Original Article

A Biomechanical Study Comparing Cerclage Wiring Performed with a Power Tool versus the Manual Method

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Abstract

Introduction: We conducted a biomechanical study comparing cerclage wiring using a power tool with the traditional manual method. Materials and Methods: Our study consisted of 4 experimental arms based on the method of fixation and diameter of wires. The 4 arms were: 1) power tool method using 0.8 mm cerclage wires, 2) power tool method using 1.0 mm cerclage wires, 3) conventional manual method using 0.8 mm cerclage wires, and 4) conventional manual method using 1.0 mm cerclage wires. Synthetic femur bones were employed in our study. Six specimens were prepared for each arm. Each specimen was cut lengthwise and pressure sensors were placed in between. For the power tool method, while maintaining tension, wires were coiled using the Colibri power tool until just before secondary coiling occurred. For the conventional manual method, each specimen was compressed by plier twisting for 10 rounds, while maintaining tension. Cerclaging and data recording was done thrice for each specimen, giving a total of 18 readings per arm. Peak and steady-state forces were recorded. Results: There was no significant difference between the peak forces recorded between the power drill and manual methods. The steady-state forces achieved using the power tool method were significantly higher than that achieved in the manual fixation method (0.8 mm wires: 54.89N vs 27.26N, *P* = 0.037; 1.0 mm wires: 71.59N vs 39.66N, *P* = 0.025). Conclusion: The power tool method achieved a superior steady-state force of compression across the fracture site for both 0.8 mm and 1 mm wires.

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Key words: Conventional method, Peak force, Periprosthetic, Steady-state force

Introduction

Cerclage wiring is a valuable technique used widely in orthopaedic surgery to compress and secure bony or soft tissue elements. Its usefulness extends through the various specialties including trauma and fracture fixation, tumour surgery and arthroplasty (especially in revision total hip replacements).[1-6] Its indications/uses include primary fracture fixation either alone or in combination with other fixation devices (ie. plate, intra-medullary nail, pins, K-wires), provisional fixation, as a reduction tool, as a tension band, allograft fixation and compression, as well as compression arthrodesis.[7] This technique represents a cheap, reliable and versatile method that can be used in various surgical situations, whether primarily or as an augment to other techniques.

By convention, tightening of cerclage wires is done manually using wire gripping devices such as pliers, wire holding forceps, cerclage twisters or jet wire tighteners. These methods can be slow, cumbersome and can also be subjected to operator fatigue. Commercially available wire twisters can be expensive and not so easily available in the operating theatres. We describe a novel way of tightening cerclage wires using a power tool, and compared it to the conventional manual method in terms of tightening properties via a dry lab study involving synthetic sawbones, and propose this as a simple, inexpensive and readily available alternative to the usual manual technique.

Materials and Methods

Our study consisted of 4 experimental arms based on the method of fixation and diameter of wires as detailed in Figure 1. The 4 arms were: 1) power tool method using 0.8

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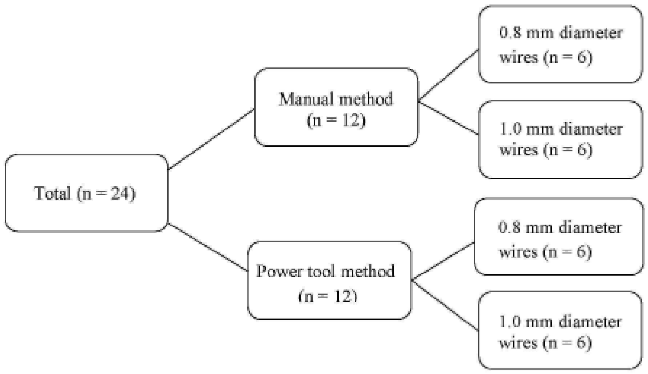

Fig. 1. Chart showing the four experimental arms.

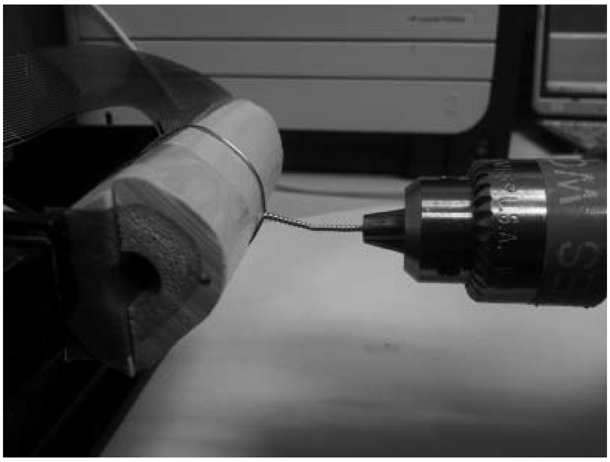

Fig. 2. Each synthetic femur bone specimen was cut into half lengthwise and pressure sensors were placed in between the fragments. The fragments were subsequently compressed via cerclage wiring.

mm cerclage wires, 2) power tool method using 1.0 mm cerclage wires, 3) conventional manual method using 0.8 mm cerclage wires, and 4) conventional manual method using 1.0 mm cerclage wires.

We included cerclage wires of different diameters to analyse if our method is consistently superior across different thickness of wires. Synthetic femur bones (Synbone© model number 2162) were employed in our study. Six specimens were prepared for each arm. Each specimen was cut into half lengthwise and pressure sensors were placed in between the fragments (Fig. 2). K-scan 4000, a piezoresistive contact pressure sensor system (Tekscan, South Boston, Massachusetts), with a standard pressure range of 62.1 MPa, and sensor density of 62 per cm^2, was used. Resistive pressure sensors have been reported to have higher accuracy and reproducibility than pressure sensitive film for contact pressure measurements.[8,9] The pressure sensors were calibrated according to manufacturer specifications before each specimen testing.

For the power tool method, we used stainless steel wires 40 cm in length; 5 cm from each end of the wire was fed into the K-wire attachment and tightened. While maintaining tension, the wires were coiled using the power tool (Colibri Power tool, Synthes; speed up to 3200 rpm) until just before secondary coiling (Fig. 3) occurred. At this point, the fracture site does not undergo further compression even if trigger depression on the power tool is maintained. Excessive secondary coiling also weakens the wire construct and may cause the wires to break. Real time data recording was started prior to power drilling.

For the conventional manual method using a pair of pliers, we used wires 30 cm in length. Each specimen was compressed by plier twisting for 10 rounds, while maintaining tension. The plier-to-bone distance was maintained at 10 mm. Real time data recording was starting prior to pliers twisting.

For each specimen, we repeated the cerclaging and data recording steps thrice, each time with new wires. With 6 specimens in each arm, this gave a total of 18 readings for each arm. The peak force was taken to be the maximum force recorded. Data recording was allowed to continue after each individual wire was either removed from the power drill, or released from the pliers, and the steady-state force was taken to be the value at which the force-time graph reached a plateau. A sample graph of data recording is shown in Figure 4.

Statistical analysis was carried out using SPSS (11 version 11.0; SPSS, Chicago, Illinois). Mann-Whitney tests were carried out to compare peak forces and steady-state forces recorded between manual and power drill fixation, as well as between 0.8 mm and 1.0 mm diameter wires. $P < 0.05$ was taken to be statistically significant.

Results

The results of our study are detailed in Tables 1 and 2. Our results indicate that there was no significant difference between the peak forces recorded between the power drill and manual methods. Likewise, for each method of fixation, there was no significant difference between the peak forces between fixation using the 0.8 mm and 1.0 mm diameter wires.

For the steady-state forces, within each method of cerclaging (power drill and manual fixation), there was no

Fig. 3. Secondary coiling of wires.

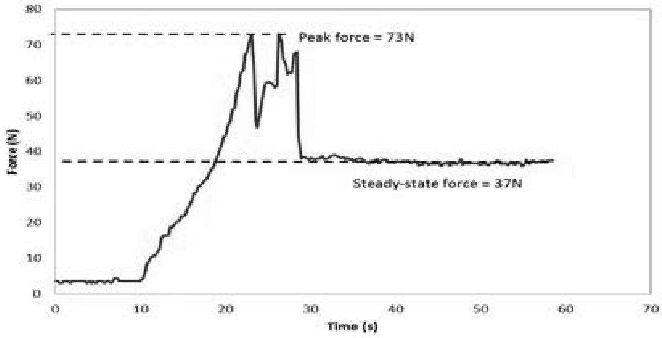

Fig. 4. Sample graph depicting the peak and steady forces recording with each sample.

significant difference between using 0.8 mm and 1.0 mm diameter wires. However, the steady-state forces achieved using the power tool method were significantly higher than the values achieved using manual fixation (54.89N vs 27.26N for 0.8 mm wires, 71.59N vs 39.66N for 1 mm wires). This difference is statistically significant, $P = 0.037$ and 0.025 respectively.

Discussion

Dry lab testing with synthetic saw bones showed that the power tool method achieved a greater steady-state force of compression across the fracture site for both 0.8 mm and 1 mm cerclage wires. The steady-state force, compared to the peak force, represents the amount of compression across the fracture site once the cerclage procedure is completed, and is the more clinically relevant reading of the 2.

The lack of significant difference in the peak and steady-state forces between the 2 diameters of cerclage wires suggests that the method of cerclaging is the key variable responsible for the amount of compression across the fracture site. This is in contrast to what Bostrum et al[10] found where increasing the diameter of the wire by 50% resulted in a load-to-failure of up to 169% and doubling the wire diameter from 0.45 to 0.98 mm increased the load-to-failure more than 300%. This disparity in findings could be due to the fact that we only used 2 different diameters in our study, and an increase of 0.2 mm in diameter represents only a 25% increase. To further study the effect of size of cerclage wires on pressure across fracture site, more sizes of wires could be used in a future similar study. Other factors such as knot configuration[11] and number of loops[12] also affects fixation strength but this was beyond the scope of our study, whose primary aim was to compare 2 different methods of tightening.

Lenz et al[13] explored the contact distribution of cerclage cables and wires at the circumferential cerclage-bone interface with a ex-vivo set-up similar to ours. They found that although cables cover larger contact areas, both cerclages exhibited an inhomogenous interface pressure distribution depending on bone surface geometry. Histology revealed intact contical bone after loading with both cerclage types. They thus concluded that cerclage-bone interface contact is dependent on surface geometry of the bone, cerclages provide a blood supply preserving point contact

Table 1. Peak Force (N)

Wire Diameter (mm)	Power Drill	Manual	
0.8 mm	79.52 +/- 32.32	55.91 +/- 9.91	$P = 0.337$
1.0 mm	105.48 +/- 13.77	79.98 +/- 28.08	$P = 0.109$
	$P = 0.109$	$P = 0.337$	

Note: No significant differences between the methods or cerclage wire diameters used.

Table 2. Steady-state Force (N)

Wire Diameter (mm)	Power Drill	Manual	
0.8 mm	54.89 +/- 23.81	27.26 +/- 6.72	$P = 0.037^*$
1.0 mm	71.59 +/- 14.00	39.66 +/- 22.36	$P = 0.025^*$
	$P = 0.262$	$P = 0.522$	

*Statistically significant

Note: The power drilling method produced significantly higher steady-state forces than the manual method for both diameters of cerclage wires used. No significant difference between the cerclage wire diameters used.

fixation, and that cortical damage and resorption is due to micromotion rather than the centripedal forces of the loaded cerclage. Our study, which explores the pressure effects of 2 different methods of cerclage wiring in a similar ex-vivo set-up, adds to the existing biomechanical knowledge on cerclage wiring.

Frisch et al[14] explored the biomechanical response of different cerclage systems for fixation of periprosthetic femur fractures on synthetic femurs and found that cobalt-chrome cables and hose clamp had the highest construct stiffness and least reducton in stiffness with increased loading in an ex-vivo study that also included monofilament wires and synthetic cables. However, for the purpose of our study using the power tool method, cables would have been too large to fit into the opening of the power tool. Wires are also the most commonly available option in any standard orthopaedic set and thus was used in our study.

The power tool cerclage wiring technique is relatively simple to perform and offers an effective method of tightening multiple cerclage wires at a single setting. This method can be considered as a viable alternative to the conventional method of cerclage tightening, which is time consuming, and subject to operator fatigue. Although there are various commercially available cable tighteners and crimpers, the power tool method utilises instruments readily available in any standard orthopaedic fracture fixation set. In addition, the conventional manual method of cerclaging requires a larger working space because the pliers need to be close to the fracture site to achieve adequate compression. On the other hand, in fractures where access might be impeded by surrounding soft tissue, the power tool method allows compression to be carried out in a tight working space.

The limitations of our study includes the fact that this is an in vitro study which investigates the mechanical forces across the fracture site and does not characterise the biological healing as observed in an in vivo study. In addition, this study measures the compressive forces at the time of fixation, and not the long-term compressive force. However, even in an in vivo model, measurement of long-term compressive forces can be difficult to achieve. Also, there is more working space in our experiments as compared to a surgical setting where working space is limited by soft tissues. However, we have ensured that both types of cerclaging are carried out under the same experimental settings.

Conclusion

The power tool cerclage wiring technique has demonstrated a superior steady-state compressive force across a fracture site in synthetic bone in a dry laboratory setting. This is consistent across 2 common cerclage wire diameters. The findings from our study can be used as a primer in future cerclage wiring studies using a power tool in an actual clinical setting, and clinical outcomes can be recorded to demonstrate that this method is not inferior and may be more efficient and effective than the conventional method.

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