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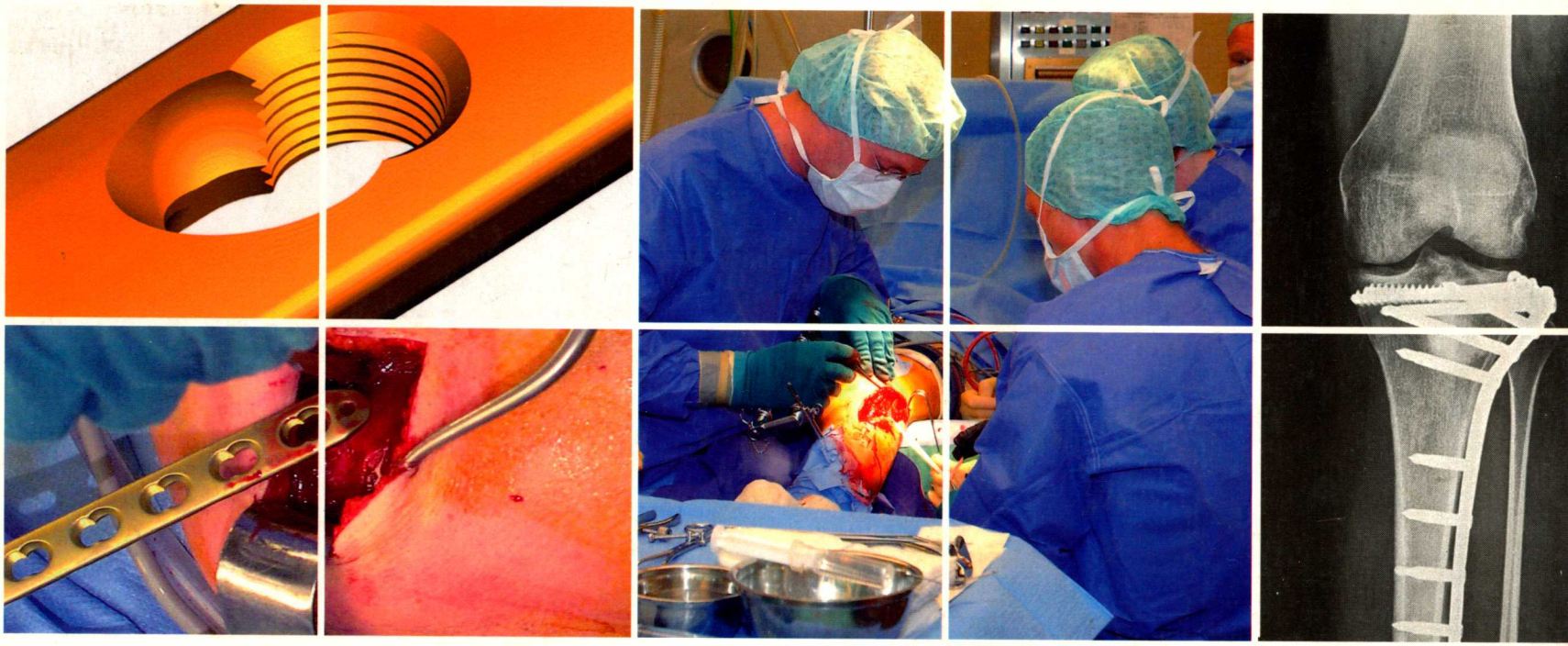
AO Manual of Fracture Management

Internal Fixators

Concepts and Cases using LCP and LISS



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Internal Fixators

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Forewords

Thomas P Rüedi

For almost 40 years AO compression plate fixation providing absolute stability—as introduced by Maurice Müller—was the gold standard in operative fracture treatment. In the 1980s the locking intramedullary nail opened up new perspectives for the stabilization of diaphyseal fractures. As an internal splint this device provides relative stability, which allows rapid fracture healing with abundant callus formation. Perren and Tepic showed in the early nineties that, thanks to locking head screws (LHS) providing angular stability, the longitudinal stabilizer, eg, a plate could be kept at a distance from the bone similar to the external fixator and without interfering with periosteal or cortical vascularity. This innovative, quite different and biologically gentle as well as less invasive fixation principle was called "internal fixation". Clinically, it was applied as the PC-Fix (point contact fixator) and LISS (less invasive stabilization system).

The actual breakthrough for the new internal fixator principle occurred however, when Michael Wagner as clinician, together with the engineer Robert Frigg, designed and developed the so-called "combination hole". The idea and new design of the screw hole—a combination of the dynamic compression unit for standard cortex screws with a threaded hole for the LHS—could be introduced in any of the existing plates and required only a few additional instruments. The new and very versatile locking compression plate system—LCP—with its three different possibilities of applications and functions found immediately wide acceptance and has revolutionized operative fracture fixation in a similar way to the original compression plate and twenty years later the interlocking intramedullary nail.

It seemed therefore logical that Michael Wagner should also pioneer the collection of LCP and LISS cases for a book that addresses not only the basic principles, attributes, and different applications of the new implants but also highlights the pearls and pitfalls of the internal fixators in the clinic. Together with the contributions of other enthusiastic but also critical users the authors share experiences with these devices and gives valuable, practical recommendations to newcomers. The best stabilization system is of little use if the vascularity of the soft as well as hard tissues are not carefully respected. An entire chapter has therefore been dedicated to the most difficult and demanding challenges of any fracture treatment—the fracture reduction.

The editors, Michael Wagner and Robert Frigg, and the coauthors have to be complimented for a most comprehensive and attractive book on the clinical applications of the new internal fixator principles with the LISS and LCP, which are introducing interesting possibilities and opportunities especially in articular fractures as well as providing new hopes for severely osteoporotic patients.

The team at AO Publishing has again displayed its ability to produce, together with Thieme Verlag, a most attractive book that will find numerous readers and thereby help to improve patient care.

Thomas P Rüedi, MD, FACS
Founding Member of the AO Foundation
Davos, April 2006

Stephan M Perren

Fracture treatment has undergone a fascinating evolution. Early in the last century the main goal of treatment was to reach solid union. Then stable fixation and functional postoperative treatment successfully eliminated fracture disease. Now we can take advantage of restoring function while inducing prompt and safe healing and reducing the risk of biological complications.

In the early days the excessive external immobilization of the neighboring articulations too often resulted in damage to the articulations and even worse to the soft tissues and blood supply. In my own "pre AO" experience I observed a high incidence of what was later called fracture disease (Sudeck's or reflex dystrophy). Swelling, pain, patchy bone loss, and stiff articulations were accepted as the natural consequence of fracture. It is interesting to note that each generation was (and is!) blinded by the "state-of-the-art".

In the late fifties the visionary Maurice E Müller and his colleagues effected a worldwide change in the fight against fracture disease. They studied and advocated precise reduction and compression fixation so that fracture healing could take place in a mechanically neutral environment. Dystrophy became a very rare incident and fracture healing showed a fascinating histology: direct healing. The price paid for focusing on mechanical advantages was that this approach did not induce early healing and so implants could not be removed earlier than one to two years postoperatively. This was not a major problem in view of the fact that the implants were mechanically protecting the fracture. Still, the observation of late union was a strong indicator that there was room for improvement. Considerable damage to the soft tissues and blood supply to bone in the hands of the less experienced resulted in complications due to a disregard for biology.

The promoters of stable internal fixation had to face harsh criticism, mainly focused on the complications of such treatment like infections and refractures. A close collaboration including clinical input, documentation, biomechanical research, and basic development allowed the AO to overcome these difficulties by defining the principles of treatment and offering thorough teaching.

From the outset less stable fixation like the more flexible version of the intramedullary nail and also external fixators, both resulting in indirect healing, were integral parts of the AO technology. But it took a long time to amalgamate observations of biological reactions to the more flexible techniques and observations relating to compression plating. As always, some ideas were not new; we mention the basic contributions to compression technology by Lambotte and Danis and those of Küntscher to nailing. Still, to bring a new method to bear on a large scale not only requires innovative and sound ideas and ingenious individual surgical skill, but also an integrated approach to improvement and teaching to allow others to achieve similar results.

In the late eighties while studying the potential of internal fixators the team of the AO Research Institute came across a more flexible plate fixation that took advantage of locked screws. The point contact fixator (PC-Fix), which is the proof of concept of the internal fixator, was born. Animal studies showed an astonishing early solid bridging of the fractures (10 weeks) and good local resistance to infection. Furthermore, the opportunity to take advantage of monocortical threaded bolts was demonstrated. Clinical studies with exceptionally high follow-up showed low complication rates in respect to infection (Norbert P Haas, Alberto Fernandez). History repeats itself as a rule: again there were pioneers:

Boitzy, Weber, and Heitemeyer (bridge plating) and we also pay tribute to Granowski (Zespol fixator). It took 40 years from the first bridge plates and nearly twenty years from successful use of the PC-Fix for the advantages of the internal fixator to be generally accepted. The difference between "me too" and leadership is rooted in basic insight and early commitment.

A new era started with great respect to biology: the era of the internal fixator. Insistence on precise reduction was replaced by restricting the aim of surgery to adequate alignment to restore the original relative positions of the two joint bearing surfaces of the long bone. Approximate alignment without touching the intermediate fragments became acceptable. The main ingredients for successful internal fixator technology still are sufficient stability for early functional treatment and, now, sufficient instability for the induction of prompt healing. The strain theory allowed definition of the degree of instability which is tolerated and the degree which induces healing.

When the bone is dead and/or infected as a result of the accident (and hopefully not of the surgery) there is a clear indication for good reduction and absolute stability and similarly precise reduction and absolute stability is a requirement for intraarticular fractures!

Living bone is able to react once it is given the chance to do so. Creating the proper biological and mechanical environment is the prerequisite. The future will show whether additional stimulation offers an advantage for fresh fractures. One may question whether stimulation will be tolerated without causing damage in desperate clinical cases such as chronic and infected nonunions. Let's not forget that it took supernatural power to revive Lazarus, in other words, I think that stimulating nearly dead cells is equally challenging.

Without perfect closure of the fracture gap it is now possible to follow the repair process within the gap radiologically. We can now pinpoint those cases that require the long-term presence of the implant to avoid refracture. Some of the ob-servations of delayed healing are not an indication of less satisfactory healing, but they are a consequence of improved visualization.

While the LISS is a further refinement of the PC-Fix, the LCP combines a stripped version of both the LC-DCP and PC-Fix with a threaded conical locking system to reduce jamming at removal. The LCP offers a convenient way of making the transition from conventional compression techniques to the internal fixator. As the two principles of plate screws, namely, screws that press the plate to the bone and those that keeping the plate elevated are incompatible, it is advisable to exercise discipline and not to mix these principles in the same bone fragment. This is also a challenge for teaching.

In view of the basic changes brought about by the internal fixator, it is of great merit that the initial chapter of this book discusses the basics of the principles. Michael Wagner has undertaken with success the task of explaining the practical aspects of the basic concepts.

The book may be understood as a technical manual but, far more, it is offering a basic understanding. This is an important aspect in view of the fact that the implant reflects only the mechanical aspect of the realization of the internal fixator philosophy; balancing biology against pure mechanics involves the implants and the surgeons. The statement of Girdlestone "rather gardening than replacement" is up-to-date.

The second chapter of the book deals with basic clinical aspects; namely reduction of the fracture as a prerequisite to successful internal fixation. When reading this chapter one is tempted to add to Girdlestone with "rather elegant surgical technique than brute force".

The chapters on LISS and LCP are actually technical manuals, "how to do it". With great care the sequential steps of the internal fixation, the special characteristics of the implants and, for instance, the importance of large span bridging and attention to screw leverage using long plates are explained.

The last chapter addresses the possible errors, "what not to do" and special procedures if difficulties arise.

I hope the reader enjoys this comprehensive book—this "first shot" as much as I have done.

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Introduction

Michael Wagner

From the very outset, the goal of the Arbeitsgemeinschaft für Osteosynthese (AO) has been to improve the treatment of fractures and their sequelae. The AO proposed this by restoring integrity to the broken bone and providing the patient with early and pain-free restoration of function. The emphasis has never been solely on bone union, but has always included restoration of function—as implied in the AO's motto "Life is movement, and movement is life."

"Fracture disease" was an obstacle to healing and mobility, and its symptoms often emerged after prolonged external splinting, immobilization in traction—consisting of chronic edema, soft-tissue atrophy, severe osteoporosis, thinning of the articular cartilage, severe joint stiffness, and sometimes chronic regional pain syndromes. Fracture disease prevented patients from starting active exercise at an early stage and delayed the return of function after bone healing. The innovative techniques introduced by the AO to combat this condition had to meet high demands. Fracture reduction had to be anatomical, and the fixation had to be stable enough to eliminate pain and allow functional rehabilitation of the limb without the risks of secondary displacement, delayed union, nonunion, or deformity. The stability produced by the compression method of fracture osteosynthesis met these requirements; it was possible to start rehabilitation immediately after the operation, and most plaster immobilization techniques became outdated.

The issues that have played an important role in stimulating progress have been,

1) differentiating between the biological requirements of articular and long bone fractures;
2) greater recognition of the importance of the type and timing of treatment;
3) specific assessment of injury to the soft-tissue envelope;
4) and attention to the patient's individual functional and physiological requirements.

It is now accepted that absolute stability is mandatory only for joint fractures and some related fractures—and then only when it can be achieved without damage to the blood supply and soft tissues. Fixation of the diaphysis should always take account of length, alignment, and rotation of the limb, and the methods of choice are splinting with an intramedullary nail or an internal fixator to promote union through callus formation.

If plate osteosynthesis is required, techniques of minimal access and fixation are able to minimize insult to the blood supply to the bone fragments and adjacent soft tissue. The fixation of articular fractures requires anatomical reduction and absolute stability to enhance the healing of articular cartilage and make early motion possible so that good ultimate function will ensue. The current principle of preserving the blood supply needs to be applied at every stage of fracture management—from initial planning to consolidation. The choice of strategy and implant depends on the biological and functional demands of the fracture and should be compatible with them.

Anatomy, stability, biology, and mobilization are still the four fundamental AO principles today. However, the implications of these principles have changed in response to the findings constantly emerging from scientific investigations and clinical observations. Progressive changes in approaches and methods have been based on continuing laboratory and clinical research, with new discoveries leading to the development of many new implants and instruments. The strategy of fracture fixation with different principles, methods and techniques of internal and external fixation are dynamic, and further advances will continue to be made.

The AO principles

AO principles THEN

- Fracture reduction and fixation to restore anatomical relationships.
- Stability through fixation with compression or splinting, as required by the fracture pattern and the injury.
- Preservation of the blood supply to the soft tissues and bone through careful handling and gentle reduction techniques.
- Early and safe mobilization of the area being treated and of the patient as a whole.

These concise principles still embody the AO philosophy of patient care. In today's approach, the emphasis is still very much on the fact that maintaining the blood supply to the soft tissues and bone is the most important aspect of fracture care—so that the principles could also be restated as follows:

AO principles NOW

- Atraumatic reduction and fixation techniques are mandatory. Reduction of long bones need not be anatomical, but instead should demonstrate axial alignment with respect to length and torsion in the diaphysis and metaphysis. Anatomical reduction is mandatory for intraarticular fractures to restore joint congruency.
- Appropriate stability of the construct has to be established. Joint surfaces require anatomical reduction with absolute stability; the majority of diaphyseal fractures can be treated with methods that provide relative stability (eg, intramedullary or extramedullary splinting).
- Atraumatic soft-tissue technique should be used with appropriate surgical approaches.
- Early active mobilization of the patient is expected as the fixation construct is stable enough to allow postoperative functional care.

A comprehensive classification of long bones has helped make treatment outcomes predictable. Neither the principles nor the approaches have changed, but definitions have become more refined in relation to the different methods and techniques of fracture fixation.

The revolution is continuing today—the principles remain the same, but the methods and techniques are continually developing and implants are being modified and newly invented. Today, the AO develops sophisticated scientific and technological instrument sets that lend themselves to applications that go beyond fracture treatment. This includes the treatment of complications related to fracture care, and more recently the treatment of degenerative diseases, deformations, and defects, the problems that are becoming increasingly prevalent in the aging population (such as osteoporosis).

There has been a progressive evolution in nailing and plating:

Nailing

- From conventional to locked intramedullary nailing, and
- from reamed to unreamed nailing.

Plating

- From very stable (absolutely stable) fixation to flexible (relatively stable) fixation, and
- from compression plate fixation to locked internal fixation.

The AO principles

AO principles THEN	Influences through clinical experiences and experimental investigations	AO principles NOW
1. Anatomical, precise reduction	Applied science concerning: – bone healings, – blood supply through soft tissue and bone, – biological shortcomings of ORIF in multifragmentary shaft fractures lead to a new way of thinking. As a consequence, indirect reduction techniques were developed	Fracture reduction and fixation to restore anatomical relationships. Reductions need not be anatomical but only axially aligned in the diaphysis and the metaphysis. Anatomical reduction is required for intraarticular reductions. The principles of articular fracture care: - atraumatic anatomical reduction of the articular surfaces, - stable fixation of the articular fragments, and - metaphyseal reconstruction with bone grafting and buttressing apply today as they did at the beginning.
2. Rigid fixation, absolute stability	The most notable change in the treatment of diaphyseal fractures has been the shift from the mechanical to the biological aspects of internal fixation. The preservation of the viability and integrity of the soft-tissue envelope of the metaphysis has been recognized as the key to success. Today the dominant theme in the fixation of fractures of the diaphysis is the biology of bone and the preservation of the blood supply to bony fragments, and no longer the quest for absolute stability. Major changes have occurred in the timing of the different steps of metaphyseal reconstruction, as well as in the fixation methods and techniques. The comprehensive classification of long bones has helped predict treatment and outcome.	Stabilization with different grades of stability, from high (absolute stability) to low (relative stability). Appropriate construct stability. Stability by compression or splinting, as the fracture pattern and the injury require. The joint surfaces require anatomical reduction with absolute stability. The majority of diaphyseal fractures are treated with relative stability methods (eg, intramedullary or extramedullary splinting).
3. Preserving blood supply	The present concept still emphasizes that the blood supply through the soft tissues and bone is the most important aspect in fracture care: – atraumatic soft tissue technique through the appropriate surgical approaches, – atraumatic reduction and fixation techniques are mandatory, – implants with new bone- implant interface.	Preservation of the blood supply to soft tissues and bone by careful handling and gentle reduction techniques and a newly designed bone-implant interface.
4. Early protective motion for rehabilitation because pain was abolished and union assured		Early and safe mobilization of the part and the patient. Early active motion can also be carried out because splint fixation is stable enough to allow postoperative functional care.

Progressive evolution is the result of a long-term collaboration between the AO Research Institute (ARI), the AO Development Institute (ADI), and the Synthes manufacturers. This manual provides details of the principles and techniques involved in internal fixation using the recently developed less invasive stabilization system (LISS) and the locking compression plate (LCP). Future developments will need to address the shortcomings of the current techniques and equipment and to assess the side effects of new techniques, as well as ways of promoting healing in cases of chronically infected, atrophic nonunion. The techniques of internal fixation will also need to be further simplified to improve both safety and ease of handling, benefiting the treating surgeon and the patient.

Suggestions for further reading

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Acknowledgments

This book represents a logical step in publications from the AO. It is some years since the development of internal fixators and initial clinical experience has now been gained so that the time has come to meet the need for a book on this subject. As we become more sensitive to the specific requirements of adult learning, an important insight has been to recognize the educational value of a case-based learning program. In the light of this, we have devised an approach to describing the management of fractures that is based on a series of clinical cases submitted by different authors worldwide.

The editors would like to acknowledge and express their thanks to all the colleagues who contributed their texts and clinical cases. Their names are given in the following list:

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