



Is Nice knot suture comparable to wire for cerclage fixation? A biomechanical performance study



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Background: Cerclage fixation is a known orthopedic technique shown to be beneficial for circumferential augmentation when screw fixation cannot be used or is undesirable. However, ongoing advances in suture materials and knot techniques exist, and there is a paucity of evidence existing which evaluates comparisons between the two. The objective of this study was to investigate the strength and durability of cerclage fixation between the Nice knot suture technique and monofilament wire.

Methods: Static displacement over time and compression load testing were analyzed. Compression testing was conducted with the Jamar Hydraulic Hand Dynamometer. Distraction testing was conducted using the Instron test system with its associated program. The Nice knot was tied using number 2 and number 5 FiberWire (Arthrex) and compared to monofilament wire. Clinical failure (displacement of 10 mm), absolute failure (opening of the knot or material failure), maximum compression achieved, and steady state compression maintained were the outcomes of interest.

Results: Double-stranded monofilament wire produces maximum consistent compression of 90 kg, followed by single-stranded monofilament wire (60 kg). Number 5 FiberWire has a higher maximum compression load than number 2 FiberWire (50 kg vs. 22 kg), but it is lower than that of the double-stranded monofilament wire constructs. When compared to the single-stranded monofilament construct, the number 5 FiberWire Nice knot is comparable ($P < .05$). Average steady state compression achieved after 10 minutes of resting showed double-stranded monofilament wire to be 65 kg compared to single-stranded monofilament wire at 42 kg, which when, compared to suture, number 5 FiberWire measured at 15 kg and number 2 FiberWire at 8 kg. Average tension results from Instron distraction testing showed the double-stranded monofilament wire construct was able to withstand greater forces up to a displacement of 6 mm, after which the number 5 FiberWire Nice knot was stiffer. Number 5 FiberWire shows the most linear tension relationship, revealing it more efficiently withstands elastic forces. Load to failure was higher in the number 5 FiberWire Nice knot construct than that in both the monofilament wire constructs. The modes of failure for the Nice knot were always at the knot suture interface rather than at the knot.

Conclusion: We propose this suture technique to be a viable alternative method for cerclaging to fix upper limb long-bone fractures.

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Cerclage fixation is a known orthopedic technique shown to be beneficial for circumferential augmentation when screw fixation cannot be used or is undesirable for cylindrical long-bone injuries such as in subtrochanteric fractures⁶ or in the management of periprosthetic shoulder and total hip arthroplasty.¹ Monofilament wire is widely used and is still considered the standard of practice,

with stainless steel being the preferred material because of its availability and affordability.¹²

However, common pitfalls with the use of the wire cerclage technique such as radiographic interference,¹¹ metallosis, and nonunion have been demonstrated. The wires also pose an intra-operative risk to the surgical team because the sharp ends may perforate surgical gloves and cause puncture wounds.

Modern suture materials have become more refined and robust with increased strength and availability.^{9,11} Furthermore, they do not pose the same risks as wire fixation. Multiple studies have examined the best knot types and tying techniques. The Nice knot is a double-stranded knot that outperformed other commonly used

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Figure 1 Jamar Hydraulic Hand Dynamometer with number 5 FiberWire demonstrating compression testing.



Figure 2 Instron testing system.

knots, such as the surgeons knot demonstrating superior biomechanical characteristics for clinical use.⁵ However, biomechanical comparison studies between wire and suture fixation have not been performed under standardized techniques.

The primary purpose of this study was to compare the biomechanical properties of the Nice knot using modern suture material as an alternative to monofilament wire in regard to cerclage fixation.

Methods

Static displacement over time and compression load testing were analyzed. The Nice knot was tied using number 2 and number 5 FiberWire (Arthrex) and compared to monofilament wire. Sutures were secured around 4 half hitches using 2 suture graspers. A 1.2-mm 18-gauge stainless steel monofilament wire with 12 twists was used for comparison. Two orthopedic surgery residents each tied 3 trials with every knot/material combination.

Compression testing was conducted with the Jamar Hydraulic Hand Dynamometer (Fig. 1). Each material was sequentially tied around the hand dynamometer in the same place as indicated by the tape marked with a permanent marker. Initial maximum compression was measured at the moment of tying. This was followed by readings 10 minutes after tying to measure the steady-state compression achieved or the amount of compression maintained by the construct.

Distraction testing was conducted using the Instron test system with its associated program (Figs. 2–4). Each material was tied around the Instron machine by anchoring to the base cylinder and tying to the displacement bar above. A constant displacement speed of 0.2 mm/s was applied until either the construct failed through rupture or clinical failure was achieved (defined as 10-mm displacement). This allowed average tension, defined as force/

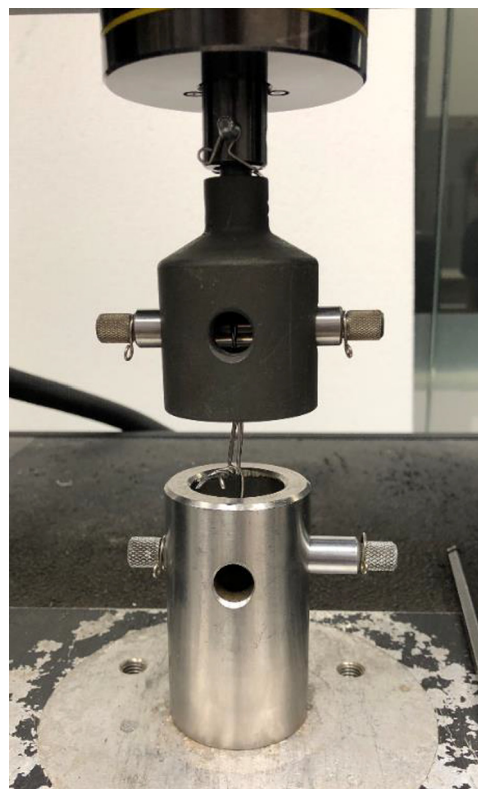


Figure 3 Instron testing system demonstrating distraction testing with cerclage wire.

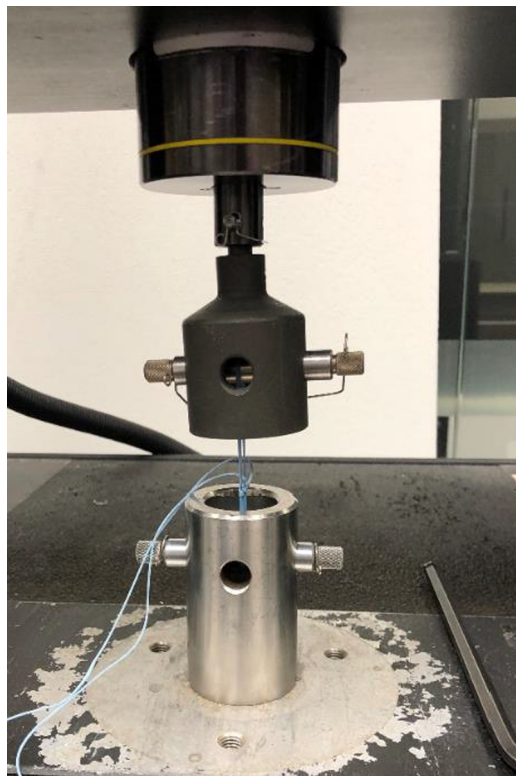


Figure 4 Instron testing system demonstrating distraction testing with number 5 FiberWire.

displacement, to determine stiffness, knot security and site, and load to failure

Results

Average tension

Number 5 FiberWire shows the most linear tension relationship when compared to the other materials showing ability to withstand elasticity/plastic deformation more efficiently than the other constructs by distributing the load along both the knot and bone-suture interface (Fig. 5). Although greater force is needed to cause up to 6 mm of displacement in double-stranded cerclage wire, number 5 FiberWire surpasses this beyond 6 mm. We believe this is due to the “give” in the suture which, upon reaching a maximum value, becomes a stiffer construct than the double-stranded cerclage wire. For load to failure, double-stranded cerclage wire and number 5 FiberWire withstood higher tensile loads than number 2 FiberWire or single-strand cerclage wire. Number 2 FiberWire demonstrates the lowest load to failure with 400 N causing failure at 4-mm tension. Both the cerclage wire constructs failed earlier than the number 5 FiberWire Nice knot demonstrated by leveling out of the cerclage wire graphs earlier than the end point of the FiberWire. All test samples met the criteria for clinical failure with no suture material failing at the knot but rather at the suture-knot interface.

Maximum compression

Double-stranded monofilament wire produces maximum consistent compression of 90 kg, followed by single-stranded monofilament wire (60 kg) (Fig. 6). Number 5 FiberWire has a higher maximum compression load than number 2 FiberWire (50

kg vs. 22 kg). The number 5 FiberWire Nice knot generates compression comparable to that of the more commonly used single-stranded cerclage wire ($P < .05$).

Average steady-state compression

Monofilament cerclage wire produced the highest steady state compression with double-stranded wire producing more compression than single-stranded (65 kg vs. 42 kg) (Fig. 7). When compared to suture material, number 5 FiberWire measured 15 kg compared to number 2 FiberWire which measured 8 kg. All materials saw a decrease from their respective maximum compression tests.

Discussion

Various treatment options for reducing and fixing fractures have been reported to obtain stable fixation including cerclage wiring, plating, and interfragmentary lag screw insertion.^{4,7,13} Testing of specific suture types and cerclage wiring have been conducted showing number 5 FiberWire has the closest material properties to 1.25 stainless steel wire.¹⁰ However, no systematic testing has occurred to determine the biomechanical properties of cerclage wiring vs. the less commonly used Nice knot suture technique. Cerclage techniques are typically used for 2 purposes: first, to reduce displaced fractures; and second, to prevent propagation of the fracture.

We showed that although the double-stranded 1.25-mm steel wire had the highest maximal compression, number 5 FiberWire Nice knot had a comparable maximal compression to the more commonly used single-stranded 1.25-mm wire. This demonstrates that number 5 FiberWire and single-stranded 1.25-mm wire have a comparable ability to compress a fracture and achieve a successful fracture reduction. Maximum compression achieved by number 5 FiberWire Nice knot falls within the recommended limits by tensioning technique systems.³ Monofilament wire is considered to be too high with hypothesized devascularization and bone death occurring from this.¹¹

The Average Steady State Compression achieved by number 5 and number 2 FiberWire sutures with Nice knot were less than that achieved with double- and single-stranded wires. This implies FiberWire suture with Nice knot alone has a lower ability to maintain a reduction than both single- and double-stranded cerclage wires. We, therefore, do not recommend the use of sutures alone for fixation of fractures. In our clinical application, we use FiberWire suture with Nice knot as supplementary fixation in conjunction with plating or intramedullary fixation, for example, suture cerclage of comminuted fragments and plate fixation of a clavicle fracture (Figs. 8–10).

We believe there are many advantages in using the suture Nice knot as an aid to augment comminuted fracture reduction. First, it is technically easier to circumferentially pass around the diaphysis of bone compared to cerclage wires or lag screws. A mayo needle is loaded with the FiberWire suture, and the blunt end is passed subperiosteal in a controlled fashion until it is seen on the other side. The suture is retrieved, and the Mayo needle is then withdrawn. This ease of technique also limits the amount of periosteal stripping that occurs when compared to passing a steel wire around a bone or a lag screw, thus potentially decreasing the risk of nonunion.

Compared to the steel cerclage wires, the FiberWire is low profile allowing many sutures to be placed to augment fracture fixation without effecting plate and screw positioning.

If fracture fixation after plating is found to be inadequate, the suture Nice knot can then also be used as augmentation around the

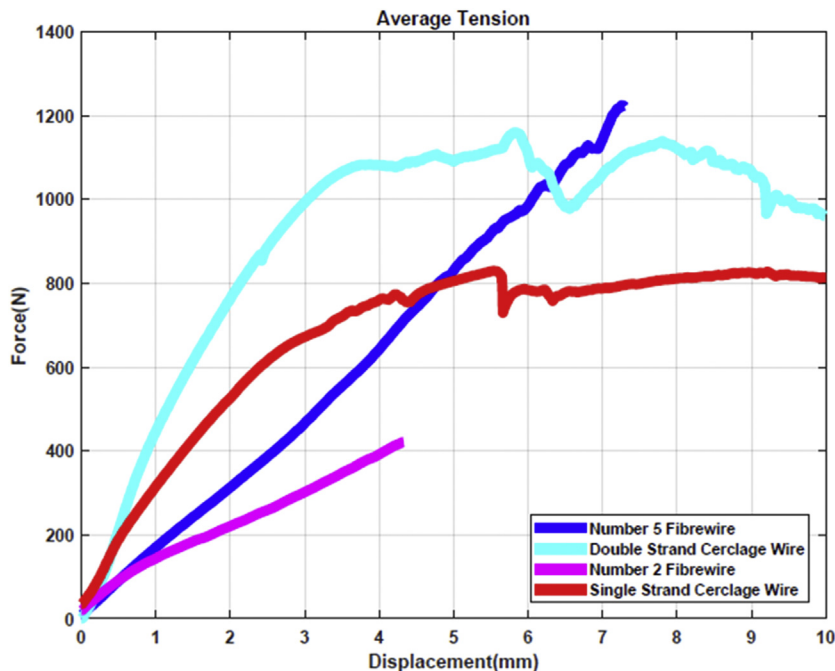


Figure 5 Average tension/load to failure.

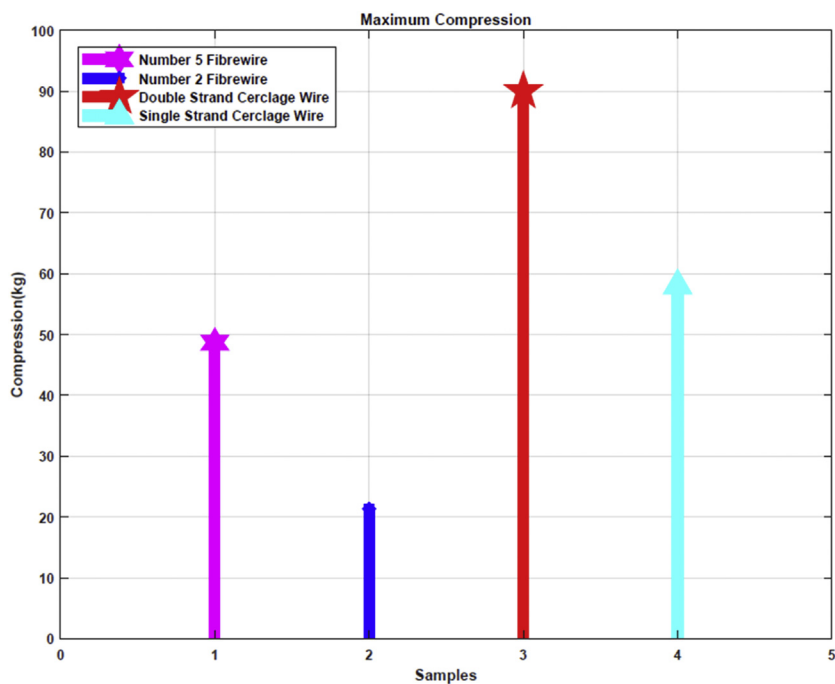


Figure 6 Maximum compression.

plate in place of screws as an alternative mode of fixation of the pate.

Finally, there is less risk of stick injuries while still being able to maintain adequate reduction of fractures.

As described by Lenz et al,⁸ failure of all cerclage wires occurred by unravelling of the twists or wire breakage at the innermost turn. On distraction testing to failure, number 5 FiberWire Nice knot also maintains tension through a wider range of forces to cause displacement/lengthening and requires

higher forces to failure than other materials. FiberWire was observed to always fail at the knot suture interface and never by knot slippage, demonstrating the failure is due to an inherent property of the suture material rather than the strength of the knot which is maintained. We showed failure of the suture occurred in a more linear pattern than the steel wires showing the suture material may be able to compensate for its elasticity by being able to distribute load through the suture and bone.¹¹

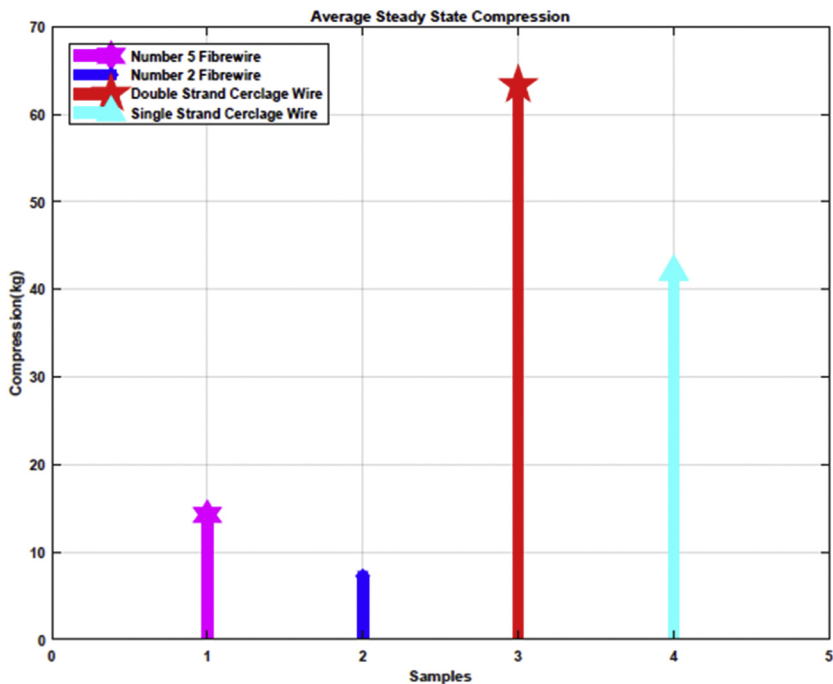


Figure 7 Average steady-state compression.



Figure 8 First clinical application example of the number 5 FiberWire Nice knot to achieve reduction of comminuted fracture patterns augmented by plate and screw fixation for clavicle fractures.

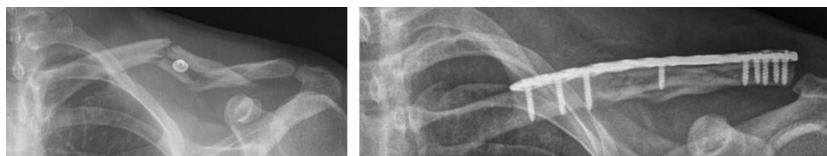


Figure 9 Second clinical application example of the number 5 FiberWire Nice knot to achieve reduction of comminuted fracture patterns augmented by plate and screw fixation for clavicle fractures.



Figure 10 Third clinical application example of the number 5 FiberWire Nice knot to achieve reduction of comminuted fracture patterns augmented by plate and screw fixation for clavicle fractures.

There are some limitations of this study, with the main one being testing being performed in static laboratory-based models. The next progression of biomechanical study will be to perform similar tests on cadaver bones or similar.

Despite the aforementioned limitations, our results appear to be in line with current data of cerclage fixation in orthopedics.^{2,4,13,14}

Conclusion

We propose this suture technique to be primarily used as a supplementary or augmentation for fracture reduction and fixation in conjunction with the use of plates and screws to fix upper limb fractures.

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