BIOMECHANICAL EFFECTIVENESS OF TAPING THE A2 PULLEY IN ROCK CLIMBERS

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Circular taping around the proximal phalanx is frequently used by rock climbers to treat tenosynovitis and to prevent injuries to the A2 pulley. The aim of this study was to determine the biomechanical effectiveness of such taping. Devices were built to measure physiological bowstringing in vivo, and to determine the force of bowstringing as well as the force applied to the pulley tape. Two kinds of taping on 16 fingers were measured during the typical crimp grip position. Taping over the A2 pulley decreased bowstringing by 2.8% and absorbed 11 % of the force of bowstringing. Taping over the distal end of the proximal phalanx decreased bowstringing by 22% and absorbed 12% of the total force. Circular taping is minimally effective in relieving force on the A2 pulley. It is probably ineffective in preventing pulley ruptures.

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Many rock climbers complain of pain over the A2 pulley and more rarely over the A4 pulley (Bollen and Gunson, 1990; Cartier et al., 1985; Hochholzer et al., 1993; Rooks 1997). The most often used finger position in rock climbers is the crimp grip (Bollen, 1988). To maximize the contact between the fingertips and shallow ledges and to allow the use of the thumb as an additional holding force, the PIP joints are flexed to 900 or more and the DIP joints are hyperextended. The A2 and A4 pulleys are maximally stressed in this position (Hume et al., 1991) and it is probably the reason for the pain. The fact that the pain disappears when the climber uses a slope grip with the PIP joint not flexed more than 40-600 indicates that probably the pulleys are the site of the pain. It seems that the pain is due to repetitive micro trauma or chronic overstrain of the pulleys rather than partial or complete ruptures (Hochho1zer et a1., 1993). Clinically there is a painful area over the site of the pulley but increased bowstringing is not detectable. However, it is not possible to exclude an isolated rupture of the A2 pulley clinically because it does not result in increased bowstringing (Marco et al., 1998). CT Scan (Le Viet et al., 1996) and MRI (Heuck et al., 1992) can be used to diagnose a ruptured A2 pulley.

Commonly rock climbers try to treat pain or tenosynovitis by application of a circular tape around the phalanx to relieve the load on the pulley (Bollen, 1990; Bollen and Gunson, 1990). They also try to prevent injuries to the A2 pulley by application of a tape (Bollen, 1990; Bollen and Gunson, 1990; Cartier et al., 1985; Gabl et al., 1992; Moutet et al., 1993). The aim of this study was to determine the biomechanical effective- ness of two different kinds of taping for the A2 pulley.

MATERIALS AND METHODS

Physiological bowstringing of the flexor tendons against resisted flexion in the crimp grip position is palpable in vivo. Bowstringing can be defined by the distance of the flexor tendons from the bone and by the force acting in the direction of bowstringing. These two parameters have been used to determine physiological bowstringing. The distance of physiological bowstringing and the ability of pulley taping to decrease bowstringing were measured. The force of physiological bowstringing and the amount of force on the pulley taping during crimp grip were also determined.

Distance measuring device (Fig 1)

This custom-made device was composed of two parts, which moved against one another around a central axle in a scissors-like fashion. The finger was clamped by two measuring arms in an anterior to posterior direction and compressed constantly bya spring. The force applied by the spring did not increase compression by more than 0.1 mm and did not disturb physiological bowstringing during measurement. As bowstringing occured, the two arms were pushed apart and the distance was measured by a scale to an accuracy of 0.05 mm.

Force measuring device (Fig 2)

This custom-made device was also composed of two main parts, which moved against one another around an axle in a clamp-like fashion. The finger was compressed by the two arms in an anterior to posterior direction with 10 N of force provided by a spring. This was necessary for the force on the flexor tendons to be measured by the device.

One of the two arms consisted of a steel plate provided with a strain gauge transducer. As bowstring- ing occured, the steel plate was minimally deformed and this was detected by the strain gauge transducer. The signal was amplified and the force could be calculated.

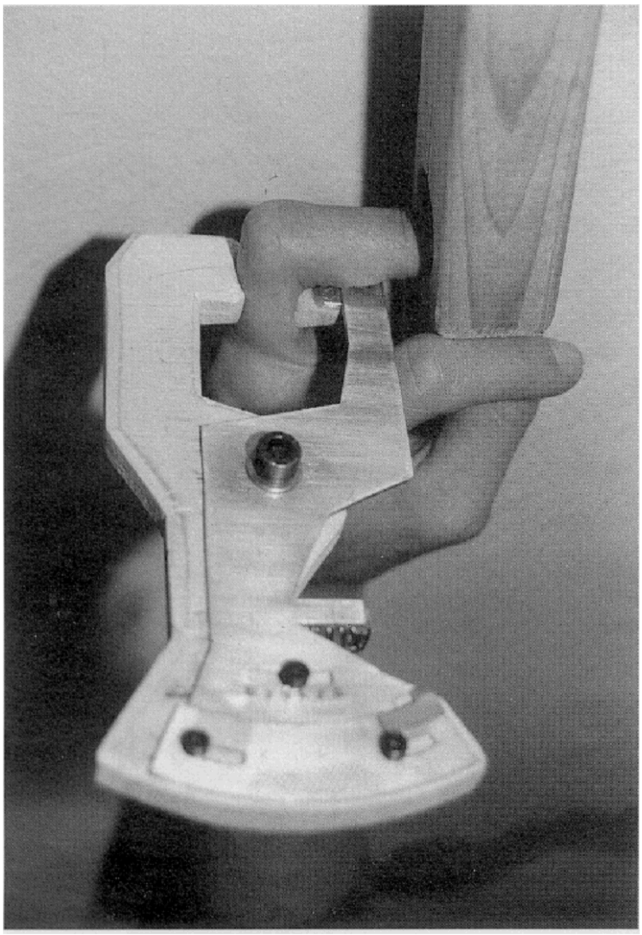

Fig 1 Distance measuring device. The contact area with the skin at the flexor surface is 5 mm in the axial direction and is concave in the transverse plane; the edges are rounded off.

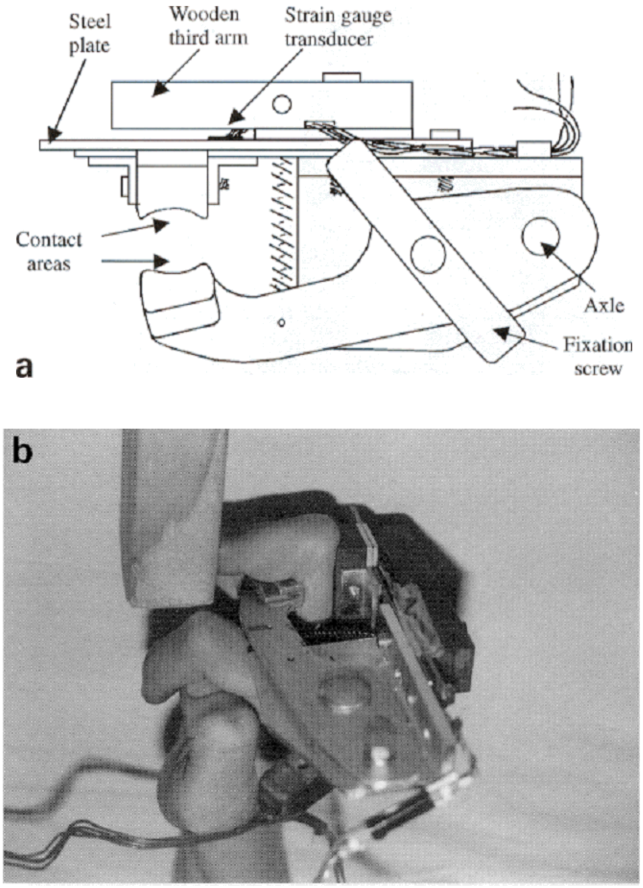

Fig 2 Force measuring device. The contact area with the skin at the flexor surface is 9 mm. It is slightly convex in the axial direction and concave in the transversal plane; the edges are rounded off.

The range of linear measurement was 0 to 400 N; the accuracy was 0.3 N.

To measure the force on the pulley taping during bow stringing, the force measuring device was applied as follows. A third arm was fixed to the base of the steel plate with the strain gauge transducer. This device was positioned on dorsum of the phalanx. Pulley taping was then wrapped four times around the finger, including the device. As bowstringing occured, the tape transferred the force to the steel plate with the transducer, so that the force could be measured (Fig 3).

To apply a controlled external force against flexion to the tip of the finger, a hole of 22 mm depth and diameter was made in a wooden slat. The slat was fixed to a commercial spring scale of a range of measurement of 0 to 200 N and an accuracy of lN. A commercially available nonelastic sports tape was used in all investigations.

Participants

Sixteen fingers (middle and ring) in four healthy adult persons (one women aged 30 years, two men aged 30, and one man aged 58 years) were studied. All measure- ments were made after a warm-up of the fingers and forearms, because of the observation that physiological bowstringing increased significantly during warm-up but became constant thereafter. All measurements were made in the crimp grip position.

Measuring the distance of bowstringing of the flexor tendons over the distal edge of A2 pulley without and with pulley taping

The physiological bowstringing was mea&ured over the distal edge of the A2 pulley, at the middle of the proximal phalanx (Lin et al., 1989), over the proximal transversal digital palmar crease. It was also measured with tape applied. The tape, 13 mm in width, was

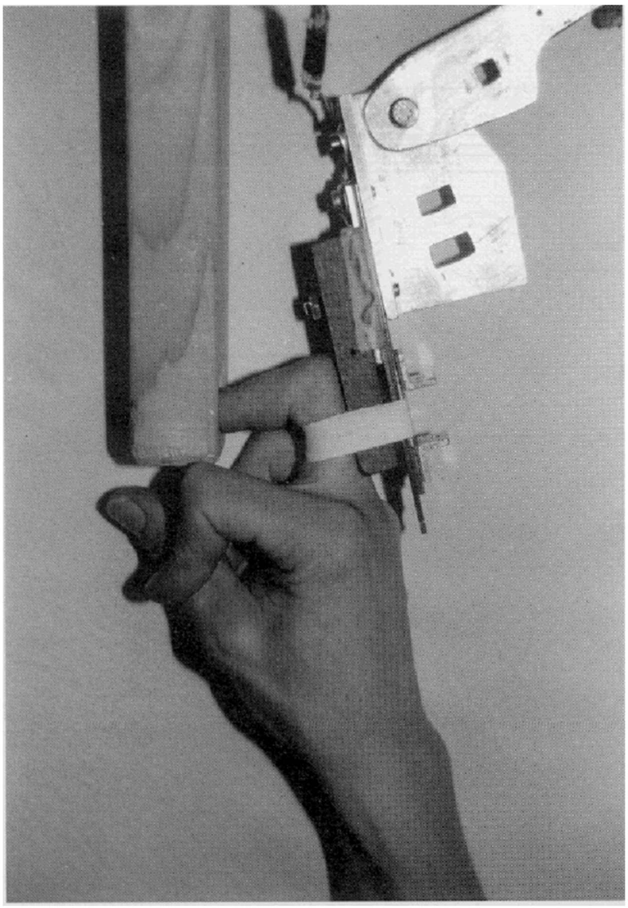

Fig 3 Arrangement used to measure the load on the pulley taping. The wooden slat is concave in the transverse plane and contacts with the whole dorsal phalanx. It is fixed to the base of a steel plate to which a strain gauge transducer is attached.

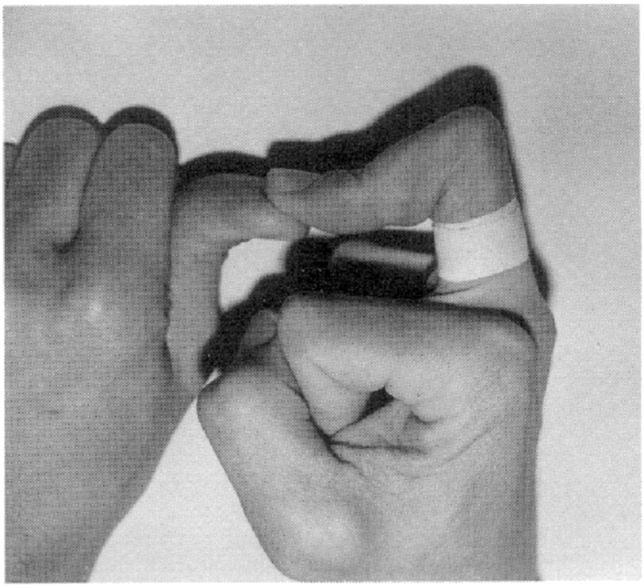

Fig 4 Pulley taping over the distal edge of the A2 pulley with the IP joints in the crimp grip position.

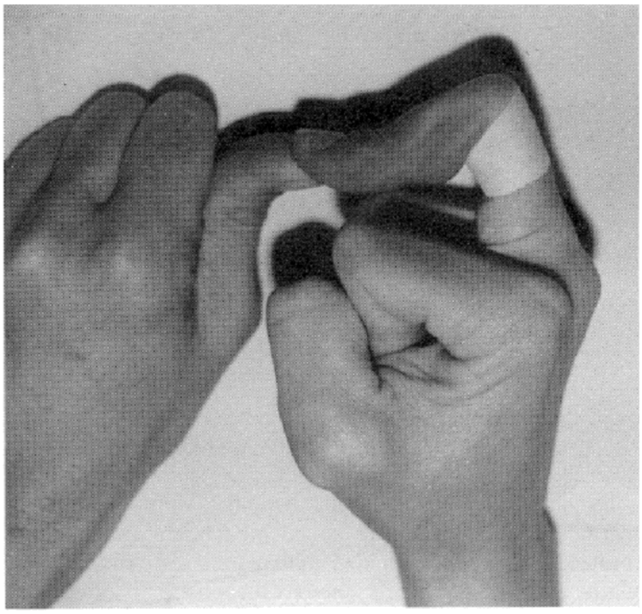

Fig 5 Pulley taping over the distal end of the proximal phalanx, proximal to the PIP joint.

wrapped four times around the finger (Fig 4). It was applied in such a way that venous return was not disturbed. Bowstringing was measured again over the applied tape. In both series external force to the tip of the finger was increased until no further bowstringing occurred (30 to 50 N).

Measuring the distance of bowstringing of the flexor tendons over the distal end of the proximal phalanx without and with pulley taping

These measurements were carried out in the same manner as for the distal edge of the A2 pulley. The location was at the distal end of the proximal phalanx, adjacent to the PIP joint (Fig 5). The idea was to apply taping to an area where bowstringing is more obvious (Lin et al., 1989; Mester et al., 1995) in order to decrease bowstringing to a greater extent. As a result, the angle and the perpendicular force component of the flexor tendons at the distal edge of the A2 pulley would be reduced (Fig 6).

Measuring the force of bowstringing of the flexor tendons in an anterior to posterior direction

The force measuring device was applied just distal to the proximal transverse digital palmar crease. Increasing

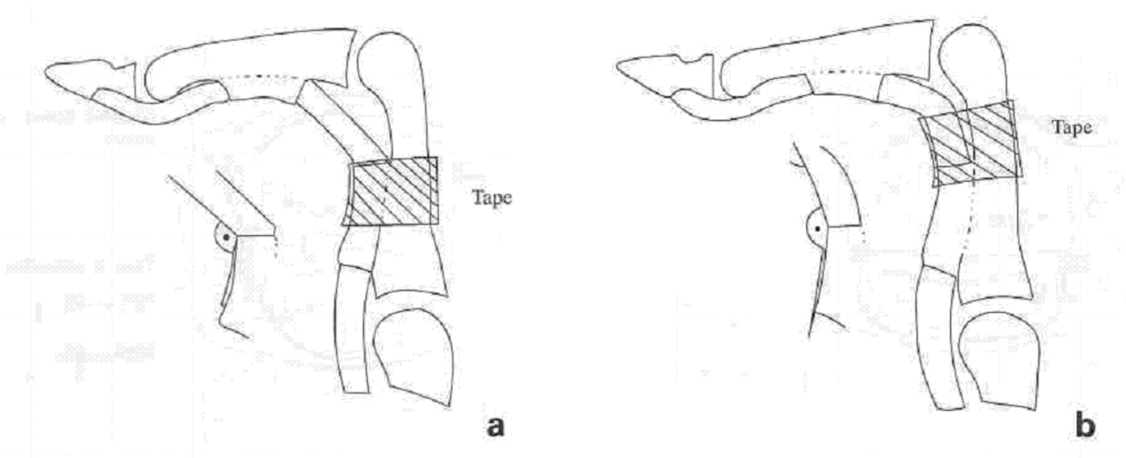

Fig 6 (a) Taping over the distal edge of the A2 pulley and (b) taping over the distal end of the proximal phalanx, which may reduce the angle the perpendicular force component of the flexor tendons at the distal edge of the A2 pulley more effectively.

external force in steps of 4.9 N was applied to the fingertip while the corresponding bow stringing force acting on the A2 pulley was measured. Due to increasing pain at the site of measurement, the study had to be stopped at an applied force above 29.4 N.

Measuring the force on the pulley taping from bowstringing

The two different locations of taping were also studied using the technique shown in Fig 3. The tape was tightened just enough so that venous return was not disturbed. Increasing external force in 4.9 N steps up to 118 N was applied to the tip of the finger at the distal phalanx. The corresponding force on the pulley taping was measured.

RESULTS

Taping over the distal edge of the A2 pulley

Pulley taping decreased the amount of bow stringing by 2.8% (0.05 mm). The mean (SD) distance of bowstring- ing over the distal edge of the A2 pulley without tape was 1.8 (0.3) mm and with tape 1.75 (0.25) mm.

Taping over the distal end of the proximal phalanx

Pulley taping over the distal end of the proximal phalanx decreased bow stringing by 22% (0.75 mm). The mean (SO) distance of bowstringing over the distal end of the proximal phalanx without tape was 3.45 (0.65) mm and with tape was 2.7 (0.45) mm. The measurement of bow stringing is probably a composition of true bowstringing and of deformation of the FOP and FOS tendons as tension occurs (Walbeehm and McGrouther, 1995) (Fig 7).

Force of bowstringing

The force of physiological bowstringing in relation to external applied force to the tip of the finger showed a constant linear gradient (Fig 8). It was assumed that further increase of external force to the tip of the finger (which was not possible due to increasing pain) would not change the direction of the graph. On this assumption, the force of bowstringing was calculated to be 373 N for an external resistance of 118 N at the fingertip. This corresponds to the theoretically calcu- lated force of ~50 N (Bollen, 1990).

Effect of taping on bowstringing force

The pulley taping over the distal edge of the A2 pulley took a maximum toad of 11 % (41 N) and the pulley taping over the dist~l end of the proximal phalanx took a maximum load of 12% (46 N) of the physiological bowstringing force.

DISCUSSION

Whatever the exact pathology of pain over the A2 pulley without increased bowstringing, firm circumferential taping is used by "rock climbers to relieve load on the pulley. The mechanical effectiveness of taping and its abilities to prevent injuries had already been questioned (Bollen and Gunson, 1990). According to the results of the present study, the pulley taping over the distal edge of the A2 pulley did not decrease the amount of bowstringing by more than 5% or absorb more than about 10% of the force on the pulley. Taping at the distal end of the proximal phalanx decreased bowstring- ing by about 20%. According to the results of Lin et al. (1989), the angle of the flexor tendons at the distal edge of the A2 pulley is calculated to be decreased by about

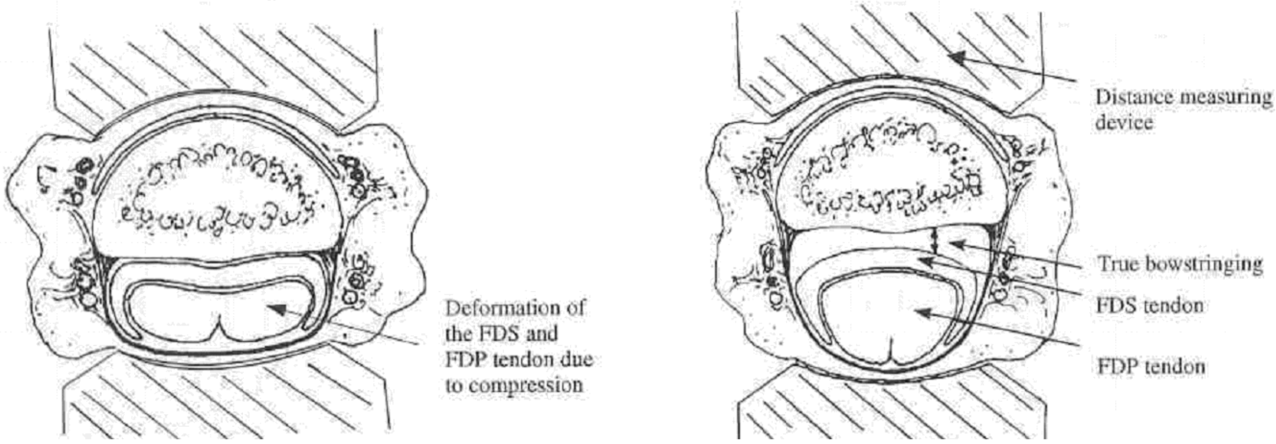

Fig 7 Behaviour of the flexor tendons during measurement of distance.

30 by this kind of taping. A reduction of 17% of the perpendicular force component at the distal edge of the A2 pulley can be assumed theoretically. However, the taping over the distal end of the proximal phalanx did not take more than about 10% of the total force of bowstringing. These results suggest that, from a biomechanical point of view, pulley taping is probably minimally effective in relieving load from the A2 pulley when used to treat pain in this region. **It** is even more unlikely that protective pulley taping will prevent traumatic rupture of pulleys.

If pulley taping is to be used, taping over the distal end of the proximal phalanx may be more effective. The fingertips should be loaded with low intensity force only because the percentage of the force of bowstringing that

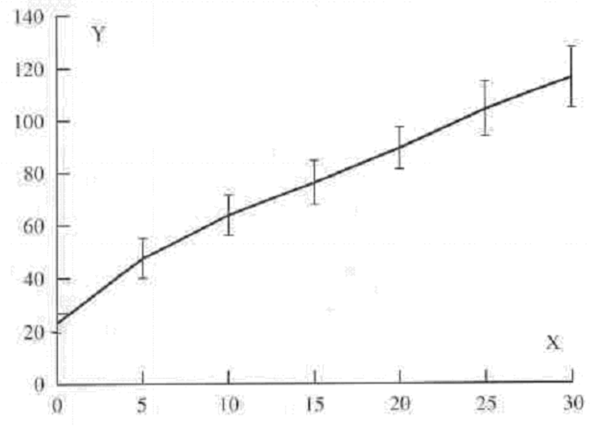

Fig 8 Force of physiological bowstringing acting on the distal edge of the A2 pulley. x: external force in N against flexion applied at the pulp of distal phalanx; y: force component of flexor tendons in N, which causes bowstringing.

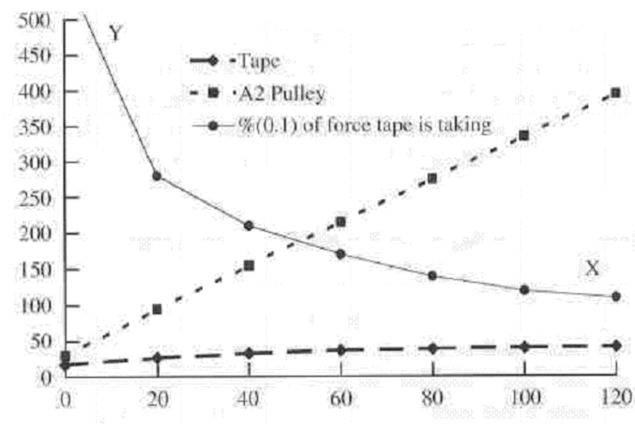

Fig 9 Force of physiological bowstringing and the corresponding force with which the pulley taping is loaded. x: applied external force against flexion at the pulp of the distal phalanx in N; y: load to taping (dashed line) and load to the distal edge of the A2 pulley (dotted line). Taping can relieve pulley load to a significant extent only when there is external force of low intensity as shown by the percentage line.

the pulley taping is able to bear decreases as the external force increases (Fig 9). Therefore, as the performance of a rock climber improves, the less effective pulley taping becomes.

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