

# Cerclage, Evolution and Potential of a Cinderella Technology. An Overview with Reference to Periprosthetic Fractures

**Cerkláž, vývoj a možnosti opomíjené techniky. Přehled s přihlédnutím k použití u periprotetických zlomenin**

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## SUMMARY

Periprosthetic fractures are increasingly frequent. The fracture may be located over the shaft of the prosthesis, at its tip or below (21). The treatment of explosion fractures is difficult because the shaft blocks the application of implants, like screws, which need to penetrate the medullary cavity.

The cerclage, as a simple periosteal loop, made of wire or more recently cable, does not only avoid the medullary cavity. Its centripetal mode of action is well suited for reducing and maintaining radially displaced fractures. Furthermore, the cerclage lends itself well for minimally invasive internal fixation.

New insight challenges the disrepute of which the cerclage technology suffered for decades. The outcome of cerclage fixation benefits from an improved understanding of its technology, mechano-biology and periosteal blood supply. Preconceived and generally accepted opinions like “strangulation of blood supply” need to be re-examined.

Recent mechanical evaluations (22) demonstrate that the wire application may be improved but cable is superior in handling, maintenance of tension and strength.

Beside the classical concepts of absolute and relative stability a defined stability condition needs consideration. It is typical for cerclage. Called “loose-lock stability” it specifies the situation where a loosened implant allows first unimpeded displacement changing abruptly into a locked fixation preventing further dislocation.

## INTRODUCTION

The goal of surgical fracture treatment is to restore early and complete function of bone, limb and patient. Cerclage, could be an attractive because simple technique. Still cerclage, as exclusive procedure is not strong enough and therefore does not allow functional aftercare. When used protected by external plaster splinting extensive immobilization prevents early function. As this procedure combines the disadvantages of both, the surgical and the conservative methods, it “hibernated” for decades (14). Its disappointing early results are listed in Table 1.

Cerclage has seen a revival with the increasing demands and incidence of periprosthetic fractures. While locked compression plates offer help in metaphyseal fractures (8), in periprosthetic fractures the intramedullary cavity is not available for penetrating implants (Fig. 1) but the stem of the prosthesis may function as an internal splint. Therefore, periosteal fixation by cerclage appears to be a valid alternative. The use of cerclage, on the one hand, as a temporarily applied tool has seen wide application in the reduction of multifragmented periprosthetic fractures. On the other hand, cerclage as a permanent fixation device may contribute to the long term stability of periprosthetic fracture fixati-

Tab. 1. The results of early treatment of long bone fractures are listed according to Leemann (1954) (11). A temporary working incapacity between one third and one half year for both types of treatment appears today as unacceptable. The cerclage cases reported here were done with wire cerclages.

R. Leemann (1954) (11)			
Author	Procedure	Cases	Temporary incapacity (w)
Berchtold	Cerclage	88	18
Kessler	Cerclage	90	18.5
Fehr	Cerclage	54	19.5
Berchtold	Cerclage	143	19
Berchtold	Conservative	100	25
Böhler	Conservative	554	22
Spohn	Cerclage	116	26
Spohn	Extension	145	29
Leemann	Folded wires	52	20



Fig 1. Treatment of a periprosthetic fracture. The proximal main fragment is connected to the distal main fragment with a locked splinting plate. Within a part of the proximal fragment the medullary canal with the stem of the prosthesis obstructs the use of penetrating implants and/or reduces the anchorage of periosteal splints. Plate screws when locked can either be used as unicortical screws or if they are of the variable angle locked (VAL) type may be tilted such, that they avoid the medullary stem while maintaining locking. In the distal fragment cerclage is used to approximate bone fragments. In any case the cerclage cable and wires improve fixation and approximate fragments. As supplementing implant their limited strength is acceptable at least for the application mentioned.

(Courtesy P. Regazzoni)

on when combined with internal splint by stem and/or locked plate.

The term “cerclage” is used here only for periosteal wire loops placed perpendicularly to the long axis of the bone. The tension band wire acts differently and is not considered. While the wire loop exerts a centripetal force reducing and keeping radially displaced fragments together, the tension band wire in turn transmits traction producing dynamic compression according to the requirements of function (3).

In the following the different functions are outlined, and then a review of the earlier results of cerclage serves to consider the functions and its requirements at the basis of the evolution of cerclage technology. Recent new insight into mechanical, mechano-biological and biological aspects allowed improving the cerclage as a tool and as an implant.

### Cerclage as tool for reduction

The cerclage functions in two basically different applications. It may be used for reduction of the fracture during surgery. Thus the cerclage functions momentarily as a tool (Fig. 2). This application was never contested because it is an efficient way to reduce multiple fracture fragments. The following discussion focuses on the application of cerclage as an implant.

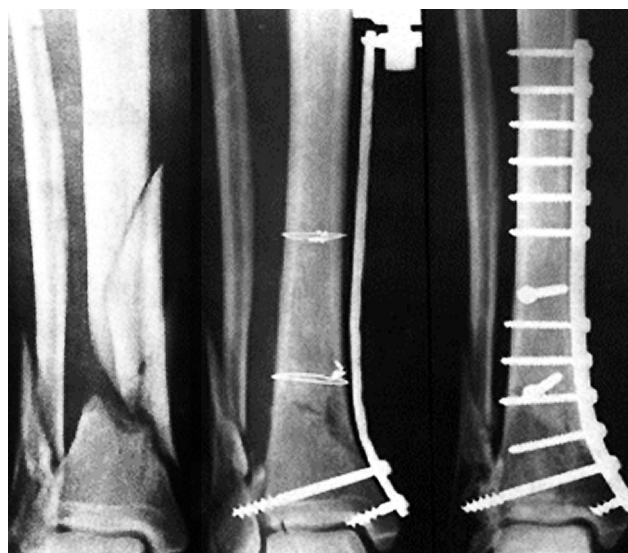


Fig. 2. Temporary use of cerclage for reduction of fracture fragments during surgery. Once the plate is in place and fixed the wires are removed. This is a generally accepted use of cerclage. Here the cerclage functions as a tool and not as an implant.

### Cerclage used as an implant for fixation

When cerclages function as implants they may be used alone or together with a protecting device such as external or internal splint. The shortcomings of an application without protection originate from insufficient mechanical strength. As a rule the cerclage alone cannot maintain stable fixation withstanding the load from functional aftercare. The situation is aggravated when the cerclages cannot be spaced enough to provide sufficient leverage (Fig. 18 and Fig. 19: Spiral fracture with butterfly fragment. In each fragment the wires are positioned 1 cm remote to the fragment tip. Applying this rule to a butterfly fracture shows that the lever arm between the outermost cerclages in the same fragment is e.g. 2 cm. This explains why butterfly fractures lend themselves not for cerclage fixation.

In the past the cerclages were protected by an external plaster cast. The shortcoming was that the protection was often insufficient due to loose coupling across soft tissues between the plaster and the bone. The procedure also combined the disadvantages of surgical and conservative treatment. Good results were rather the exception than the rule.

The weakness of the single wire cerclage led to the development of the twin folded cerclage, which takes

advantage of a doubled wire (12). This did improve the situation but still required additional protection by plaster and needed application of many cerclages (Fig. 3).



Fig. 3. Long spiral fractures with long butterfly fragment in a 35 year old patient, treated with six twin folded wire cerclages. 15 weeks plaster cast, result after 14 months, callus free healing (11). This kind of healing after cerclage was rather the exception than the rule

The major change brought about by today's technology consists in protecting the cerclage using internal instead of external splinting. Such splints are plates, nails or stems of the prosthesis or a combination thereof. Furthermore the connection of the wire is now improved.

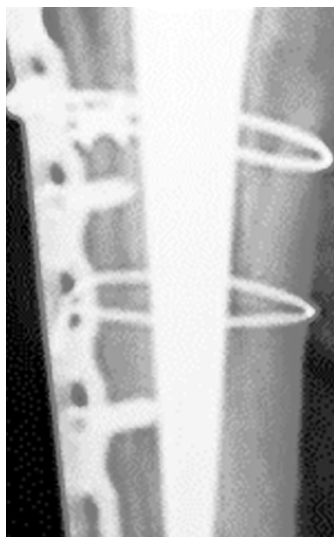


Fig. 4. Cerclage cable and wire used to improve anchorage of a locked plate (enlarged extract from Fig. 1). The cortex does not offer good purchase to the screws. The presence of the stem prevents the use of penetrating implants, thus only unicortical screws were used. The proximal cerclage consists of a cable whereby its insertion through an eyelet prevents displacement of the cable in relation to the long axis of the plate. The distal cerclage consists of wire connected by a twisted knurl. (Courtesy P. Regazzoni)

The use of the internal splint provides tight coupling of a rigid splint. A typical application consists of applying a splinting locked plate which connects the main fragments. The cerclage then is used to reduce and maintain radially dislocated fragments. When applied to periprosthetic fractures the cerclage can also replace or support plate screws for fixation of the plate to bone Fig. 4.

To take advantage of the potential of cerclage the first step consists in reducing the trauma brought about when passing the cerclage around the bone. Basic require-

ments were optimal instrumentation allowing minimally invasive application of the cerclage. Furthermore mechanical performance needed improvement; deleterious mechanobiological reactions were to be avoided. Last but not least keeping blood supply to bone and soft tissues intact was an essential requirement.

### Evolution of wire passer technology

The dislodging of the soft tissue when guiding the cerclage around the bone with conventional instruments may result in damage of the soft tissues, of the blood supply to bone and it may inadvertently strangulate major blood vessels.



Fig. 5. Former wire passer (so called "Beranger"). The tool used earlier on consists of a cannulated semicircle with a straight or angulated handle.

The conventionally used instrument for passing the cerclage around the bone is shown in Fig. 5. It consists of a cannulated half circle with a straight or angulated handle. The half circle is guided around the bone. Allowing insertion of the cerclage at one end and catching the cerclage protruding at the other end requires a major dislodging of the soft tissues (Fig. 6). With the new MIO wirepasser such dislodging is minimized (Fig. 7) because the insertion of the wire and its exit are accessible within the handle outside the body. The application of the MIO wirepasser is visualized in (Fig. 8 through Fig. 11: Final step: The two halves of the wire passer are assembled outside the body. The wire passer forms now a full circle and the wire can be passed through from outside as shown. Disassembling is done in reverse sequence from Fig. 11 back to Fig. 8 whereby the cerclage is left in place.

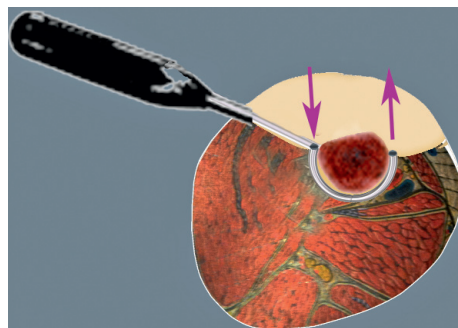


Fig. 6. Large tissue dislodging at application of the conventional wire passer ("Beranger"). After insertion the tool needs to be rotated to present the exit point. The method requires dislodging a major part of the soft tissues in order to bring the exit hole of the semicircle channel into a position where the wire can be caught. This applies to the wire passer with straight and angulated handle as well as to the technology of using a hooked wire catcher.



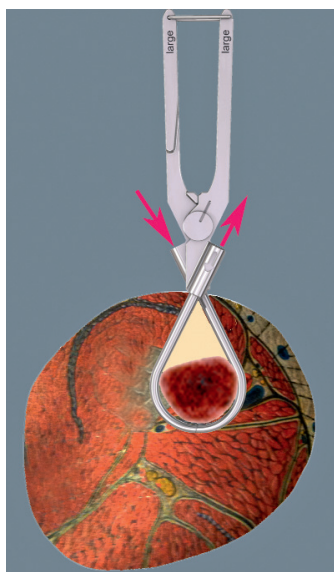


Fig. 7. Comparably small tissue dislodging at application of the new cerclage passer. The latter is an improved atraumatic version using two semicircles which can be applied avoiding major tissue dislocation. When the two parts inserted sequentially are assembled they form a solid full circle channel, which allows passing the wire or cable with minimal tissue dislodging. The arrows visualize the application of the cerclage. The two semicircles can be disassembled for atraumatic removal.

To reduce tissue dislodging and with it to minimize vascular damage the wires can be applied using a tool which consists of two semi circles. This allows guiding the two halves through a small incision and snugly around the bone. Thereupon the two halves are connected forming a full channel around the bone allowing to feed the wire or cable through. Disassembly and removal of each half sequentially leaves the cerclage in place.



Fig. 8. Application of the MIO wire passer. First step: insertion of the first half of the wire passer. It can be inserted through a very small approach. (Courtesy D. Höntzsch)



Fig. 9. Insertion of the second half of the MIO wire passer. Second step: The two halves are inserted thus the small incision is sufficient. (Courtesy D. Höntzsch)



Fig. 10. Assembling the two parts of the MIO wire passer. The arrow shows how the lower part is inserted into the slot, solid coupling results. To take full advantage of the minimally invasive wire passer, front end cutting and crimping tools are required.



Fig. 11. Final step: The two halves of the wire passer are assembled outside the body. The wire passer forms now a full circle and the wire can be passed through from outside as shown. Disassembling is done in reverse sequence from Fig. 11 back to Fig. 8 whereby the cerclage is left in place 10.

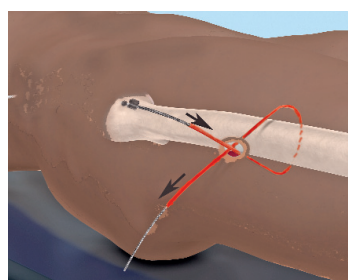


Fig. 12. Use of the MIO wire passer for application of cable. The fact that the cable crimp presents a larger width is offset by using a plastic tube through which the cable is passed. The tube is then removed as shown by the arrows.

### Evolution of cerclage cable technology

The cerclage cable consists today of a multitude of finest metal fibers braided to form subassemblies which in turn are braided and twisted to form the final cable.

The free end of the cable is fed through a hole in the crimp where it comes to rest due to the larger ball attached to the other end of the cable. The free end is then passed around the bone and inserted through the second opening in the crimp (Fig. 13). Tension is then applied e.g. with the instrument shown in Fig. 15 and using a special forceps (Fig. 16) the crimp is squeezed to maintain the tension applied.



Fig. 13. Cable, crimp and crimping tool

Fig. 13a. Cable is insert into the crimp, the picture shows the situation before crimping. The structure of the cable is visible in Fig. 23.

Fig. 13b. Crimping forces as used non minimally invasive technique. (Synthes Ltd. 391.882)

The cross sectional structure of such a cable, mostly made of titanium, is visualized in Fig. 23. The improvements of cable technology concern the junction of the free ends applying improvements to the conventional crimping technology (10) and instrumentation for cutting.



Fig. 14 Front end cutter for minimally invasive procedure. The figure shows the wire cutter. A similar de-sign for cable is required when cable cerclage is to be applied minimally invasive. The same holds true for the crimping tool Fig. 13b. (Synthes Ltd. 03 607 113)

As Wähnert et al. show the crimped cable connection is more resistant than the twisted wire connection. The application of the cable cerclage under minimally invasive conditions requires a special tool for tensioning and maintaining the cable during surgery. It consists of a pencil like tool (Fig. 15) that allows to tension through a small incision. The main body of the tool carries a knurled knob which when twisted applies tension. The temporary tension holder can be locked and disassembled maintaining the tension while additional cables are applied (Fig. 15a left). The next step in the development of minimally invasive cable cerclage will have to solve the

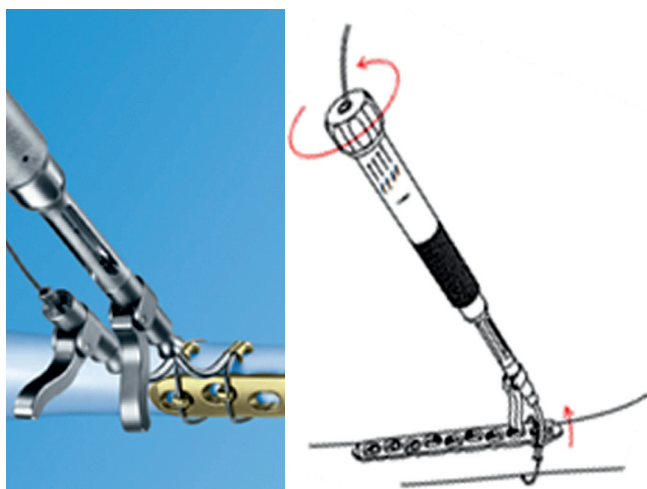


Fig. 15. Cable tensioner, the cable is passed through the crimp and further on through the tensioner. After locking the cable can be tensioned by twisting the knurled knob. The temporary tension holder maintains cable tension while additional cables are applied (see Fig. 15a and Fig. 16). (Synthes Ltd. 391.201, 391.883, 391.884)



Fig. 16. Squeezing the crimp while the retention device maintains the tension in the cable. The tension holder is part of the tensioner and can be disassembled to allow better access while maintaining the tension. (Synthes Ltd. 391.882)

problem of crimping (Fig. 16) and cutting through a small approach.

While the handling of the twist connection of the cerclage wire is critical and bending flat as well as cutting the twist results in drop of tensions as Wähnert observed (22) squeezing and cutting of the cable is not critical.

When cables are applied to a metaphyseal bone which tapers from large to smaller diameter the cable slides on an inclined surface from large to smaller diameter. This results in loss of tension. To prevent the said displacement of the cable along the plate the cable is fed through eyelets which are locked within the screw hole.

### Evolution of cerclage wire technology

The improvements of wire technology consist of avoiding recently detected pitfalls regarding mechanics and mechanobiology as outlined in the following paragraphs. The improvement concerns rather application than instrumentation.

Cerclage loops may be made of metal or plastic. The metal of wires is mostly steel, the use of titanium is also reported (23). Plastic will not be considered here because of its lack of strength which led to increasing the dimension of the loop cross-section and with it increasing the area of contact impeding blood flow. Stress relaxation with creeping loss of pre-tension is also a disadvantage of some plastics. The metal loop may consist of a solid wire or of a multi stranded cable (9). The connection of the wire may consist of a simple twisted knurl that induces and maintains the tension of the solid wire.

### Mechanical aspects

When playing with different modes of application of the knurled twist it became apparent that the stability provided by the solid wire was strongly affected by the amount of plastic deformation of the twist (Fig. 17). The critical part of the twist determining the achieved and maintained tension in a solid wire cerclage is the innermost turn i.e. the one turn near the bone surface. This effect has been recently studied by Wähnert et al. 2011 (22). Their results show that a twist may be inadvertently applied in a way which due to elastic spring back does not maintain sufficient tension. To avoid such an effect





Fig. 17. Different types of twisting the knurled knot, visual aspect and corresponding radiological pictures.

Fig. 17a. Twisting up to reaching maximum torque and not further on results in elastic deformation of the turns immediately close to the bone with consecutive spring back. Thus when the torque is released the tension may drop off strongly. The surface of the wire appears glossy, it is not plastically deformed.

Fig. 17b. Twisting further on after reaching the peak torque value results in plastic deformation which includes also the innermost turns. The surface of the plastically deformed wire appears frosted.

Fig. 17c. The x-ray shows that the surgeon may have reached a level of twist which he assumes to be sufficient but the wire may not be in contact with bone around the entire circumference.

Fig. 17d. The twist lays snug against the bone surface, the cerclage wire spans tight from peak to peak while the valleys in between show no contact.

special attention is required. Tension is sufficient if it holds the fracture fragments together without dynamic displacement during functional aftercare. Wähnert shows that for installing sufficient tension the wire must be twisted in way to produce plastic deformation of the twist including the turn near the bone. The improved application is based on understanding the underlying mechanics and acting upon rather than being guided by gut feeling.

Insufficient wire tension creates a condition of micromotion at the interface between bone and cerclage when the functional load exceeds the compressive preload of the cerclage. This condition is deleterious because it induces a mechano-biological reaction resulting in secondary loosening (see below).

The twist of the wire may stick out and irritate the surrounding tissue. It is, therefore, standard technique to cut the twist and bend it flat onto the bone surface.

The same authors have shown that there is an important effect depending on how the bend is produced, either maintaining the tension or abolishing it.

One further aspect of the knurled twist which requires attention is that when applying torque there is a possibility that one wire stays straight and the second wire turns around it resulting in an asymmetric twist which probably forgives strength. The ideal twist consists of symmetrically deformed wires. To assure this type of deformation the surgeon applies at the same time torque and traction which tries to pull the twist away from the bone surface in order to avoid that one wire remains straight. This is general knowledge among the surgeons using cerclage.

A generally accepted rule concerns positioning of the wire loops in relation to the tip of the bone fragments. For best leverage one tries to space the cerclages along the long axis of the bone as far as possible towards the tip of the fragments. Still, because the fragments taper and become fragile towards the tip, the rule is to place the outermost cerclage at least 1 cm from the tip of a single fragment (Fig. 18) (12). When one applies this rule to e.g. a butterfly fragment it is obvious that keeping the distance of 1 cm for each tip of a fragment the leverage may be compromised. This effect may explain why cerclage treatment of butterfly fragments requires additional splinting in practically all cases (Fig. 19).

One question, which requires further attention, concerns the mechanical load which the cerclage wire exerts onto the bone. The high tension of the wire especially under functional load together with the small area of contact may imply the risk of local mechanical overload exceeding the strength of bone. Here further studies

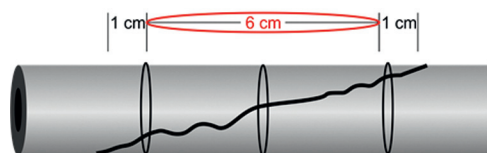


Fig. 18. Long oblique fracture. The position of the cerclage along the long axis of the bone is determined by the minimum distance of the wires near the tips of the fragments where at least a distance of 1 cm must be achieved. Thus the fragile tapering fragment ends are protected from breakage. Applying this rule to a long oblique or spiral fracture shows that the lever arm between the outermost cerclages in the same fragment is e.g. 6 cm.

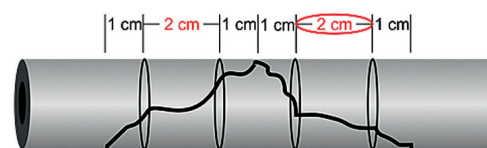


Fig. 19. Spiral fracture with butterfly fragment. In each fragment the wires are positioned 1 cm remote to the fragment tip. Applying this rule to a butterfly fracture shows that the lever arm between the outermost cerclages in the same fragment is e.g. 2 cm. This explains why butterfly fractures lend themselves not for cerclage fixation.

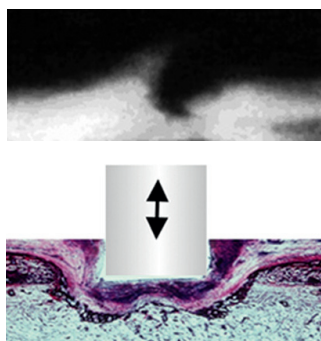
are required to find the optimal balance between stabilization and strength of bone.

### Mechano-Biological aspects

The use of cerclage in the treatment of periprosthetic fractures will profit from application of new insight in bone reaction (15). The first "pressure necrosis of bone" is not induced by even high static compressive forces acting onto the bone or fracture surface.

Living bone can tolerate static compression up to but not reaching the limit of mechanical strength (17). The effect of micro-motion at the interface of bone-to-implant or bone-to-bone is that bone "backs out" by resorption whereby the distance between implant and bone is increased by bone surface resorption (Fig. 20b). The increase of the distance reduces in turn the mostly high dynamic strain (Fig. 21) at the bone surface.

*Fig. 20a. Biological loosening of a cerclage. The observation of (4) showing bone loss immediately deep to the cerclage. This type of bone reaction was called "pressure necrosis" assuming that similarly to the necrosis of skin under continuous pressure also bone would give way. Understanding bone resorption induced by load would be incompatible with the function of bone maintaining support and locomotion under load.*

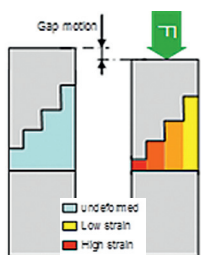


*Fig. 20b. The observation of (20) concerning the bone reaction in the vicinity of a moving plunger. Even without contacting the bone the plunger induces a high strain condition at the interface and bone backs out by surface resorption, a process which reduces the strain.*

A minimal level of dynamic strain is on the one side the basis of inducing bone formation. Therefore, one observes the appearance of callus under conditions of instability. When, on the other hand, the strain exceeds the limit of tolerance namely the elongation at rupture of bone (16) the bone cannot bridge the gap and a non-union results when this condition lingers on.

### Biological aspects of cerclage

Blood supply to bone is an essential prerequisite for uneventful bone healing. Two mechanisms are in the



*Fig. 21. Strain: The same displacement of the fracture fragment ends (gap motion) results in markedly different deformation of the interfragmentary tissue according to the width of the gap. The effect of instability should rather be understood as a result of strain than a result of movement (24).*

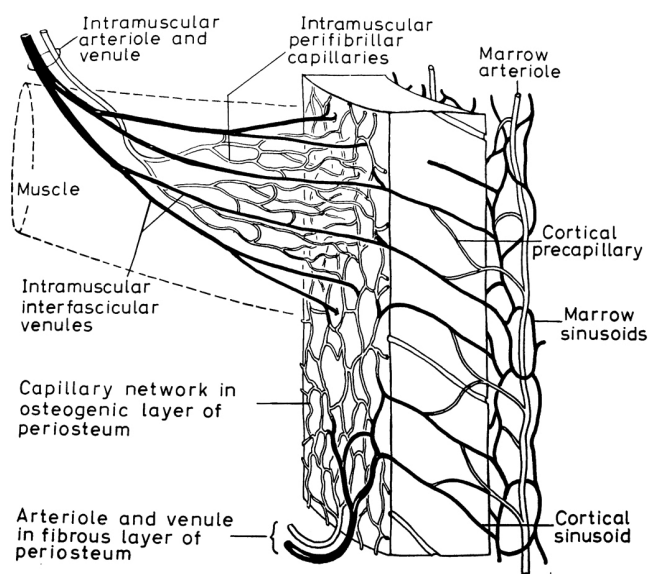
foreground when considering the effect of cerclage upon blood supply to bone: 1. passing the cerclage around the bone and 2. the effect of the contact between cerclage and bone surface.

Any contact of an implant with the bone surface covers by necessity a surface area and impedes blood inflow and outflow (7). When the cerclage consists of a solid wire or a cable the area of contact is a rather narrow line and its effect on blood supply to bone is minimal. If the cerclage consists of a band like plastic strap, one can assume a somewhat larger avascular zone. To prevent vascular damage of cerclage bands with wider contact area, these bands are often provided with means keeping the contact to bone small. Plastic straps have been introduced with small transverse undercuts to produce a surface that reminds a cogwheel. Another way to reduce the area of contact is the use of protrusions. Similar designs have been proposed for wires such as elevating the wire from the bone surface using spheres for the same purpose. As the vascular damage of the wire is small and because the reduction of contact area results in comparably high local surface stress we consider the use of wires with spacing spheres not to be an essential or urgent solution.

### Strangulation of periosteal blood vessels?

A frequent argument put forward against the use of cerclage for "permanent" application is that the cerclage would strangle the bone blood supply. Fig. 22 visualizes that the blood supply reaches the bone essentially in a radial direction (5). Thus one can expect that the strangulation would have a small effect. Rhinelander and Stewart (1983) have shown in the rabbit that the necrosis is minimal (19).

In our own hands application of wires and cables results in a minimal area of impeded blood supply. In



*Figure 22. Blood supply to bone according to Brooks (1971) (5). The vessels reach the bone mainly in a centripetal direction and are therefore less sensitive to strangulation by a cerclage loop around the bone. Vascular connection between bone cortex, periosteum and attached muscle.*

a pilot experiment on sheep using fluorescent dyes to visualize the blood perfusion area, the effect of the cerclage was minimal (Fig. 23) (6).

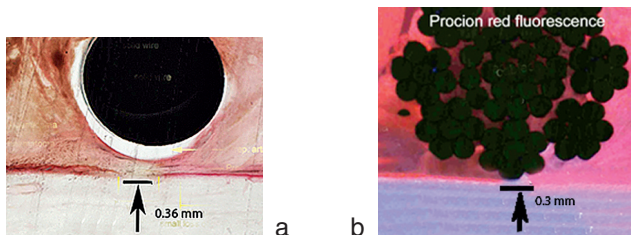


Fig. 23a. Solid wire cerclage. The periosteum exhibits a lack of blood perfusion which is only about 0.36 mm wide. The space immediately near the wire is an artefact from histological preparation but there is a small distance between wire and bone filled with soft tissue suspect of secondary loosening.

Fig. 23b. Cerclage cable in immediate contact to the bone surface with a very small <0.3 mm wide lack of perfusion of the periosteum.

### Strangulation of large blood vessels

Strangulation of the superficial femoral artery has also been reported (1). The inadvertent strangulation of a major artery has been observed in clinic (13) and in a cadaveric experiment Fig. 24 (2). This is a major complication which should be avoided by guiding the tip of the wire passer in contact with the periosteum.



Fig. 24. Experimental reproduction of strangulation of *A. femoralis profunda* in an experiment using a human cadaver.

### The use of cerclage in periprosthetic fractures

Fig. 25 shows a typical application of cerclages in the treatment of a periprosthetic fracture under consideration of the mentioned aspects for improvement. Within the proximal fragment the medullary canal with the stem of the prosthesis obstructs the use of penetrating implants and/or reduces the anchorage of periosteal splints.



Fig. 25. Treatment of a periprosthetic fracture (18). The proximal main fragment is connected to the distal main fragment with a locked splinting plate. At the proximal plate end the cerclage is used to lock the plate to bone. In the distal fragment cerclage is used to approximate and maintain bone.

(Courtesy P. Regazzoni)

Plate screws when locked can either be used as unicortical screws or if they are of the variable angle locked (VAL) type they may be tilted such, that they avoid the medullary stem while maintaining angular stability. In any case the cerclage wires improve fixation and approximate fragments. As supplementing implant their limited strength is acceptable at least for the application mentioned.

### Special aspects of stability of fixation

Considering the fixation with cerclage, the conventional terms for stability, namely absolute and relative stability, require the definition of an additional type of stability, which is distinctive for cerclage stabilization: “loose-lock stability” with its two distinct components.

#### Absolute stability

The highest degree of stability, called absolute stability, is characterized by absence of displacement locally within the fracture. It depends on sufficient compressive preload of the fracture surfaces, which at any moment in time is greater than tension produced by functional loading. Using cerclage this type of stability requires that sufficient tension of the cerclage is maintained until the fracture is solidly united. Such tension may be installed at surgery; its maintenance depends on:

- Sufficient strength of the wire. The rare incidence of wire breakage outside the twist indicates that wire strength is usually sufficient to withstand functional load.
- Sufficient strength of the connection between the ends of the wire (e.g. the knot). When the loop fails this happens usually by opening of the wire connection with or without wire breakage within the twist.
- Maintained close reduction of the bone fragments (i.e. no slippage of the fracture surfaces). Even small adjustments of fragment position may result in gross instability because the tension of the wire is lost.
- Maintained mechanical integrity of the entangled bone fragments (i.e. no fracture of the tapered ends of the fragments). This problem occurs when the wire is placed too close to the tip of the fragment.



### Relative stability

Reversible displacement, as observed when fragments are splinted with an elastic element, is correlated to the load applied and inversely correlated to the stiffness of the splint. Functional loading will result in displacement within the fracture which is restored at unloading by returning of the fragments to their original position. The occurrence of relative stability is a rather rare incidence after cerclage application.

### “Loose-Lock stability”

When tension of the wire is not installed or lost due to load exceeding the strength, a type of stability is present which is characterized by two distinct phases with an abrupt changeover:

- Phase 1: If the wire is initially not under tension, the wire does not stabilize and the fragments displace freely.
- Phase 2: With increasing displacement of the fracture fragments the wire is tensioned and obstructs further displacement. The fragments are thereby stabilized mostly in some degree of malalignment.

In phase 1 minimal load will displace the fracture fragments; still, after a certain amount of travel the fragments will abut against the wire loop and then in phase 2 further travel is minimized. This situation represents a combination between free displacements of the fragments changing abruptly into an elastically (or plastically) resisted displacement. This is a frequent situation after application of a cerclage similarly to the situation of conventionally locked i.m. nails where also two different phases of stability (loose-lock) prevail. The same holds true for an external plaster with its loose coupling. It also is the case when resorption of the bone at the interface results in loss of contact between bone and implant and also between bone and bone e.g. at fracture surfaces.

### CONCLUSION

Cerclage can offer essential help in the treatment of periprosthetic fractures where the stem of the prosthesis impedes the use of implants which need to penetrate the medullary cavity. Cerclage used as an implant suffered in the past from disrepute based on mostly disappointing results when applied to diaphyseal fractures together with plaster. Replacing the external plaster splinting with solid internal splints like locked plates, nails or stems of prostheses opens a new field of stabilization using cerclage. This combination is applicable to periprosthetic fractures but most probably also to multifragmented diaphyseal fractures. Together with improved technology of application, taking advantage of a better understanding of mechano-biological bone reaction and considering that cerclage damages blood supply to bone less than expected, cerclage is a potentially valuable tool and implant.

Wire technology can be improved but cable technology is definitively stronger and maintains better ten-

sion (Wähnert). Wherever applicable, cables offer better performance.

The conventional terms describing stability of fixation, namely either “absolute stability” or “relative stability” need to be supplemented for cerclage applications by the term “twin loose-lock stability”. Loose lock stability applies to cerclage but also to conventional locked nails and to the situation produced by biological loosening of any implant.

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