdeltoid approach and osteosuture of displaced fracture of the greater tuberosity

- **Displaced lesser tuberosity fractures**
  Anatomic reduction and fixation with screws is warranted to preserve subscapularis function.

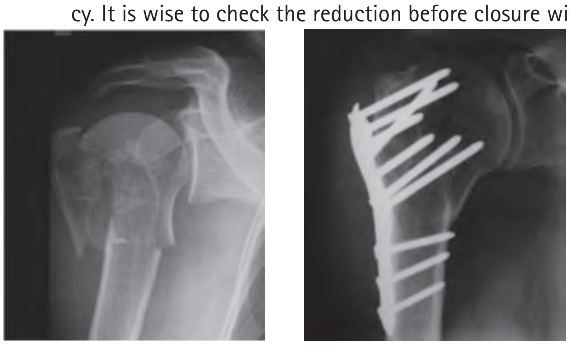
- **Two part displaced surgical neck fracture**



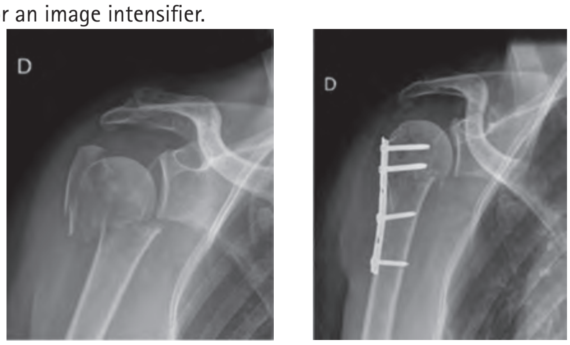
Plating or IM nailing can be used successfully in this indication.

Two part fracture fixed with a locking plate

- **Three part fractures**
  In strong bone percutaneous pinning may be used although accurate reduction is best achieved with an open technique. Some authors favour locked nailing for these fractures. In weak bone a deltopectoral approach with plate fixation with or without fixed angle screws or an osteosuture technique will be indicated. The biceps if well aligned in the bicipital groove is a precious indicator as to reduction accuracy. It is wise to check the reduction before closure with an X-ray or an image intensifier.

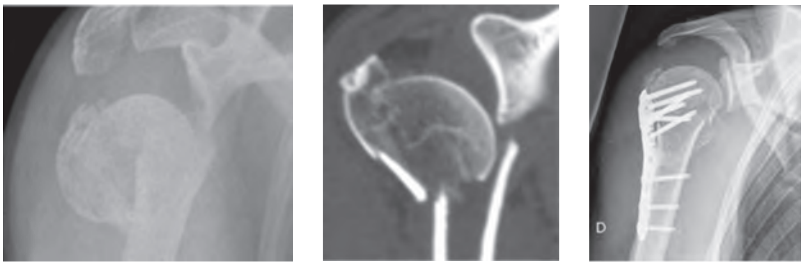


Three part fracture fixation with a locking screw plate

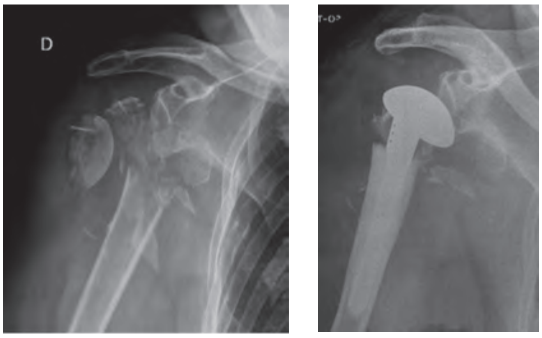


Three part fracture fixation with a third tubular 3.5 locking screw plate

- **Four part fractures**
  Prosthetic replacement respecting height, version and tuberosity fixation will be used in the elderly patient. In high demand young patients it is probably best to attempt plate osteosynthesis with angle stable screws. This is an acceptable solution only if an adequate anatomical reconstruction has been achieved. If not, a hemiarthroplasty with careful reconstruction of the tuberosities is an acceptable option.

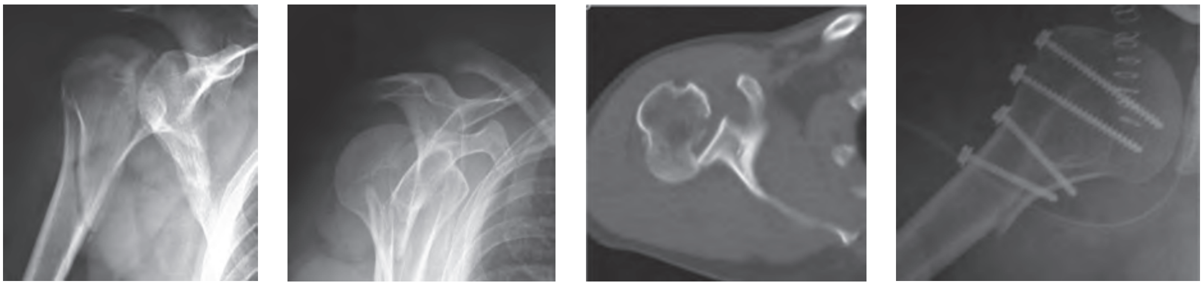


Four part fracture: X-Rays, CT evaluation and plate fixation (Deltopectoral approach)



Four part fracture (major displacement) treated with a hemi-prosthesis

- **Fracture-dislocations**
  Reduction must be obtained under anaesthesia so as not to displace a pre-existing humeral neck fracture. If there is doubt an open reduction should be done. Fixation will then depend on the fracture pattern. In very difficult situations it may be necessary to do a deltoid take-down to increase exposure. Careful neurovascular assessment must precede any surgical act and if necessary appropriate vascular imaging should be obtained.



Posterior fracture dislocation : X-rays, CT and screw fixation after reduction

- **Posterior dislocations**
  This may be a difficult to diagnosis often associated with seizures, although a fall on the outstretched hand can cause posterior dislocation. The hallmark is lack of external rotation passive or active. Plain x-rays must be scrutinized and if there is a doubt a CT scan is the best option. Active investigations should include neurological assessment to rule out intracranial tumours or other causes of seizures. If a large reverse Hill Sachs lesion is present or if a head splitting fracture is present the treatment may have to be surgical. The McLaughlin procedure is the insertion of the subscapularis tendon into the reverse Hill-Sachs lesion while the Neer modified approach osteotomizes the lesser tuberosity which is fixed with screws into the bed of the Hill-Sachs lesion. In all cases, whether the treatment is operative or conservative, post-reduction immobilisation is in external rotation often with the help of a splint.

The Shoulder, Fourth Edition. Editors CA Rockwood, FA Matsen, MA Wirth, SB Lippitt. 2009, Philadelphia, Saunders Elsevier
Hoffmeyer P. The operative management of displaced fractures of the proximal humerus. J Bone Joint Surg Br; 2002.84(4):469–480.
Gerber C, Werner CM, Vienne P (2004) Internal fixation of complex fractures of the proximal humerus. J Bone Joint Surg Br; 86(6):848–855.
Brems JJ (2002) Shoulder arthroplasty in the face of acute fracture: puzzle pieces. J Arthroplasty; 17(4 Suppl 1):32–35.

Humeral shaft fractures

In the AO manual that covers all important fixation techniques the reader will fact pertinent facts related to the topic at hand: *AO Principles of Fracture Management. Second expanded edition, TP Rüedi, RE Buckley, CG Moran. Georg Thieme Verlag; 2 Har/Dvdr edition (2007).* For the latest in fracture fixation techniques the reader is also invited to visit the AO surgery reference site: *AO surgery reference: http://www.aofoundation.org.* Another most useful publication containing pertinent facts related to orthopaedics and musculoskeletal in general trauma is the *AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.* For surgical approaches the most useful reference is without doubt: *Surgical Exposures in Orthopaedics: The Anatomic Approach. Hoppenfeld S, deBoer P, Buckley R. Lippincott Williams & Wilkins; Fourth Edition edition 2009.*

Introduction

Fractures of the humeral shaft represent 2-3% of fractures and are distributed in a bimodal mode. High energy fractures are typical of younger patients while low energy fractures are more commonly seen in the elderly osteoporotic individual. These fractures are the result of blunt trauma resulting from a fall and more rarely from gunshot wounds or war injuries. Sports are associated with these fractures such as hangglider inuries or result from arm wrestling. Pathologic fractures are also commonly seen arising from bony fragilisation resulting from metastases (8% of humeral fractures). All neoplastic diseases solid or haematological may cause metastatic disease. The neoplasms most frequently involved are those arising from: Breast, kidney, thyroid, lung, prostate or multiple myeloma. Chronic osteomyelitis either primary or associated with haemoglobinopathies may also cause associated fractures.

Ekholm R, Adami J, Tidermark J, Hansson K, Törnkvist H, Ponzer S Fractures of the shaft of the humerus. An epidemiological study of 401 fractures. J Bone Joint Surg Br. 2006;88(11):1469-73.

Sarahrudi K, Wolf H, Funovics P, Pajenda G, Hausmann JT, Vécsei V. Surgical treatment of pathological fractures of the shaft of the humerus. J Trauma. 2009;66(3):789-94.

Frassica FJ, Frassica DA. Metastatic bone disease of the humerus. J Am Acad Orthop Surg. 2003;11(4):282-8.

Biomechanics

The main forces acting on the humerus are torsional.

Anatomy

The main anatomical feature is the medial to lateral posteriorly running spiral groove housing the radial nerve beginning at 20 cm medially from the distal articular surface and ending 14 cm proximal to the distal joint surface. The radial nerve is reported to be injured on average in 11.8% in fractures of the humeral shaft.

Shao YC, Harwood P, Grotz MR, Limb D, Giannoudis PV. Radial nerve palsy associated with fractures of the shaft of the humerus: a systematic review. J Bone Joint Surg Br. 2005;87:1647–1652.

AAOS Comprehensive Orthopaedic Review. Jay R. Lieberman, MD, Editor 2009 Rosemont, IL, American Academy of Orthopaedic Surgeons.

Classification of humeral shaft fractures

The AO classification is popular. It classifies the fracture patterns of the humeral shaft as type A (simple, transverse or spiral) type B (wedge with a butterfly fragment) and type C (segmental or comminuted fragments). Open fractures are classified according to Gustilo and Anderson: Type I inside-out (< 1 cm), Type II outside-in (> 1cm), Type III A (open, osseous coverage possible), type III B (open, necessitating a local or free flap), Type III C (Open fracture with vascular injury).

AO Principles of Fracture Management. Second expanded edition, Thomas P Rüedi, Richard E Buckley, Christopher G Moran. Georg Thieme Verlag; Har/Dvdr edition (2007).

Gustilo RB, Mendoza RM, Williams DN. Problems in the management of type III (severe) open fractures. A new classification of type III fractures. J Trauma 1984, 24:742-746.

Gustilo RB, Anderson J. Prevention of infection in the treatment of one thousand and twenty-five open fractures of long bones: Retrospective and prospective analyses. J Bone Joint Surg Am 1976;58:453-458.

Clinical presentation

A deformed extremity is present. Look for neurovascular injuries (radial nerve) carefully before any manipulation of the injured extremity. Plain X-rays including the shoulder and elbow are generally sufficient in acute traumatic cases. MRI, CT, Bone scintigraphy are useful in special situations such as chronic infection, metastatic or primary tumors.

Conservative treatment

Usually if conservative treatment is chosen the patient is first immobilised in a Velpeau type bandage and after two to three weeks when swelling has diminished a functional brace is applied. There exist no guidelines but many agree that planar angulations of 20° sagittally and 15° frontally, malrotations up to 15°, and shortening up to 3 cm are acceptable. According to Sarmiento the most common complication of conservative functional bracing is varus angulation:16%>10°-20°.

Sarmiento A, Latta LL. Humeral diaphyseal fractures: functional bracing. Unfallchirurg. 2007;110(10):824-32.

Sarmiento A, Zagorski JB, Zych GA: Functional bracing for the treatment of fractures of the humeral diaphysis. J Bone Joint Surg Am 2000;82:478-486.

Surgical Approaches

- **Antero-lateral approach**
  The radial nerve may be identified in the intermuscular groove between the brachialis and the brachioradialis. It is followed up into its entry into the groove. The brachialis is then split to reveal the entire length of the shaft if necessary.

Mekhail AO, Checroun AJ, Ebraheim NA, Jackson WT, Yeasting RA.Extensile approach to the anterolateral surface of the humerus and the radial nerve. J Shoulder Elbow Surg. 1999;8(2):112-8.

- **Posterior approach**
  The radial nerve is identified running obliquely from medial to lateral under the heads of the triceps. The ulnar nerve runs along the medial border of the medial head of the triceps. This is not a suitable approach for proximal fractures because of the deltoid insertion.

Zlotolow DA, Catalano LW 3rd, Barron OA, Glickel SZ. Surgical exposures of the humerus. J Am Acad Orthop Surg. 2006;14(13):754-65.

Operative treatment indications

The list is not exhaustive and includes the following: Open fractures, bilateral fractures, vascular injury, immediate radial nerve palsy, floating elbow, failure of closed treatment, pathologic fractures (bone metastases), brachial plexus injury, and obesity.

- **IM Nailing**
  Nailing is an advantageous minimally invasive technique that is suitable for unstable fractures. Control of rotation is achieved with locking bolts. Shoulder pain is common after anterograde nailing. Non-unions are more common with nailing than with plating.
  - Anterograde
    Care must be taken with an adequate point of entry; most nails enter through the cartilaginous surface of the head thus minimizing injury to the rotator cuff.
  - Retrograde
    Entry point must be well above the olecranon fossa to avoid fragilizing the distal humerus. This is not suited for distal fractures.

- **Plating**
  Using a lateral or a posterior approach, plates suitable to the anatomy (broad plates in a large bone, narrow plates in a small bone) should be used. Attempts at minimally invasive approaches with incisions proximally and distally (radial nerve) allowing closed plate insertions are being developed. Locked screws may be useful in osteoporotic bone. Union rates of more than 94% are achieved with plating.

- **External fixation**
  Indicated in polytrauma (Staged in damage control orthopaedics), open fractures or situations were formal osteosynthesis with nailing or plating is not possible. Open approaches are recommended to avoid injuring nerves. If the elbow must be spanned it is preferable to insert the pins in the ulna.

Bhandari M, Devereaux PJ, McKee MD: Compression plating versus intramedullary nailing of humeral shaft fractures—A meta-analysis. Acta Orthop 2006;77:279-284.
Popescu D, Fernandez-Valencia JA, Rios M, Cuñé J, Domingo A, Prat S. Internal fixation of proximal humerus fractures using the T2-proximal humeral nail. Arch Orthop Trauma Surg. 2008
Park JY, Pandher DS, Chun JY,et al. Antegrade humeral nailing through the rotator cuff interval: a new entry portal. J Orthop Trauma. 2008;22(6):419-25.

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