Knot strength of nylon-band cerclage

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Nylon bands of five sizes were tested to failure using a splint circular jaw mounted on a tensile testing machine. Four treatment groups of each of the five sizes were tested: as supplied by the manufacturer, ethylene oxide sterilized, autoclave sterilized, and saline-soaked. Comparisons were made between groups and to previously reported results of similar testing of stainless steel wire of three sizes. All the bands failed at the lock mechanism. Knot strength increased with increased size of nylon band. There was no difference between untreated and ethylene oxide sterilized bands, whereas bands subjected to autoclaving or saline soaking failed at less force. The knot strength of all the treatment groups in the three smaller sizes of bands was less than twist-knotted 0.8-mm wire cerclage; and when soaked in saline for 24 hours, the knot strength of the two largest size bands dropped to less than 1.2-mm twist-knotted wire.

Nylon bands have particularly been recommended for use in fixation of fractures in the elderly with osteoporotic bones (Partridge and Evans 1982). In experimental femoral osteotomies fixed using nylon straps, longitudinal and/or lateral displacement of the osteotomies occurred. This was attributed to lengthening of the straps in vivo either by stretching of the nylon or by loosening of the locking mechanism (Rhinelander and Stewart 1983). A retrospective report of 50 patients whose median sternotomy incisions were closed with nylon bands found a higher incidence of complications compared with patients with standard closure techniques (Sanfelippo and Danielson 1972). Many complications were attributed to slippage of the band through the lock or breakage of the band early in the postoperative period. The superior knot-slip resistance of twist-knotted wire cerclage over loop-knotted wire cerclage and metal-band cerclage has been reported, suggesting that fixation with multiple cerclage wires may be stronger than similar fixation with bands (Wilson 1988).

We evaluated the knot strength of nylon bands and the effect of sterilization and saline soaking, and compared the strength with wire cerclage.

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Materials and methods

Commercially available nylon cable ties of five sizes were used (Pan-Ty®, Panduit Corp Electrical Group, Tinley Park, IL, USA). The five sizes were PLT1.5M (2.5 mm wide, referred to as miniature), PLT1.5I (3.6 mm wide, intermediate), PLT1.5S (4.8 mm wide, standard), PLT2H (7.6 mm wide, light-heavy), and PLT5H (9.0 mm wide, heavy). Ten bands of each of these five sizes were tested under four conditions. The *untreated* group was tested as supplied from the manufacturer. The *ethylene oxide* group was packaged in polyethylene bags, sterilized in ethylene oxide for 12 hours at 22 °C (Anprolene Co., Naperville, IL, USA), and allowed to aerate for at least 24 hours. The *autoclaved* group was double-wrapped in cotton-barrier wraps and sterilized in steam at 18 kg/cm^2 for 30 min. The *saline* group was immersed in sterile physiologic saline for 24 hours prior to tensile testing. The miniature, intermediate, and standard size bands were applied to predetermined tension as recommended by the manufacturer using a GS2B installation gun and the light-heavy and heavy bands were applied using a GS4H installation gun. All the bands were applied to a 2.5-cm-diameter split circular jaw mounted on a tensile testing machine (MTS tensile testing machine type T5002, Minneapolis, MN, USA). Output was recorded on a X-Y potter with load at failure (knot resistance) measured in newtons and deformation measured in mm. All the specimens were run at a

Table 1. Load to failure (newtons) of nylon bands tested under tension. Mean, *SD* and percent load compared with untreated in brackets for 10 bands per group

	Miniature	Intermediate	Standard	Light-heavy	Heavy
Untreated	112 *31*	225 *27*	314 *22*	972 *51*	1338 *87*
Ethylene oxide	101 *9* (90)	206 *21* (92)	301 *34* (96)	794 *59* (82)	1439 *61* (108)
Autoclaved	71 *19* (63)	144 *10* (64)	198 *16* (63)	547 *33* (56)	671 *193* (50)
Saline-soaked	34 *6* (30)	87 *16* (39)	167 *16* (53)	463 *58* (48)	777 *223* (58)

Table 2. Comparative knot slip resistance for wire and nylon cerclage. Mean *SD* for 10 specimens per group. Data for twist-knotted wire cerclage from Wilson 1988

	Stainless steel wires			Nylon bands	
	0.8 mm	1.0 mm	1.2 mm	Intermediate	Light-heavy
Untreated	362 *7*	560 *11*	887 *23*	225 *27*	972 *59*
Autoclaved				144 *10*	547 *33*
Saline-soaked				87 *16*	463 *58*

cross-head speed of 30 mm/min. Testing was stopped once complete disruption of the band was achieved.

The force-deformation curves for each test group of each band size were digitized and an average curve drawn. The data for groups and band sizes were analyzed by one-way analysis of variance, with a P-value < 0.01 considered significant.

Results

Autoclaving bands discolored them yellow, and they were subjectively more brittle. Ethylene oxide-sterilized bands could not be distinguished from untreated bands. Saline-soaked bands were indistinguishable in appearance from untreated bands, but were subjectively more pliable. The saline-soaked bands stretched visibly and sometimes broke while being tightened. All the other bands were automatically cut by the applicator gun. The saline-soaked bands visibly stretched during testing. All the bands failed at the lock mechanism. In 17 of 20 groups, the band simply pulled out of the lock. In the three largest sizes of autoclaved bands, the lock broke.

Knot-slip resistance increased with increased width of bands (Table 1). There was no difference between untreated and ethylene oxide-sterilized bands. Knot-slip resistance decreased in all the sizes when bands were autoclaved (average 59 percent of untreated load) and even further decreased when bands were soaked in saline. Only the two largest sized saline-soaked bands had mean peak loads equaling even the smallest gauge (0.8 mm) twist-knotted stainless steel wire (Table 2).

Discussion

Advantages cited for the clinical use of nylon cerclage bands in preference to wire cerclage include ease and speed of application (Schmidt and Davis 1981). Decreased intraoperative injury to soft tissues, decreased manipulation required at the fracture site, accurate maintenance of reduction while primary fixation was applied, and lack of scuffing of metal plates as may occur with metal clamps were

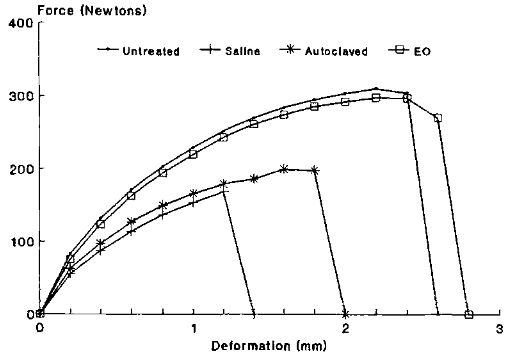

Figure 1. Force-deformation curves for four treatments of standard nylon bands tested to failure using a split circular jaw mounted on a tensile testing machine. EO ethylene oxide sterilized.

also cited as advantages (Schmidt and Davis 1981). Commercially available nylon bands are manufactured of nylon 6/6, a biologically inert material, and several studies have supported minimal tissue reactivity (Strömberg and Karlström 1986, Nolan et al. 1980). The light weight of nylon bands may be advantageous in certain applications (MacCoy and Haschk 1988). Slight lengthening of the nylon bands was considered advantageous in that it was considered responsible for the lack of impairment of the underlying cortical vascularity.

A substantial decrease in maximal torque capacity of rabbit femurs banded with nylon straps for 8 weeks was attributed to cortical atrophy under the nylon bands (Strömberg and Karlström 1986). A time-dependent decrease in applied tension of the implants was noted, but was not considered clinically important. However, another study noted slight displacement of fracture fragments attributed to loosening of the nylon bands (Rhinelander and Stewart 1983). In a retrospective clinical study, nylon bands alone were considered insufficient internal fixation for primary fractures of the femur or fractures in the vicinity of a hip prosthesis, and their use as sole fixation in those instances has been abandoned (Partridge and Evans 1982). Nylon cerclage has been associated with high incidences of wound dehiscence and wound infection (Sanfelippo and Danielson 1972).

Our study shows that nylon bands are adversely affected by autoclaving, but not ethylene oxide sterilization. The manufacturer rates nylon 6/6 ties for temperatures not exceeding 85 °C. When the fluid environment of in vivo used nylon bands was simulated by saline soaking, a dramatic decline in their load to failure was found. The fluid environment of the body may thus be responsible for loosening of bands. The manufacturer reports water absorption by nylon bands of as much as 8.5 percent in a 100 percent relative humidity environment, resulting in a 50 percent reduction of tensile strength (Panduit Corp Wiring Products Catalog). We observed even greater loss of tensile strength in a saline environment.

Twist-knotted stainless steel wire cerclage has superior knot resistance compared with miniature, intermediate, and standard nylon bands. Although the two largest size untreated and ethylene-oxide sterilized bands achieved failure loads greater than 1.2-mm stainless steel wire, when autoclaved or saline soaked the knot resistance was less. These largest bands are very stiff and would be difficult to apply tightly around an irregular-shaped bone. The width of the larger nylon bands would allow fewer band than wires to be applied over the same cortical area, thus total strength of fixation would be less with bands than wires. The width of the larger nylon bands may be detrimental to cortical vascularity (Brookes and Heatley 1980).

We conclude that wire cerclage is superior to nylon band cerclage for all applications except temporary intraoperative fixation of fractures.

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