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Intra-Articular Fractures

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In the discussion of intra-articular fractures the knee joint will be used as an example. The knee joint is a major weight-bearing joint which in order to meet its functional demands must retain a range of motion and must retain stability and integrity of mechanical function as well as freedom from pain.
Following intra-articular fractures, stiffness, mechanical joint derangement and post-traumatic arthritis are the main causes of disability.
Post-traumatic osteoarthritis results first, from the damage to the articular cartilage at the time of injury. In addition, incongruity of the joint surfaces results in a decrease in the surface area of contact. As force across the joint remains constant a decrease in the area leads to an increase in stress.
If we accept the thesis of Pauwels that in the normal joint there is a balance between regeneration and destruction, as stress is increased a level is reached where regeneration is no longer possible for maintenance and degeneration begins.
In addition to the incongruency is added the stress of overload from axial mal-alignment.
Supracondylar fractures of the femur and fractures of the tibial plateau continue to be a major source of the disability. A recent review of the literature indicates that in many series the failure rate is still as high as 50 %.

Markus Stewart in 1966 and Charles Neer in 1967 condemned surgery as an acceptable form of treatment of the supracondylar fracture. They pointed out, in their respective reviews, that for those treated surgically, only just over 50 % achieved acceptable results. Both authors strongly advocated skeletal traction as the choice method of treatment. Stewart even went so far as to postulate that metal subcutaneously, in periarticular areas, is poorly tolerated, that it leads to marked inflammatory response and that it predisposed to sepsis.
In 1969 the AO Group published the results of surgical treatment of 112 cases of supracondylar fractures. 75 % of patients achieved good to excellent results. This was a salvage rate better than any previously published reports of either closed or open treatment.
The members of the AO were responsible in the late 1950's for the development of new methods and principles of open reduction and internal fixation, and were responsible for the development of new implants which make the execution of some of the newly enunciated principles possible. The emphasis was now placed on atraumatic anatomic reduction, particularly of the articular components of the fracture and on stable fixation, a principle previously not recognized which made early painless movement possible. The emphysis was on joint and soft tissue rehabilitation with bone union relegated to the last place of importance. Stable fixation was an entirely new concept which was realised through the observance of biomechanical principles and through the use of compression.

In 1973 I reviewed the Toronto experience of the supracondylar fracture of the femur. The Orthopaedic Clinics of the University of Toronto enjoyed the reputation as excellent exponents of the closed method of fracture treatment. The mid 1960's saw the introduction of the AO-method into our departement. Thus my review afforded an excellent comparison of the results achieved with the closed and open methods in the treatment of these fractures. The same criteria were applied to the 39 patients whose fractures were treated 'closed' and to the 32 patients whose fractures were treated 'open'. The difference in the results was astounding. Only 32 % of the patients treated by closed means achieved acceptable results. When all the patients treated surgically were grouped together, 63 % achieved an acceptable result; but this figure was already twice as good as the results achieved by closed means. When the 24 patients, who were treated in accordance with the AO-method and with the AO-implants, were isolated, the acceptable results rose to 75 %, because the other patients treated by other surgical means all ended in failure.

Whereas in a supracondylar fracture the difficulties are rarely related to the joint component of the fracture the tibial plateau presents the problem of articular surface comminution and depression with resultant instability, axial deformity and joint overload. Here once again the disability rate following fracture, in some series reported recently, exceeds 50 %.

We have reviewed our experience with the tibial plateau fracture between the years 1968 and 1977. 142 patients were carefully analysed. Those treated by closed means achieved 63 % acceptable results. 78 % of those treated by open means achieved an acceptable result. Thus they did far better. Once again when those patients, who were treated by the AO-method were isolated and analyzed, the results of excellence rose to 88 %.

A number of very important lessons emerged from these clinical studies.

1. A plaster immobilisation of intra-articular fractures results in irreversible joint stiffness.
2. Open reduction and internal fixation followed by prolonged plaster immobilisation, results in even greater joint stiffness.
3. Traction and early motion preserve joint mobility.
4. If displacement of fragments remains after initial manipulation and traction, further traction will not lead to their reduction.
5. Impacted and depressed articular fragments cannot be reduced by closed manipulation and traction. (There is no evidence that joint depressions fill with fibro-cartilage and the associated instability and consequent axial deformity ever corrects as a result).
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7. Major intra-articular fractures are quite frequently associated with major ligamentous disruptions, which may escape detection in closed treatment.
8. In the presence of major ligamentous injuries, traction is ill-advised because it will lead to permanent joint instability. If a major ligamentous disruption is present, it must be repaired surgically and the fracture reduced and stabilised.
9. An open reduction must not only be directed to the joint, but must also include the metaphyseal component to prevent mal-union.
10. Condylar fragments require buttressing, in addition to screw fixation, to prevent displacement.
11. The implant used must be sufficiently strong to withstand the forces, in order to prevent mal-union.
12. The design of the implant must be such that it observes the biomechanical demands of the fracture and provides sufficiently stable fixation to permit early motion.
13. Unstable internal fixation leads to the worst of both worlds. It destroys all soft tissue hinges, increases necrosis of tissue, delays healing, predisposes to sepsis and leads to prolonged immobilisation with resultant joint stiffness. Such was the fixation practiced during the time-span encompased by the reviews of Neer and Stewart. Their comments therefore are fully justified when applied to unstable internal fixation.
14. The results should not be compromised by surgical errors of implant insertion, by failure to bone graft, or by failure to observe the principles of stable internal fixation.
15. The strength of an internal fixation is only as strong as the bone which has been fixed. This is clearly seen when the end result achieved is reviewed in terms of patients' age and stable or unstable fixation. In many of the elderly patients, failure to achieve internal fixation was not by design. It must be recognised that extremes of comminution and severe osteoporosis must be considered as relative contra-indications to internal fixation.

In order to outline the treatment of an intra-articular fracture, a precise diagnosis is necessary. It must be based first, on a very careful physical examination. Specific findings, such as tenderness over collateral ligaments, is frequently the only clue available to a major ligamentous disruption.

An antero-posterior and lateral radiograph is never enough. It must be supplemented by oblique projections. Frequently two-plane tomography and now, even computer-assisted tomography may be necessary to reveal important details which would otherwise remain unavailable; and yet which must be appreciated to enable the surgeon to formulate a careful plan of the operative procedure. Such a plan includes the surgical approach, a careful drawing of the fracture and all the steps of the internal fixation.

A classification of the fracture is useful if it helps in the treatment. Thus, for example, in supracondylar fractures we recognise broadly three types:

Type I comprises those not involving the joint. These are most often stabilized with the condylar plate;

Type II, those involving the condyles only, such as the fractures of one condyle or of both. Here the fractures are first stabilized with lag screws which provide inter-fragmental compression. A buttress plate is subsequently necessary to prevent axial displacement;

Type III comprises those involving the articular surface as well as the supracondylar region. Here, the comminution is frequently great. And at times even the use of two plates is necessary to provide stability.

The first step is a meticulous reconstruction of the articular surfaces. In a supracondylar fracture this means reducing the condyles and securing stable fixation with cancellous screws. Occasionally the articular surface is badly comminuted. In such cases the fragments are reduced one by one and held in place with Kirschner wires until reduction and fixation is accomplished.

In tibial plateau fractures, which are depressed, the joint reconstruction is more difficult. Here it becomes necessary to approach the joint depression from below and to secure elevation of the fragments en masse by gentle upward hammering of the pieces back into place. The disimpaction invariably results in a metaphyseal defect which must be filled with an autogenous cancellous bone, to prevent redisplacement of the joint fragments. The vertical fracture lines are then compressed with lag screws. This frequently also closes the fissures between those fragments of articular cartilage which are still attached to the underlying metaphyseal bone. This principle of reduction and fixation applies to any depressed articular fracture whether it be the tibial plateau, the dome fragment of an acetabular fracture, the distal tibia in a pilon fracture, or the distal radius in a compression type of Colles fracture.

The second step of the reduction is the stabilisation of the metaphyseal and diaphyseal components of the fracture. In a supracondylar fracture as long as the condylar plate is inserted parallel to the knee joint axis, axial alignment follows automatically. The difficulties arise if there is a segmental comminution with shortening. Often special techniques of reduction, such as the use of a distractor, must be employed to regain length, before any reduction of the comminuted fragments is attempted. If the segmental comminution is extensive, then two plates should be used in the metaphyseal area to regain stability. If there is comminution of the so-called medial buttress, the cortex opposite the plate, or if there is a segmental defect which was bridged with plates, then extensive autogeneous bone grafting of the defects must be carried out, or failure will be certain.

In the metaphyseal fractures where one cortex remains intact such as in the wedge depression type tibial plateau fracture, the reduction of the metaphyseal component is simple and requires only buttress plating to prevent redisplacement due to axial force.

The fracture which involves both cortices, such as a comminuted type V or type VI tibial plateau or the distal tibial pilon fracture, is technically much more challenging. Here the problem is not only of reconstructing the articular surface, but of reconstructing the shattered metaphysis and re-estabilishing structural continuity, regaining length, and restoring axial alignment. Frequently in these complex tibial plateau fractures, two plates must be used in order to restore stability, length and normal width to the proximal tibia. The comminuted segments must also be bone grafted.

The details of postoperative management are as important as the details of the surgical reconstruction. Although we speak of early

function, we do withhold weight-bearing until union occurs. We withhold motion and immobilise the joint in a splint in a specific attitude for the first three to four days to ensure, first of all that wound healing progresses without complication, and secondly to maintain a range of motion.
In fractures above the knee, particularly in supracondylar fractures, the knee should be immobilized in 90 degrees of flexion to ensure flexion. At the end of day 4 or 5, the period of immobilization, the knee regains full extension shortly after active moton is permitted. The important fact is that 90 degrees of flexion is always retained and we have never seen an extensor lag as a result of such immobilization.
Some evidence is becoming available that continuous passive motion which is executed very slowly on special mechanized splints can be started even earlier without leading to any complications. This has clear biological advantages, but it is still in a research phase and further clinical trials have to be carried out before it is recommended.
The simple supra-condylar fracture in a young patient presents little challenge and accurate reduction and stable fixation is simple. Even before suture removal, such patients usually regain an excellent range of motion.
The severely comminuted open fracture is always a challenge. If the principles outlined are adhered to, even the seemingly impossible situation can be brought to a satisfactory conclusion. As we see here, at two years post fracture there is no evidence of osteoathritis and the patient has retained an excellent range of motion.
Errors in surgical technique and judgement can lead to disasters and must be avoided. An open joint fracture should have the joint closed. Here, primary musculo-cutaneous shifts should be considered if the capsule cannot be closed securely. The damaged soft tissue envelope however must be left open or infection and/or soft tissue necrosis is invariably the rule. In a patient in whom the surgical principles enunciated were violated, and an open fracture with severe contusion of the soft tissues envelope was closed per primam, resulted in wound necrosis with secondary sepsis. After debridement, a secondary joint closure with the musculo-cutaneous flap was undertaken to salvage the joint. During the six months of intensive rehabilitation the patient regained only a 30° range of motion.
It is important to realise that early in the course, an X-ray sheds little light on the degree of articular cartilage destruction. Although a patient may have regained 90 degrees of motion, the patient's articular damage is permanent and irreversible, and is the result of mishandling of the tissues which made immobilization of the joint necessary.
In the treatment of these difficult fractures the surgeon must evaluate the personality of the fracture, the environment and his skill. Clearly the difficult intra-articular reconstruction is not a surgical exercise for the novice. It must be recognised however, that modern techniques offer a salvage and that patients should be referred to centres which have the facilities and the skill to deal with these fractures which were once considered an insoluble problem.
The lessons learned from clinical observation have recently received further support from the investigative work of Salter on the effect of continous passive motion on cartilage healing and from the work of Mitchell on the effect of accurate reduction and stable fixation on the healing of articular cartilage defects.
Salter studied the healing of articular cartilage defects in the distal femur of three groups of rabbits. One group had the knee immobilized in plaster. The second group was allowed cage activity. In the third group, the leg was attached to a device which provided continuous passive motion. In this model of a type IV epiphyseal plate injury, we see in group I the effects of one week of immobilization and 25 weeks of cage activity, in group II the effect of 26 weeks of cage activity, and in group III, one week of continuous passive motion instituted immediately following trauma and 25 weeks of cage activity. Salter's experiment illustrates most strikingly the adverse effects of immobilization of articular injuries even for one week, and the complete regeneration following early continuous passive motion.
Mitchell studied the effects of accurate reduction, of compression, and of the stable fixation with full painless early motion, on the healing of intra-articular fractures. He

showed that poor reduction and lack of immobilization, the type of reduction which one can expect in closed treatment of intra-articular fractures, results in articular disorganization with the defect filling with fibrous tissue and poorly organized fibrocartilage. Reduction and co-optation but unstable fixation resulted in healing of the defect with fibrocartilage.

Anatomical reduction and stable fixation with compression resulted in hyaline cartilage regeneration, a biological event hitherto thought impossible, but a manner of healing clearly of great benefit to the patient. We are now in a position, enriched by both principles of treatment of articular injuries.

The principles are:

- Anatomical reduction of the articular surface is essential to ensure congruence, increase the surface area of contact, ensure proper functioning of articulation without internal derangement, and ensure prevention of axial deformity and overload.
- Stable internal fixation with compression must be achieved to ensure freedom from pain which results only when stable fixation has been secured. It makes early movement possible, which is necessary to ensure articular regeneration and to prevent intra-articular adhesions, cartilage atrophy and joint stiffness. Stable fixation is also necessary to ensure healing of the metaphyseal and diaphyseal components without mal-union, or non-union.

These are the only means which allow the surgeon to prevent the ravages of these devastating injuries.

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