A Precursor of the Locking Plate System: Noncontact Plate Osteosynthesis by Zespol, Construction, Technique, and Tactic

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Summary: A review of the literature in 2002, analyzing 13 articles with 895 tibial shaft fractures treated by cast immobilization, fixation with plate and screws, and reamed or unreamed intramedullary nailing, concludes that the combined incidence of delayed union and nonunion was lower with operative, surgical treatment especially with plate osteosynthesis, than with closed treatment. This incidence was respectively 2.6% with plate fixation, 8.0% with reamed nailing, and 16.7% with unreamed nailing compared with 17.2% with closed treatment. On the contrary, the incidence of superficial infection was most common with plate infection—9.0%, compared with 2.9% for reamed nailing, 0.5% for unreamed nailing, and 0% for closed treatment. The incidence of osteomyelitis was similar for all groups. Rates of reoperations ranged from 4.7% to 23.1%. The dynamic compression plate (DCP) has been used for many years as a method of internal fixation of fractures. A problem that has created concern after plate fixation is the appearance of porous bone under the plate during the course of healing. This has been attributed to disruption of the blood supply near and beneath the plate. In an attempt to address this problem, plate designs that make only limited contact (LC-DCP), point contact (PC-Fix internal fixator), or noncontact plates (NCP) with the underlying bone surface have been designed. Key Words: Locking plates—Osteosynthesis.
first reduced by indirect means. The zone of fragmenta-
tion is then bridged with a plate, which is fixed only to
the main proximal and distal fragments and is used to
maintain length, rotation, and axial alignment. In this
case it functions as an internal splint and the fixation is
only relatively stable, so the bone union in multifrag-
mentary diaphyseal fractures is therefore achieved by
secondary callus formation. If one chooses to plate a
simple fracture, be it spiral, oblique, or transverse, then
absolute stability must be achieved by means of inter-
fragmental compression with lag screws or with com-
pression plates, or failure is likely to follow because of
excessive strain at the fracture site.19,20

Each year more articles appear, which report the best
clinical results of fracture healing of any location with
bridging internal or external fixation.4,12–18,22 Karnezis,
using a composite femoral model, investigated the rigid-
ity characteristics of 3 fixation methods (short DCP,
“bridging” and “wave” plates). His in vitro study failed
to show any significant mechanical advantages of the
“wave” plate technique over the “bridging” plating
method. He concludes that it seems that the “bridging”
plate fixation may be the mechanically optimal “biologic”
plating method for the femoral diaphysis fractures.8

Fracture treatment by internal fixation has undergone
important changes in recent years. The original emphasis
on the mechanical aspects has shifted toward biologic
considerations with preservation of the viability and
integrity of the soft-tissue envelope.2,3,8–11,19,20 Indirect
reduction techniques and minimal but optimal use of
implant material is the new concept to achieve undis-
turbed fracture repair in diaphyseal and metaphyseal
fractures.

Contemporarily, the rigid fixation of the bony frag-
ments strongly emphasized in the past for comminuted
diaphyseal fractures is no longer a goal. Rapid integra-
tion of unreduced but vital fragments into the fracture
callus, which increases the mechanical strength of the
fracture and reduces the risk of overload and fatigue
failure of the implant, seems to be of the greatest impor-
tance. Thus, the “biologic” techniques maintain align-
ment by bridging the fracture without compression rather
than relying on absolute rigid fixation through compres-
sion. They are frequently referred to as “internal splint-
age” fracture fixation methods.

ZESPOL METHOD

A technique of fracture fixation, which implements guid-
ing principles of both ideas—biologic and internal splint-
age—is the original Polish method of osteosynthesis called
Zespol. The invention of this technique is the result of a
5-year biomechanical investigation and an even longer
period of time of clinical experience. The platform screws
and auto-compression plates were patented in November
1979 by Ramotowski and Granowski,15–17 before Wolf-
gang, Bryant, and O’Neill22 and later improved by Marcin-
iak and Ramatowski.12,18

The first osteosynthesis with Zespol technique was
performed at the Central Clinical Hospital in Warsaw on
June 1, 1982. It was paraosseous compression osteosyn-
thesis of the femur shaft. In the following year, the first
subcutaneous osteosynthesis of humerus was performed.
In February 1984, the first external osteosynthesis of
tibia was performed in Lublin. Since 1986, the range of
clinical application has been widening constantly.

Further biomechanical studies, clinical experience, de-
velopment of the implants, manufacture of the special tools,
and instructive courses for surgeons contribute to the grow-
ing popularity of the technique in Poland.

Zespol technique produces much better results than
any other technique used before. Elasticity of the
fixator and negligible damage to the tissues during
operations with Zespol technique result in clinical efficacy.
Additionally, Zespol is the least expensive of known fix-
ators (Fig. 1).

FIG. 1. Brochure of original Zespol from Poland. (1999, Prof. P. J.
Bilinski original collection)
Multidirectional investigations of traditional plate stable osteosynthesis performed in Poland affirmed that stability of the junction is inseparably connected with pressure of plate onto bone resulting from out power of draft of osseous screws. Cortical screws tightened by 15 Nm have power of draft swaggered 750 N. It results from this: the plate attached by 6 screws will cling onto surface of bone with power of $6 \times 700 = 4200$ N. This force distributes onto 15% of the surface of adhesion of whole surface of plate that is on about 1.5 cm$^2$.21

**MAIN FEATURES AND MAIN ADVANTAGES OF ZESPOL FIXATOR**

**Principles of Operation of Zespol Fixator**

1. Special construction of the platform screws. The plate is fixed to the platform screws and does not exert any pressure on the bone.
2. Firm fixation of the screws to the plate is important for fixator elasticity.
3. Small fixator is able to resist even considerable force moments due to short distance between the plate and the bone.

The new construction is distinguished by the following qualities:

1. The plate is fixed to the screw heads but not directly to a bone; therefore, it does not cause any damage of the bone surface.
2. Firm screws–plate joining results in elastic work of fixator.
3. A very small and smooth fixator does not hurt soft tissues, and it is comfortable for patients.
4. Simple construction and easy to use.
5. It is possible to correct bone fragment alignment changes in axial compression and dynamization of osteosynthesis without disassembling of fixator and the utilization of electromechanical effects in the bone for its adhesion activation.

**Main Application**

The Zespol and its new version POLFIX system shall be used in osteosynthesis for fractures, nonunions, after osteotomies, arthrodeses, and bone resections. For fibia, ulna, and distal half or radius, the fixator is used externally, but for femur, humerus, and proximal radius it is usually used internally. The system enables a surgeon to perform bridging, contact, protecting, and compression osteosynthesis. The Zespol system consists of the plate platform screws and nuts, forming together a clamp fixator (Fig. 2).

The plate has symmetrically spaced cone-shaped (90°) autocompression holes. The passages within holes are lengthened (1.5 mm) to allow screws axial displacement. A furrow for the platforms of screws is at the back of the plate. Seven types of plates are manufactured.

The platform screw consists of the tapped pin, square platform, and bone screw, all in 1 piece. In all, 5 types of the screws are manufactured.

Nuts are also cone-shaped (90°) with square heads from wrench.

Principles of Zespol fixator are the following:

1. Special construction of the platform screws is the essence of the technique. The plate is fixed to the
platform screws and does not exert any pressure on the bone.

2. Firm fixation of the screws to the plate is important for fixator elasticity.

3. Small fixator is able to resist even considerable force momentum due to the short distance between the plate and the bone.

Zespol system makes nonaxial compression (neutralization, contact, bridging) and compression osteosynthesis possible. In all types of the osteosynthesis, Zespol fixator may be used either internally or externally. This noncontact plate system Zespol (NCP-Zespol) stands completely off the bone surface and can be placed at different distances from the bone surface, depending on the nature and location of the fracture. It can be placed paraosseously (<5 mm from bone surface), subcutaneously (>55 mm but underneath the skin), or as an external plate (outside the skin). Zespol can be used for contact and bridging osteosynthesis.

The principle of a nonaxial compression osteosynthesis is drilling the canals into the bone fragments, precisely at the axis of plate holes. It is possible with the use of a special drill-guide tool.

Nuts are screwed after setting platform screws in line and putting on the plate. Then, the plate and screws become a firm construction, which does not exert any compression on the bone fragments. The fixator prevents only excessive movements of the fractured bone.

Neutralization osteosynthesis is frequently used in oblique fractures and nonunions. A lag screw and the fixator are applied.

However, Zespol neutralization osteosynthesis produces stable and elastic construction, resulting in little

FIG. 4. Bone model with positioning of the Zespol plate component and interfragmentary compression clamp.

FIG. 5. (a) Comminuted tibia fracture. (b) Bridging osteosynthesis.
external callus and bone fragments of a proper density (Fig. 3).

Contact osteosynthesis is also used in oblique fractures and nonunions. It differs from neutralization osteosynthesis because an interfragmentary compression with lag screw, clamps, or cerclage is applied only for a short period of time and removed when the fixator is completed (Fig. 4).

Closed contact osteosynthesis is a special kind of Zespol technique.

In case of a comminuted fracture or bone defects, bridging osteosynthesis is used (Fig. 5).

A plate of an adequate length is required, depending on the size of the fracture. Therefore, we have introduced a technique of plates joining to achieve suitable construction. Because the range of the bone fragments’ movement is relatively the widest at the side opposite to the plate, these elastic motions produce the right stimuli for external callus formation—called by the inventors of Zespol (Ramotowski, Granowski, Marcinia and Bielawski) “banana callus” (Fig. 6).

Performing mechanical studies on Zespol bridging osteosynthesis, these authors have applied torsional, bending, and axial loadings. The loadings did not exceed those in nonplaster treatment of femur fractures. They have concluded that the bone fragments’ movements have ranged up to 2 mm at the single plate and up to approximately 4 mm at the joined plates. Zespol tech-

FIG. 6. Example of callus formation opposite to Zespol plate position (“banana callus”). (Prof. P. J. Bilinski collection)

FIG. 7. Zespol instruments: drill-guide tool with tubular drill and cube drill.

FIG. 8. Platform screws and nuts of the Zespol locking fixation set.
nique assures a good stability in bridging osteosynthesis, similarly to other external fixators (AO, Hoffman).

Compression osteosynthesis may be used in transverse or slightly oblique fracture and nonunions. Osteotomies and arthrodeses also constitute special indications to the compression osteosynthesis. Axial compression of the bone fragments with the aid of Zespol technique depends on the elastic bending of the platform screws. The value of the axial compression force is a function of platform screws’ shift along the plate holes after tightening the nuts. Total compression depends on the number of platform screws, the way of their axial shift, and the distance between the plate and the bone surface. Distribution of the compression force on the bone cross-section depends, however, on bending moments of the plates. Authors have elaborated on the method of controlling axial shift of the platform screws and plate bending within its range of elasticity.

Models of Zespol compression osteosynthesis, made out of fresh human tibial specimens, were used in the assessment of the bone fragments’ mobility, and it was found that Zespol osteosynthesis provides complete stability in the nonplaster treatment of even femur and tibia fractures.\textsuperscript{6,15}

**Zespol Osteosynthesis. Tactics and Techniques**

Zespol osteosynthesis requires special operating tools. The basic instrument for this purpose is a drill-guide tool. Actually, 3 tools are used: the universal drill-guide with adjusting screw, tubular drill-guide, and a cube drill-guide (Fig. 7).

The latter is the most useful tool in the set. It consists of special cubes with drill sockets, which are attached to the same type plate being used for the osteosynthesis. A set includes 3 cubes: those marked “0” for noncompression osteosynthesis, 1 cube marked “1” for compression osteosynthesis with the plate placed near the bone (2–10 mm), and 1 cube marked “2” for compression osteosynthesis with the plate placed at the distance more than 10 mm from the bone surface. There is a special wrench for

![FIG. 9. Lag screw positiones for the original Zespol locking system. (Prof. P. J. Bilinski collection)](image1)

![FIG. 10. (a) Paraosseous positioning of the Zespol plate. (b) Bone model.](image2)
the platform screws and nuts (Fig. 8). Its head has a square hollow for the platform screws and Zespol nuts. There are also 3 taps, special elastic clamps, and an instrument for inserting lag screws (Fig. 9) in the set.

Zespol fixator may be used in bridging, contact, neutralization, and compression osteosyntheses. In all these types, Zespol fixators may be applied either internally or externally. Paraosseous, subcutaneous, and external osteosyntheses are distinguished (Fig. 10).

The prepared drill-guide tool is placed against reduced bone fragments. The first hole in the bone is drilled through the outer drill socket; then the drill-guide is fixed to the fixing bolt. Another outer hole is drilled next and the fixing bolt is inserted as before. The bolts should remain in place while other holes are being drilled (Fig. 11).

The holes should be tapped after removal of the drill-guide (Fig. 12).

The platform screws are inserted into the trapped holes (Fig. 13).

In the case of noncompression osteosynthesis, all platforms of the screws should be set at the same level. In case of compression osteosynthesis, the platforms of inner screws should be closer to the bone surface than the outer ones (Fig. 14).

The plate is placed onto the platform screw and screwed. It is important to screw the inner nuts first because it results in bending of the plate (Fig. 15). Operation ends with drainage of the wound and suturing soft tissues.

In external osteosynthesis, the holes are drilled in the bone without incision, directly through the skin. In such cases, the bone fragments are reduced through a short skin incision located beyond the screws. In open fractures, reposition of the bone fragments may be achieved through the wound. In some cases, reposition of the bone fragments may be achieved without approaching the bone. Then, Zespol fixator is applied instead of the plaster cast.
In case of the extended comminuted fractures, linked Zespol plate should be applied (Fig. 16).

Zespol is a technique stable enough that it does not require other immobilization. Plaster casts should be applied occasionally because of the weakened bone fragments or for the patient’s mental comfort.

Isometric and isotonic exercises are to be introduced a few days after surgery. Healing of the bone after Zespol osteosynthesis may be either primary or secondary. The secondary healing is faster than that in the conservative treatment. The primary osseous tissue is formed along the bone axis. It is not woven bone, which should be reconstructed first and remodeled later. Zespol osteosynthesis produces the primary osseous tissue followed by the mature bone tissue.

**Osteosynthesis of Femur**

The main type of femur osteosynthesis is paraosseous. Subcutaneous osteosynthesis is used rarely. It may be valuable in the treatment of infected pseudarthroses and muscle atrophy due to the long-term plaster immobilization. Thick cortical screws are used usually for the femur osteosynthesis. It is possible to stabilize diaphysis and metaphyses of the femur (Fig. 17).

Femur diaphysis is approached laterally. Vastus lateralis muscle is separated from the lateral fasia and displaced anteriorly. Periosteum remains unseparated. Only thin elevators are placed above the periosteum. As a rule, the plate should be placed laterally. It may be placed anteriorly only occasionally. In metaphyseal fractures, Zespol fixator replaces well-known thick condylus plates.

Pseudarthroses of the femur are the most frequent indications to Zespol paraosseous osteosynthesis. This technique is valuable because of its low aggressiveness to the living tissue and easy choice of osteosynthesis type and technique. Pseudarthroses are approached by Judet’s method, depending on the dissection of a thin layer of the bone together with periosteum. Then, pseudarthroses should be resected and the bone ends formed so that compression osteosynthesis becomes possible.

In case of hypervascular pseudarthroses, only Judet’s procedure and osteosynthesis are sufficient for the bone healing. In avascular pseudarthroses, autogenous sponge grafts are needed.

As it was already mentioned, infected pseudarthroses require rather subcutaneous osteosynthesis. In such cases, the plate is placed far enough from the bone, enabling the application of gentamycin chains, suction drainage, and bone grafts, if necessary.

**Bone Coalescence in Zespol Osteosynthesis**

An introduction of the external Zespol osteosynthesis into long bones’ fracture treatment has widened the range of indications to this technique. All types of Zespol osteosynthesis (ie, bridging, contact, neutralization, and compression) may be used externally in the fractures of the tibia. However, closed external Zespol osteosynthesis is a special kind. In case of a proper conservative reduction of the fractured tibia, there is a possibility to use the closed external fixation with Zespol fixator (Fig. 18).

An extra-focal Zespol fixation is advantageous in the treatment of open fractures, infected nonunions, and pseudarthroses (Fig. 19). It results from our clinical experience with severe open fractures that 17% of cases were complicated by superficial infections when the A.O.-internal plate fixator was used. Since 1984, when we introduced Zespol internal fixation, traumatic infections decreased to 9.3% of cases. The average time of the complete consolidation of the open fractures has also been shorter by 7 weeks. The infected fractures and pseudarthroses of the tibia may be fixed externally with little lesion to the soft tissues. We have noted no complications after the insertion of the platform screws into the skin cicatrices.

An existence of infection and disorders in the local blood should always be considered apart from stable
osteosynthesis of open fractures and nonunions of tibia. Noninfected nonunions and pseudarthroses may be treated in a single phase. However, infected nonunions and pseudarthroses are usually treated bi- or more phasically.

The main objective of therapy, ie, bone fragments’ coalescence and control of infection, sometimes requires multiphasic procedure. Therefore, reosteosynthesis resulting from the weakening of the bone fragments should not be considered treatment failure. Osteosynthesis of the atrophied bone requires additionally plaster casting, especially between the third and the eighth week after the surgery.

Fractured humerus is infrequently treated surgically. Indications to the osteosynthesis are the following: open fractures, muscular interpositions, and injuries to the blood vessels or nerves.

Tactics of the osteosynthesis depend on the localization of the fracture; 1/3 proximal segment of the humerus requires paraosseous osteosynthesis. In case of the fracture of mid-segment of humerus diaphysis, paraosseous or subcutaneous osteosynthesis might be applied as well.

The humerus is approached by the lateral incision between the biceps, brachioradial, brachial, and triceps muscles. In case of subcutaneous osteosynthesis, the radial nerve should be placed under the plate. Because of this, removal of the fixator is quite simple. In case of the transverse slot fracture, compression osteosynthesis is usually required.

Pseudarthroses should be approached with Judet’s procedure. Bone grafting is performed as a rule. Defect and atrophic pseudarthroses should be treated with corticospongious bone grafts. The grafts may be obtained from the autogenous tibia. It should be fixed at the opposite side or perpendicularly to the plate.

Postoperative mobilization should be carried out very carefully. The redressions are contraindicated. Move-
ments of the joint should be enlarged before osteosynthesis and after bone healing.

**Osteosynthesis of the Forearm**

Fractures or nonunions of the single or both bones in the forearm may be stabilized with Zespol fixators. The ulna should be stabilized externally, whereas the radius may be stabilized either externally or internally; subcutaneous osteosynthesis is prevailing. In case of the external osteosynthesis, a 6-hole plate is usually fixed to 4 platform screws. The internal osteosynthesis of radius may be performed with a 4-hole plate.

Zespol external osteosynthesis is mainly indicated in nonunions of the ulna and radius. Autogenous spongious grafts may be used to stimulate bone coalescence. In the case of bone defects, cortical autogenous grafts may be applied.

Pseudarthrosis of the ulna complicated by the luxation of radius should be treated with resection of the radius head. This enables the equation of both bones of the forearm.

Osteosynthesis of the thin bone fragments is difficult and requires a scrupulous operative technique.

An external immobilization after compression osteosynthesis is superfluous, whereas rehabilitation should be cautious. Noncompression osteosynthesis, especially bridging, requires immobilization in plaster casts for 6 to 8 weeks.
REFERENCES


