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A review of metallic and non-metallic cerclage in orthopaedic surgery: Is there still a place for metallic cerclage?

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ABSTRACT

Cerclage techniques are simple, yet effective techniques to treat certain fractures and are known as one of the first operative techniques in orthopaedic surgery. The days when a twisted metal wire was the only available cerclage technique nonetheless have passed and today there are many different materials and techniques available.

This review evaluates the differences between metallic and non-metallic cerclage techniques, thereby looking at biomechanical, technical and biological aspects. It also provides an overview of clinical applications for non-metallic cerclages.

The use of metallic versus non-metallic cerclage might differ depending on indication, location and involved tissues. Currently metallic cerclage is mostly used to repair fractures because of its believed higher absolute strength. More recently though, non-metallic cerclage has been proven to withstand the same loads, while having a lower complication rate.

This review suggests that mainly in the upper limb a non-metallic cerclage technique might become the golden standard, while in the lower limb both metallic and non-metallic cerclage techniques are complementary and dependent on indication.

Introduction

Cerclage techniques are simple, yet effective techniques to treat certain types of fractures and have been known since the 18th century. Briefly, a cerclage technique is a simple internal fixation method using a wire or cable looped and tightened around bone fragments or soft tissue. Its primary indication in orthopaedic surgery is to stabilize and secure bony structures or soft tissues to allow for repair to take place. Its effectiveness has been established in clinical practice for years. Currently there are many different materials and techniques available, which is luxury when confronted with difficult cases, but at the same time creates a challenge to define the optimal cerclage method and configuration. Considering the ageing population and the rapidly increasing number of peri-prosthetic fractures, we believe it is of utmost importance to establish recommendations on optimal configurations of cerclage [1–4].

Cerclage material and configuration

There are two main categories of cerclage materials: metallic and non-metallic. Metallic cerclage is usually made from stainless steel or titanium. Different available types are simple wires, cables and also braided configurations in which simple wires are twisted around each other [3,5,6]. Applying metallic cerclage can be done freehand, but usually a wire passer is used to minimize soft tissue damage [1,4,7]. Wires and braided wires are fixed with a twist, cables are always fixed with fixation tools [2–5,7–10].

On the other side there is non-metallic cerclage, which is made from different types of (non-)absorbable suture material and also exists in different sizes and different strengths. The suture material is mounted on the loop end and passed freehand around the relevant tissues, without additional tools and the suture is fixed with a knot made manually by the surgeon [1,3,7–9,11–17]. Commonly used suture materials for cerclage are FiberWire, Ethibond, Force Fiber, Ticron, Vicryl, Ultrabraid, Orthocord and Supercable [5,8,9,12–16,18–25]. Almost all of these suture types are coated with ultra-high molecular weight polyethylene to increase the tensile properties. Supercable is a design that is applied, tightened and fixed with a power tool in a similar way as a metallic cable [5,18,23].

Purpose

This report evaluates through a comparative literature study the differences between metallic and non-metallic cerclage techniques, thereby looking at biomechanical, technical, and biological aspects.

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Table 1
Overview of the discussed biomechanical cerclage parameters.

	Pretension (N)	Load to plastic deformation (N)	Load to failure (N)	Load to displacement (N)	Load to subsidence of protsthesis (N)	Strain (%)	Stiffness (N/mm)	Peak load (N)	Peak elongation (mm)	Knot slippage (mm)	Remaining pretension (%)
SSC[1] Single looped (1.7 mm) [3]	292	646	1622	–	–	–	–	–	–	–	–
SSC[1] double looped (1.7 mm) [3]	442	1334	2734	–	–	–	–	–	–	–	–
SSC[1] two single looped (1.7 mm) [3]	392	1191	2675	–	–	–	–	–	–	–	–
SSW[2] single looped (1.5 mm) [3]	181	343	606	–	–	–	–	–	–	–	–
SSW[2] double looped (1.5 mm) [3]	335	752	1359	–	–	–	–	–	–	–	–
SSW[2] two single looped (1.5 mm) [3]	220	520	1140	–	–	–	–	–	–	–	–
SSW[2] braided, single looped (2 x 1.5 mm) [3]	119	225	919	–	–	–	–	–	–	–	–
FiberWire size 5 [21]	–	–	620	–	–	23	62	–	–	–	–
FiberWire size 2 [21]	–	–	282	–	–	16	35	–	–	–	–
Ethibond size 5 [21]	–	–	247	–	–	18	25	–	–	–	–
Ethibond size 2 [21]	–	–	134	–	–	18	13	–	–	–	–
Ethibond size 1 [21]	–	–	118	–	–	15	12	–	–	–	–
Ethibond size 0 [21]	–	–	73	–	–	13	12	–	–	–	–
Ticron size 5 [21]	–	–	226	–	–	22	19	–	–	–	–
Ticron size 2 [21]	–	–	136	–	–	16	14	–	–	–	–
Vicryl size 1 [21]	–	–	130	–	–	16	15	–	–	–	–
Vicryl size 0 [21]	–	–	105	–	–	16	12	–	–	–	–
Vicryl size 2-0 [21]	–	–	76	–	–	15	10	–	–	–	–
Nice knot with half hitch (FiberWire) [15]	–	–	–	155	–	–	–	–	–	0.6	–
Nice knot with 3 half hitches (FiberWire) [15]	–	–	–	228	–	–	–	–	–	0.4	–
Nice knot with half hitch (Ultrabraid) [15]	–	–	–	99	–	–	–	–	–	2.0	–
Nice knot with 3 half hitches (Ultrabraid) [15]	–	–	–	110	–	–	–	–	–	1.6	–
Racking hitch knot with half hitch (FF[3]) [16]	–	–	–	168.2	–	–	–	199.2	0.52	–	–
Racking hitch knot with 4 half hitch (FF[3]) [16]	–	–	–	311	–	–	–	428.8	0.05	–	–
FiberWire size 2 [16]	–	–	–	190.1	–	–	–	302.0	0.16	–	–
Ethibond size 2 [16]	–	–	–	174.5	–	–	–	270.4	0.09	–	–
SSW[2] (1.25 mm) [9]	618	–	1775	1820	+/-1400	–	–	–	–	–	–
4-throw knot (FiberWire) [9]	131	–	+/2750	1289	–	–	–	–	–	–	–
Simple hitch (FiberWire) [9]	133	–	2642	1709	–	–	–	–	–	–	–
Cow hitch (FiberWire) [9]	137	–	2804	1803	+/-1250	–	–	–	–	–	–
SSW[2] (1 mm) [10]	80	–	–	–	–	–	–	–	–	–	77
SSW[2] (1.25 mm) [10]	158	–	–	–	–	–	–	–	–	–	47
SSW[2] (1.5 mm) [10]	237	–	–	–	–	–	–	–	–	–	40
Metallic cable (1 mm) [10]	155	–	–	–	–	–	–	–	–	–	89
Metallic cable (Zimmer 1.8 mm) [5]	–	–	–	–	–	–	–	–	–	–	48.2
Metallic cable (DePuy-Synthes 1.8 mm) [5]	–	–	–	–	–	–	–	–	–	–	81.7
Metallic cable (Smith &Nephew 2.0 mm) [5]	–	–	–	–	–	–	–	–	–	–	70.7
Metallic cable (Stryker 2.0 mm) [5]	–	–	–	–	–	–	–	–	–	–	66.7
Non-metallic cable (Kinamed 1.5 mm) [5]	–	–	–	–	–	–	–	–	–	–	54

(*continued on next page*)

Table 1 (*continued*)

	Pretension (N)	Load to plastic deformation (N)	Load to failure (N)	Load to displacement (N)	Load to subsidence of protsthesis (N)	Strain (%)	Stiffness (N/mm)	Peak load (N)	Peak elongation (mm)	Knot slippage (mm)	Remaining pretension (%)
SSW[2] 0.8 mm manual [7]	27.3	–	–	–	–	–	–	–	–	–	–
SSW[2] 0.8 mm power tool [7]	54.9	–	–	–	–	–	–	–	–	–	–
SSW[2] 1.0 mm manual [7]	39.7	–	–	–	–	–	–	–	–	–	–
SSW[2] 1.0 mm power tool [7]	71.6	–	–	–	–	–	–	–	–	–	–
Nicky's knot (Ethibond) [12]	–	–	–	–	–	–	45.05	334.80	–	–	–
Nicky's knot (Ultrabraid) [12]	–	–	–	–	–	–	80.71	522.84	–	–	–
Nice knot (Ethibond) [12]	–	–	–	–	–	–	49.18	335.75	–	–	–
Nice knot (Ultrabraid) [12]	–	–	–	–	–	–	77.38	527.01	–	–	–
SSW[2] single stranded (1 mm) [6]	–	–	–	–	–	38.95	–	384.9	98.9	–	–
SSW[2] double stranded (1 mm) [6]	–	–	–	–	–	30.55	–	1009.6	110.7	–	–
SSW[2] braided (2 x 1 mm) [6]	–	–	–	–	–	35.45	–	878.1	90	–	–
SSW[2] single stranded (1.5 mm) [6]	–	–	–	–	–	40.74	–	1057.3	142.2	–	–
SSW[2] double stranded wire (1.5 mm) [6]	–	–	–	–	–	47.43	–	2077.3	120.5	–	–
SSW[2] braided (2 x 1.5 mm) [6]	–	–	–	–	–	40.65	–	2083.3	104.6	–	–
SSW[2] (18 gauge) [26]	–	–	61.8	–	–	–	–	–	–	–	–
Nice knot (FiberWire) [26]	–	–	232	–	–	–	–	–	–	–	–
Nice knot (Ethibond) [26]	–	–	164	–	–	–	–	–	–	–	–
Nice knot (Ultrabraid) [26]	–	–	95.7	–	–	–	–	–	–	–	–

[1] Stainless steel cable.
[2] Stainless steel wire.
[3] Force Fiber.

Also, an overview of clinical applications of non-metallic cerclage techniques is given.

Materials and methods

A screening of the literature was performed from November 2017 until September 2018 in the online databases PubMed, Google Scholar and Web of Science. Relevant articles discussing biomechanical, technical and biological aspects of metallic and non-metallic cerclage published in the last decade were selected. Further all articles and case-reports describing clinical applications of non-metallic cerclages were included.

Results

Biomechanical aspects

In literature, there is no consensus regarding the definition of strength of cerclage. Pretension, load to failure, load to plastic deformation, load to gap opening are some of many different measurements related to strength and are all important in the evaluation of the efficacy and usefulness of cerclage. In this review, we will define strength as the (pre)tension force. The load to plastic deformation (elongation), load to gap opening and the load to failure are factors indicating (clinical) failure more than a measure of strength per se. Nonetheless these elements are equally important when looking at the outcome of the surgery. An overview of the discussed biomechanical aspects can be found in Table 1.

Metallic cerclage

Lenz et al. [3] evaluated the biomechanical performance of seven stainless steel cerclage configurations (Fig. 1). Configurations in which there are two loops, either double looped or two single loops, perform better than single configurations. In this study cables are stronger and have a higher load to deformation and failure in all configurations compared to wires. The braided cerclage (two metal wires twisted around each other) was the first of the seven configurations to show tension loss [3].

Non-metallic cerclage

Najibi et al. [21] evaluated FiberWire (size 5, size 2), Ethibond (size 5, size 2, size 1, size 0), Ticron (size 5, size 2) and Vicryl (size 1, size 0, size 2-0) by measuring load to failure, strain and stiffness

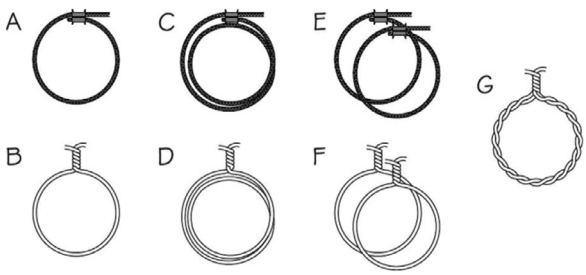

Fig. 1. Metallic cerclage configurations. **A** single looped cable. **B** single looped wire. **C** double looped cable. **D** double looped wire. **E** two single looped cables. **F** two single looped wires. **G** braided wires.

using a SMC knot. In this study FiberWire performed significantly better than the other suture materials, also when the diameter was taken into account. Suture breakage at the knot was the only failure mechanism for all sutures and no knot slippage was observed [21], which is in contrast with Fleischer et al. [13] who describes knot slippage of FiberWire as the main failure mechanism.

Hill et al. [15] evaluated FiberWire and Ultrabraid with a nice knot. The load to clinical failure (defined as 3 mm slippage or the opening of the suture loop) was highest in FiberWire and also had the least slippage. Kelly et al. [16] evaluated Force Fiber (size 2 and size 3–4), FiberWire (size 2) and Ethibond (size 2) using a racking hitch knot. Force Fiber (size 2) had the highest peak load and Ethibond the lowest, but Ethibond showed the least slippage [16]. No studies were found evaluating the strength of the Supercable.

Metallic versus non-metallic cerclage

Renner et al. [9] compared stainless steel wire (1.25 mm) to FiberWire (size 5). Although the pretension of the stainless-steel wire was higher than in FiberWire, the load to gap opening was comparable and load to failure was in each FiberWire configuration higher than the stainless-steel wire [9]. Metallic cerclage is stronger, but non-metallic cerclage can withstand greater loads to failure.

Westberg et al. used the Surgeon's Knot, the Nice Knot and the Modified Nice Knot, to compare using FiberWire (size 2), Ultrabraid (size 2) and Ethibond (size 5) with a stainless steel wire (1.2 mm). Fiberwire and Ethibond showed significantly higher loads to failure, while Ultrabraid showed comparable results with wire.

Fleischer et al. [13] compared Ethibond (size 2), Orthocord (size 2) and FiberWire (size 5) to titanium wire cerclage (0.8 mm) in tuberosity repair. When looking at the load to failure, FiberWire showed superior results in comparison to the titanium wire, while Orthocord and Ethibond had inferior results [13]. It has to be noted though that the difference in the diameter of the suture is not taken into account. The mechanism of failure for Ethibond and Orthocord was breakage of the suture, while in FiberWire there is elongation and slippage, but only at much higher loads [13].

Knierzinger et al. [8] compared Ethibond (size 6) to titanium cable (DePuy) (1.0 mm), again in tuberosity repair. Ethibond was fixed with a nice knot and titanium cable was fixed with a clamp. Ethibond this time had a lower load to failure than the titanium cable and Ethibond showed also a higher fragment motion than the titanium cable [8].

Nwankwo et al. [22] compared double looped FiberWire (size 5) to single looped stainless-steel wire (18 gauge). The ability of the cerclages to withstand axial load to the proximal femur by measuring the strain at the proximal femur was evaluated. Measurements showed no significant difference among the cerclages: FiberWire resulted in 286% lower strain, the stainless-steel wire resulted in 308% lower strain [22]. It was concluded that both cerclage techniques could be used as prophylactic cerclage in lower limb.

Technical aspects

Although cerclage is theoretically a relative simple technique, in practise it sometimes is very challenging to achieve a satisfactory peri- and post-operative result. Simple wires can break during twisting, the tension applied is often subjective, sutures can slip, power tools or clamps can lose grip and many other factors can influence the desired outcome.

Metallic cerclage

Wahnert et al. [10] evaluated the influence of twisting of stainless-steel cerclage on the fixation strength. Wires (1.0 mm, 1.25 mm & 1.5 mm) and cables (1.0 mm) were looped once around two bone shells. Wires were closed with a twist and cables witch a clamp. The twist was made manually, with or without traction, by a surgeon with pliers. Then the free ends were cut off and bent forward (in the direction of twist), backward (in the opposite direction of the twist) or perpendicular (perpendicular to the twist). Before twisting, measurements showed a relation between the diameter and pretension. After twisting though, an inverse relation was seen: a larger diameter results in higher tension loss, resulting in possible cerclage loosening. The load to failure increased when the diameter increased. A twist made without traction showed lower pretension than a twist made with traction. The bending direction of the twist also influenced the pretension: backwards showed the highest tension loss (90%), forward and perpendicular showed the least tension loss (47%; 55%). The backward bent had the lowest load to failure, the forward and perpendicular had the highest load to failure [10].

Menard et al. [5] evaluated different metallic cables (Cobalt-Chrome) and one non-metallic nylon cable (Supercable). Results showed important tension loss in all cable configurations, this phenomenon appeared after fixing the cables and also additional tension loss was seen after removing the tensioner kit. Considering these results, it seems that cable configurations are also more submissive to tension loss than previously believed [5].

Koo et al. [7] compared tightening stainless-steel cerclage wires (0.8 mm and 1.0 mm) performed with a power tool to the conventional manual method performed with pliers. The peak forces of compression among the four trials were similar. The steady-state forces of compression were higher when using the power tool than manual tightening [7].

Another technical aspect concerning metallic cerclage techniques is possible irritation or damage to surrounding soft tissue and skin, even more when the metallic cerclage is subjected to micromotion, possible loosening or breakage [6,11]. The cause of breakage can be insufficient reduction of fracture elements, micromotion, overtightening, early rehabilitation and loading, bad technique or mechanical failure. In certain situations or at certain locations, it is therefore sometimes necessary to remove metallic cerclage. This of course means a second, possibly unnecessary, operation. According to Huang et al. [28] the removal rate of metallic cerclage used in patellar fracture goes up to 25% and when used for olecranon fractures even up to 75% according to Phadnis et al. [29].

Non-metallic cerclage

There are many studies evaluating knotting techniques and configurations. The most used knots in the selected studies in this review are the nice knot (Fig. 2), nicky's knot, cow hitch and racking hitch knot [9,11,12,14–17]. Compared to the nice knot, the racking hitch knot is less symmetric, less straightforward and less easy to perform [11].

Collin et al. [12] evaluated Ethibond and Ultrabraid sutures fixed with a nice or nicky's knot. In static testing using Ethibond, the nice knot resulted in higher stiffness and less elongation than the nicky's knot. When using Ultrabraid there was no significant difference. In dynamic testing though the nice knot was much more resistant against elongation for both Ethibond and Ultrabraid than the nicky's knot. The main reason was slippage of the nicky's knot in comparison with the nice knot [12].

Hill et al. [15] compared the nice knot to three other knots with different suture materials to evaluate its performance. Next to the load to clinical failure, which was described earlier in the biomechanical aspects, he also evaluated the required number of post half hitches for maximum knot security. Addition of half hitches resulted in a higher load to failure in the nice knot. Two half hitches resulted in the highest load to failure, adding more half

Fig. 2. The double sutured nice knot is a sliding knot that is non-slipping, adjustable and can be used in open and arthroscopic surgery [11,12,15,17].

hitches did not additionally increase the knot security. The nice knot showed the least knot slippage among the three knots [15].

Kelly et al. [16] also evaluated the optimal number of post half hitches by measuring the peak load to failure. Force Fiber (size 2 and size 3–4), FiberWire (size 2) and Ethibond (size 2) were used to perform the racking hitch knot. Results showed that knot performance improved when the number of half hitches increased: load to failure with one half hitch was 199.2 N, with four half hitches it was 428.8 N. Four additional half hitches resulted in the highest load to failure [16].

In comparison with the metallic cerclage Camarda et al. [31] reported that non-metallic cerclage reduces the rate of surgical complications and re-operation [31]. Non-metallic cerclage is easier to apply, it is less traumatic to the surrounding soft tissue both on insertion and also when possible breakage should happen [11]. When non-metallic cerclage needs to be removed, it is much easier to cut with scissors and pull out [11]. Renner et al. [9] also reports that non-metallic cerclage does not interfere with radiologic imaging and has no risk of metallosis because there is no metallic contact [9].

Biological aspects: vascularisation

One of the concerns when tightening a cerclage is the potential risk on vascular necrosis. The necrosis could theoretically arise from three mechanisms: (1) the effect of the contact between cerclage and bone surface; (2) the strangulation of periosteal blood vessels and (3) the effect like “Gigli saw” during passage of the cerclage around the bone [1].

Steinberg et al. [6] therefore introduced a new configuration in order to reduce the risk of periosteal vascular strangulation: braided metallic cerclage. Two stainless steel wires (1 mm, 1.5 mm) and three wire configurations (braided, single stranded and doubled stranded) were used and wire pressure imprint points, peak load and elongation load were evaluated. Considering the wire imprint, the braided cerclage showed decreased contact area due to an interrupted dotted imprint, resulting in a theoretical reduced risk of periosteal vascular strangulation [6]. However, another biomechanical study showed no biomechanical advantage of the braided wire, because of the difficulties in twisting causing loss of pretension [10].

Lenz et al. [2] evaluated the cerclage-bone interface mechanics of metallic wire (1.5 mm) and metallic cable (1.7 mm). The contact area, bone pressure on the interface and possible cortical damage was analysed by executing a distraction test on two bone shells (loading of 400 N). The analysis showed that the tension on the surface was not homogeneous. Cerclage fixation stability was based on point-contact fixation and thus dependant on the bone geometry. In between the areas of compression there are non-loaded, spanned zones which makes strangulation of periosteal vascularisation unlikely. Histological evaluation also showed unaffected cortical bone after loading of both the cerclages. This study indicates that cortical bone withstands the static concentric compression of the metallic cerclage techniques. Cortical groove formation is the result of cerclage instability under functional load, not because of weakness of the cortex [2].

Clinical aspects of non-metallic cerclage

Hereby we present a non-exhaustive list of indications of non-metallic cerclage in orthopaedic surgery described in literature and if available also the clinical outcomes. This list serves as representation of the possibilities of non-metallic cerclage.

Shoulder

Boileau et al. [11] suggests and has used non-metallic cerclage for different applications in shoulder surgery: tuberosity fixation during fracture treatment with humeral hemiarthroplasty or reverse shoulder arthroplasty; fixation of an isolated greater tuberosity after acute fracture/non-union/malunion or 3- or 4-part fractures together with a lateral locking plate or intramedullary humeral nail; humerotomy fixation during revision arthroplasty; fixation of small butterfly fragments; side-to-side rotator cuff repairs or anchorless, transosseous repairs; fixation of both posterior and anterior bone blocks for the treatment of shoulder instability and for all-arthroscopic reconstruction of acromioclavicular joint disruptions [11].

Edwards et al. [18] reviewed studies about the use of Supercable for reverse total shoulder arthroplasty and for the revision of unconstrained total shoulder arthroplasty using humeral osteotomy for stem or cement removal and allograft augmentation. No loosening or migration of cerclage or allograft and no complications linked to the cerclage were reported. The clinical healing time of the fracture (or osteotomy) was 4 months [18].

Ladermann et al. [20] used Ethibond (size 6) for stabilisation of acute acromioclavicular joint dislocations. This study reported 919% excellent, 2.7% good, 2.7% satisfactory and 2.7% fair results. No complications linked to the cerclage or need for cerclage removal were reported [20].

Triceps

Jaiswal et al. [19] reported 3 cases about trans-osseous non-metallic cerclage for repairing triceps tendon rupture (bone to tendon repair). In case 1 Ethibond (size 2) was used, in case 2 Ethibond (size 5) and in case 3 Ethibond (size 5). The postoperative protocol was the same among the cases: elbow immobilization in plaster for three weeks, triceps strengthening was started after three months and full triceps strength was reached after 1 year. In case 1 a 10° terminal restriction of elbow flexion was established and in case 2 and 3 full triceps strength and range of motion was established [19].

Olecranon

Phadnis et al. [29] describes a technique to treat simple olecranon fractures and chevron osteotomies with suture techniques. With Orthocord (size 2) they mimic the tension band principle. Immediate mobilization is allowed as in normal tension band surgery. At the time of publication, the authors have treated 18 patients successfully with full recovery and healing of the fracture [29]. Also Boileau et al. used a Nice knot technique with a high-caliber (minimum size 1) braided, absorbable or non-absorbable suture in olecranon fractures [11].

Hip

As already mentioned in the biomechanical aspects Nwankwo et al. [22] suggested that non-metallic cerclage can be used as prophylactic cerclage to decrease the incidence of intraoperative fractures during hip surgery. This study demonstrated for non-metallic cerclage the significant reduction in strain of more than 25% experienced at the proximal femur [22].

Ting et al. [23] evaluated the use of Supercable in primary and revision total hip arthroplasty. The indications for the use of Supercable included fixation of an extended trochanteric osteotomy

(ETO), intraoperative fracture of the proximal femur, strut allograft fixation and periprosthetic fracture of the femur. The rehabilitation protocol included early mobilization, physical therapy and toe-touch weightbearing on the involved side. After an ETO, avoidance of active abduction for six weeks was necessary. After that, patients were allowed active abduction and weight bearing as tolerated. An acceptable non-union rate of 7% was achieved and a 14% dislocation rate postoperatively. No complications linked to the cerclage or cerclage failure were reported [23].

Quadriceps

Wordsworth et al. [24] described a simple and cost-effective transosseous non-metallic cerclage technique to repair quadriceps tendon ruptures with the use of metallic cerclage as a suture passer. Ticron (size 5) was used for definitive repair. This technique does not require additional tools, it's quick and not expensive. Clinical results were not reported [24].

Patella

Camarda et al. [31] reviewed studies about the use of non-metallic cerclage for patellar fracture fixation and reported good clinical results. Ultrabraid (size 2), FiberWire (Size 5), Ticron (size 5) and Ethibond (size 5) were used. Post-operative immobilization period varied from 1 to 6 weeks, 3 of the 9 reviewed studies allowed functional movement the first day after the operation. Only 3.2% of the patients needed additional surgery for cerclage removal. This study concluded that the success rate of non-metallic cerclage for patellar fracture fixation was 90% [31].

Gilmore et al. [27] reviewed reconstruction techniques and clinical results of patellar tendon ruptures. For the acute primary non-absorbable suture showed the best clinical results and only had a 2% failure rate. For chronic and post-TKA repair though, autogenous grafts showed better results. In all repair techniques, immediate post-operative mobilization should be the standard [27].

Maniar et al. [30] suggested the use of transosseous non-metallic anchors (Twinfix Ti 2.8) for periprosthetic patellar fracture fixation. The postoperative protocol was to apply a cylinder slab initially, and after the 5th postoperative day a cylindrical cast. Partial weight bearing was then started and after four weeks full weight bearing in a knee brace was started. After 6 weeks postoperative, range-of-motion exercises were initiated. After 3 months, the patient could walk with a cane. Fracture-union was established 1 year postoperative. No patellar subluxation, necrosis (avascular) or refracture occurred and a good range-of-motion without extensor lag were reported. The patient could walk without support for 1.5 km 1 year postoperative [30].

Tibia

Zonnenberg et al. [25] reviewed cases about tibial tubercle osteotomy (TTO) with absorbable suture fixation in revision total knee arthroplasty. Vicryl (size 1) was used. The postoperative protocol was immediate full weight bearing when the surgical procedure was uneventful (78.2%). A removable knee extension splint for 6 weeks postoperative was used for osteotomy healing. 6 weeks postoperative 4.3% showed TTO fracture but 1 year later the fracture was healed without clinical consequences. 21.7% showed intraoperative tibial plateau fracture (not related to the surgical technique), with the consequence of 6 postoperative weeks partial weight bearing. No migration of the TTO was seen and no cerclage removal was necessary [25].

Discussion

This review evaluates the differences between metallic and non-metallic cerclage. The ongoing technical development, boosted by the ageing population and increase in peri-prosthetic fractures, has led to an abundancy of new cerclage materials and tools. The differences in biomechanical, technical and biological aspects in the available literature between metallic and non-metallic cerclage were compared and an overview of clinical applications of non-metallic cerclage was provided.

Intuitively, when considering biomechanical aspects, one would logically assume that metallic cerclage is stronger than non-metallic cerclage. In the absolute definition of strength, (pre)tension, this still might be the case. However, when we look at the load to failure or load to clinical failure there are many biomechanical studies that show that non-metallic materials actually are able to reach higher loads [9,13]. A dogmatic assumption that metallic cerclage is always stronger should be abandoned. Among the different suture materials, FiberWire overall performs the best [9,13–16,21,22].

This leads us to the first and most important conclusion of this comparative report: as a surgeon, one should ask himself what the goal of the applied cerclage in a certain patient has to be. Is it maximal tension or maximal load to failure, or even both? Reaching higher tension when using metallic cerclage might be desirable when fracture apposition is the goal, but when tightening soft tissues this might cause necrosis. In the prevention of subsidence in prosthesis too much tension is also not necessary and theoretically might cause bone necrosis. A high load to (clinical) failure when using for example FiberWire seems desirable in all repair techniques, including fracture repair or prevention of subsidence in prosthesis placement. So, when selecting a technique, the biomechanical goal of cerclage has to be evaluated and is an important aspect to consider before each surgical repair.

Looking at the technical aspects of metallic cerclage, there are more pitfalls in practise than one would expect. Even twisting or bending metal wires influences the efficacy of the fixation and if it is done incorrectly, this can lead to tension loss of up to 90%. Thus, when using metal cerclage as fixation, either wires or cables, it is recommended to use power tools. Nonetheless, even when power tools are used tension loss is seen in biomechanical studies. In comparison to metallic cerclage non-metallic cerclage has less disadvantages. It is easier to apply, it is less traumatic to the surrounding soft tissue, there is no need for power tools, there is no interference with radiologic imaging and there is no risk for metallosis [9,11]. Another major benefit is that there is usually no indication or necessity for removal of non-metallic cerclage.

Among the discussed knots for non-metallic cerclage, the nice knot seems to be the best choice, because it showed the least elongation and it is easy to perform due to the self-gliding and locking principle [11,12,15]. The necessity of adding half-hitches has been established already for some time in different knots. In these studies we note that for the nice knot adding two half-hitches is sufficient, while for other knotting techniques minimum 4 half-hitches have to be used. The Supercable also shows promising results in clinical studies, but biomechanical information is lacking and power tools are necessary.

Considering the biological aspects, the cortical bone seems to withstand the static concentric compression of metallic cerclage, although compression areas of the metallic cerclage showed regional strangulation of the cortical vascularisation [2]. Nonetheless recovery of the strangulation is seen after removal and the strangulation theory of metallic cerclage is being abandoned more and more in literature [1,2]. Since current existing non-metallic materials produce a lower pretension than the metallic cerclage, the likelihood of strangulation is even smaller and therefore biological studies on bone necrosis are probably considered obsolete and are currently not found. If a fracture in an elderly patient with poor bone quality has to be treated with cerclage, theoretically a non-metallic cerclage could be a safer option, although this hasn't yet been proven clinically.

Conclusion

During the last years a lot of literature and clinical experience in non-metallic cerclage became available. Different authors have advocated the use of non-metallic cerclage to treat not only soft tissue but also many different types of fractures. Also in our practise, during the last 10 years, we routinely use non-metallic cerclage.

Considering the biomechanical, technical and biological aspects this review supports the increasing use of non-metallic cerclage. In the majority of operations, especially in the upper limb, metallic cerclage can be replaced by non-metallic cerclage techniques. When treating peri-prosthetic or other fractures in the lower limb, cerclage should be able to withstand greater forces and both metallic or non-metallic cerclage are considered viable options. As a final conclusion we believe that the choice of the cerclage technique and cerclage material should not be taken lightly and should depend on the indication, the location and involved tissue.

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