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The effect of surgical washers used with olive K-wires on bone surface kinetics in external fixation: a biomechanical study

Eksternal fiksasyonda stoplu K-teli ile birlikte cerrahi pul kullanımının kemik yüzey kinetikleri üzerine etkisi: Biyomekanik çalışma

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Amaç: Eksternal fiksasyonda K-tellerinin tipi ve konfigürasyonunun fiksasyon stabilitesi üzerinde önemli etkisi vardır. Osteoporotik hastalardaki çeşitli kas-iskelet patolojilerinin tedavisinde eksternal fiksatör uygulama endikasyonları artmıştır. Bu biyomekanik çalışmada, stoplu K-teli ile birlikte cerrahi pul kullanımının kortikal kemik arasındaki yüzey kinetiği üzerine etkisi incelendi.

Çalışma planı: Çalışmada, bir yaşındaki koyunlardan çıkartılmış 32 adet tibia kemiği kullanıldı. Tibiaların proksimal kısımlarından sekizerli dört grup halinde deney piyesleri oluşturuldu. Tibiaların proksimal metafizer bölgelerine 1.8 mm'lik stoplu (olive) K-telleri gönderildi. Kontrol grubu dışındaki gruplarda stoplu K-teli ile birlikte sırasıyla 5 mm, 7 mm, 10 mm çaplarında cerrahi pul kullanıldı. Örneklere, özel tasarım ile imal edilmiş servo-hidrolik üniversal test makinesinde, kırılma noktasına kadar 10 mm/dk ile statik çekme kuvveti uygulandı.

Sonuçlar: Ortalama kırılma kuvveti kontrol grubunda 806.9 N bulunurken, stoplu K-teli ile birlikte 5 mm, 7 mm, 10 mm çapında cerrahi pul kullanılan gruplarda sırasıyla 1285.9 N, 1317.9 N ve 1345.9 N bulundu. İstatistiksel karşılaştırmada, kontrol grubu ile diğer üç grup arasındaki fark anlamlı iken ($p<0.0001$), cerrahi pul kullanılan gruplar arasında anlamlı fark saptanmadı ($p=0.574$).

Çıkarımlar: Stabiliteyi artırmak ve yüzey basıncını azaltmak amacıyla stoplu K-telleriyle birlikte cerrahi pul kullanımı belirgin bir avantaj sağlamaktadır. Osteoporotik kemik segmentlerinde ve osteoporotik hastalarda eksternal fiksasyon cerrahisi için cerrahi pul kullanımını öneriyoruz.

Anahtar sözcükler: Biyomekanik; kemik teli; ekipman tasarımı; kırık tespiti/enstrümantasyon; eksternal fiksatör; osteoporoz/komplikasyon; koyun.

Objectives: In external fixation, the type and configuration of K-wires have a considerable effect on fixation stability. Indications for external fixation have recently increased in the treatment of various musculoskeletal pathologies in osteoporotic patients. This biomechanical study was designed to determine the effect of surgical washers used with olive wires on surface kinetics of the cortical bone.

Methods: The study included 32 tibiae obtained from one-year-old sheep. Samples were prepared from the proximal parts of the tibiae which were then divided into four groups equal in number. A 1.8-mm olive K-wire was inserted into the proximal metaphyseal regions of the tibiae. Except for the control group, surgical washers were used with olive K-wires in the three study groups, with diameters of 5 mm, 7 mm, and 10 mm, respectively. The samples were then placed in a specially designed servo-hydraulic universal testing machine for static tensile test at 10 mm/min.

Results: The mean failure load was 806.9 N in the control group, compared to 1285.9 N, 1317.9 N, and 1345.9 N in the three groups in which 5-mm, 7-mm, and 10-mm surgical washers were used, respectively. While there were significant differences between the control and study groups ($p<0.0001$), failure loads did not differ significantly between the three study groups ($p=0.574$).

Conclusion: The use of surgical washers in combination with olive K-wires offers a significant advantage to increase stability and to decrease surface pressure. We recommend utilization of washers for external fixation surgery in osteoporotic patients and osteoporotic bone segments.

Key words: Biomechanics; bone wires; equipment design; external fixators; fracture fixation/instrumentation; osteoporosis/complications; sheep.

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Several mechanical and biologic factors are proven to effect the result of distraction osteogenesis.[1-2,14] Stability of fixation is an important mechanical issue in order to achieve a good regenerate bone.[1-2,14] Type and configuration of K-wires are considered to have a great effect on fixation stability.[2-3]

Crossing angle between the K-wires, increased wire diameter, tension and number and use of olive wires have already been identified to increase frame stability.[2,3-7,4] Osteoporotic bone is characterized by alterations in the architecture and composition of the osseous tissue. Change in structural properties lead to a thin, weak and brittle bone.[5] Use of external fixation has gained popularity in the treatment of various musculoskeletal pathologies in osteoporotic patients recently.[6]

In our daily practice, we observe many osteoporotic patients complicated by olive wire migration during the application of external fixator (Figure 1). This experience has brought us to create mechanical solutions to increase the stability and decrease surface pressure on the olive wire-bone unites. The following biomechanical study investigates the effect of surgical washers on surface kinetics between the olive wire and the cortical bone.

Material and method

Thirty-two 1 year-old sheep were sacrificed, their tibiae were isolated and all soft tissues were removed except the periosteum. All tibia specimens, which were placed in deep freezers, within one hour. Particular attention was paid to thaw the specimens at room temperature (23.9°C) 24 hours before assessments. And their bone densitometry measurements were obtained by dual-energy x-ray absorptiometry (DEXA)(g/cm^2) (Explorer S/N 90140, Hologic Inc., Bedford, MA, USA). Average bone densitometry results of all of 4 experimental groups were 0.656 g/cm^2 (between 0.598-0.704 g/cm^2) and there was no significant difference between them. The proximal 17 centimeters of the bones were kept and the distal tibiae were removed (Figure 2A). Two Kirschner wires, crossing each other perpendicularly, were inserted into the proximal and distal parts of the experiment bone segments. These sites including the K-wires, were encrusted into plastic moulds filled with polyester cement in a vertical plan, and the cement was frozen by mixing an appropriate cement catalyst (Figure 2B). Afterwards, 1.8 mm stopped (olive) Kirshner wires (Smith and Nephew, Memphis, Tennessee) were inserted into the proximal metaphysis of the tibiae 7cm below the joint surface, at an insertion point previously marked on the mediolateral cortex. These 32 prepared experiment units were divided into four groups consisting of eight tibiae. In the control group (group A), only K- wires with olives were used. In the remaining three groups, olive K-wires were inserted with surgical washers on the olive, with olive diameters of 5mm, 7mm, 10mm (groups C1, C2, C3), respectively (Figure 2C). Prepared experimental units were positioned, on traction mode, on the Servo-Hydrolic Universal Testing Machine (Istanbul Technical University- 2003, 200 Psi). The plastic molds on each end of the bones were coupled with custom designed steel cylindrical tanks. The distal end of the K-wires, were attached to a metal jaw including a load cell, and designed with a system that can lock the wire as the traction force increases.

During the traction procedure , digression of K wires from traction axis and formation of a spinning moment have been prevented by the stable fixation of the due molds in cylindrical steel tanks in three different plans. With the Servohydrolic testing machine, a traction force of 10mm/min. was applied to K-wires. On each experiment sample, a traction force was applied statically starting from 0 Newton, until olives of K-wires and/or surgical washer obliterate the metaphyseal cortex and penetrate the bone (Figure 2D). During this procedure, simultaneous force change (Load Cell, ESIT, SPA 300kg, S/N 223) and displa-

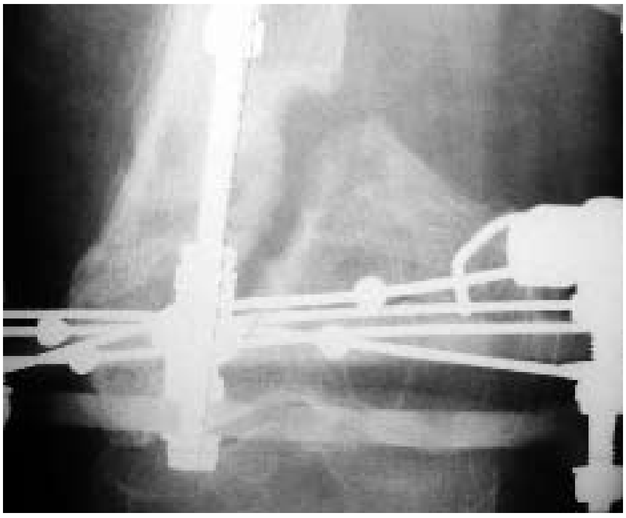
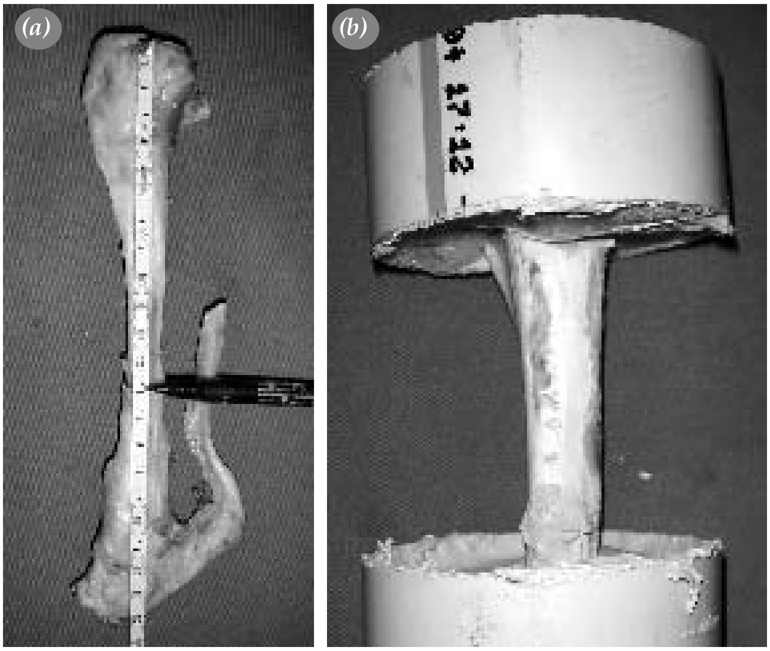
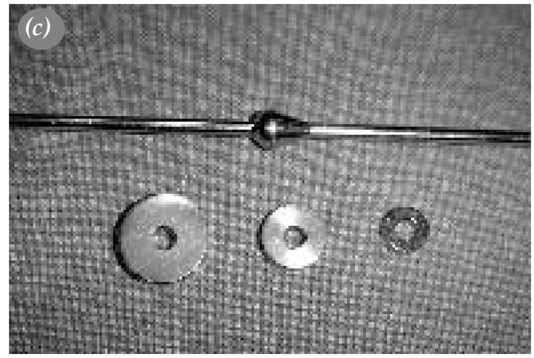


Figure 1. Penetration of an olive wire through an osteoporotic distal femur during external fixation.





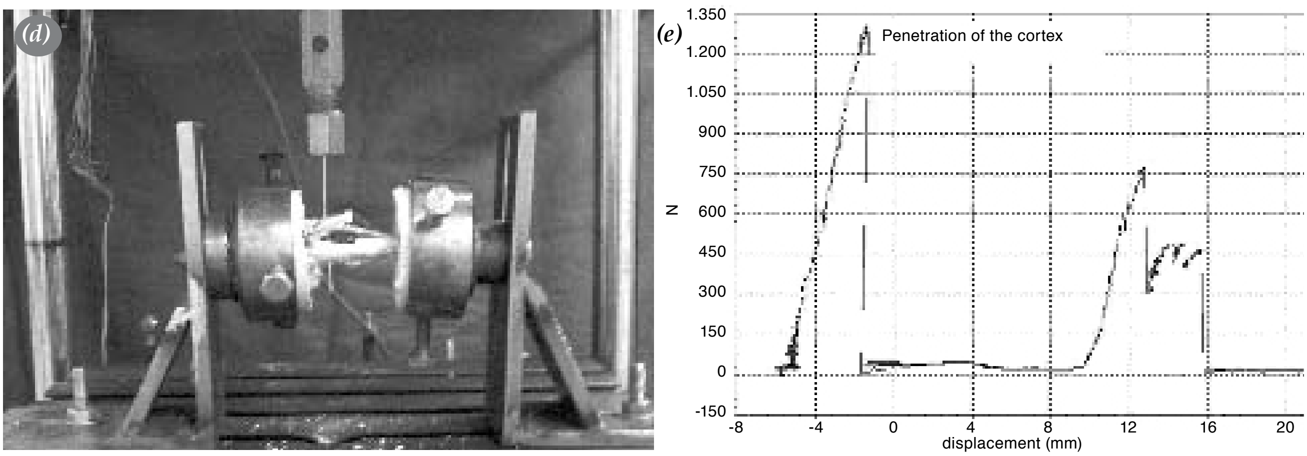


Figure 2. **(a)** Preparation of an experimental bone segment. **(b)** Fixation of the bone segment in plastic molds. **(c)** The 1.8mm K-wire and surgical washers of different diameters **(d)** Olive of K wire and/or surgical washer obliterate the metaphyseal cortex and penetrate the bone **(e)** Relative changes in force and displacement values on graphic and the yield point.

cement values were transmitted to the computer with the help of a potentiometer displacement transducer (Displacement Transducer, Micro-Epsilon WDS 300 P60 CR P, S/N 4600). Data gathering operation was directly saved on the computer through ESAM Traveler data gathering system (ESA Messtechnik GMBH, Type 1032-S, S/N 0060502) by 100 Hz per second. Relative changes in force and displacement values, which have been simultaneously saved on the computer, were recorded on graphics (Figure 2E).

Statistical analysis

Statistical comparison among the four different study groups was performed using the one-way ANOVA test. A value of 0,05 has been accepted as the point of significance.

Results

The mean break-off forces for the experimental groups are: Group A: 806.86 N, Group C1: 1285.88 N, Group C2: 1317.88 N, Group C3: 1345.88 N.

The statistical comparison revealed a significant difference between the control and all study groups, but no significant difference among the three surgical washer groups (Table 1).

Discussion

External fixators are devices, which mobilize bone fragments for purposes like lengthening, deformity correction etc. For a successful result, the fixator must have an inherent stability and possess control of the direction of the moving bone fragments. An inferior stability results in the formation of fibrous tissue

Table 1. Results of the experiment and statistical comparison

	Force to failure (N)				
	Average±SS	Distribution	%95 confidence Interval	p_1	p_2
Group A	806.9±135.6	668 - 1060	671 - 942	<0.0001	
Group C1 (5 mm)	1285.9±279.7	825 - 1720	1051 - 1519		0.574
Group C2 (7 mm)	1317.9±259.9	996 - 1763	1100 - 1535		
Group C3(10 mm)	1345.9±187.1	1127 - 1654	1189 - 1502		

p_1: Control versus study goups; p_2: Among study groups.

instead of solid bone.[9, 10] To attain superior stability of the bone fragments, Ilizarov recommended application of olive K-wires, especially in metaphyseal bone segments.[11] Paley et al. reported in their biomechanical study comparing four different external fixators, that crossing olive K-wires establish the most rigid configuration against shearing forces.[1,12,13,14]

The rigidity of each K-wire depends on its diameter and module of elasticity. To increase wire diameter may cause morbidity to surrounding soft tissues during insertion and cause complications like infection. [8,11] An additional olive on the wire shall increase it's stability on the cortex of bone. One of the major principles for fixation in osteoporotic bone is use of devices with a wire buttress. [5]

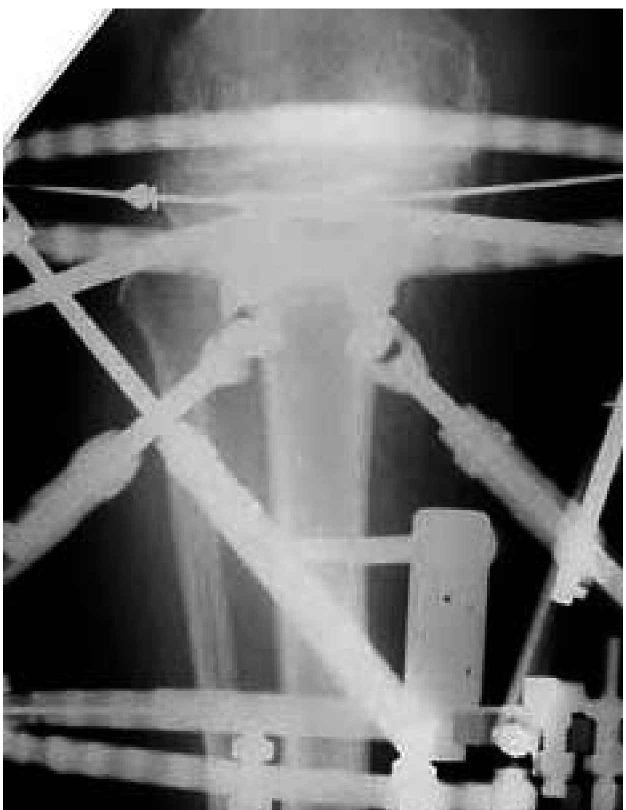


Figure 3. Utilization of K wire with surgical washer in on osteoporotic bone segment.

For use in osteoporotic bone, a stopper with a larger surface area can be created by bending a normal transosseous wire into different configurations.[3,7] Olive wires are also recommended for increased stability in osteoporotic bone.[3,8] (Figure 3).

The results of the current experiment display a significant advantage of adding surgical washers to olive K-wires to increase the stability and decrease surface pressure.

As there was no statistically significant difference among groups C1, C2 and C3, regarding the failure to crack values, we recommend utilization of washers with the smallest possible diameter in order to prevent injury to the anatomical structures between the skin and the bone.

Conclusion

The established pressure equation in physics predetermines that an increased surface area between the olive wire and cortical bone also increases the tension of the K-wire, hence the stability of the ex.fix. Surgical washer utilized for this purpose decrease surface contact pressure and increase stability of bone wire unit in patients with osteoporotic bones.

This study proves the benefit of washers on contact pressures without depending on their diameter. Therefore we recommend use of washers with the smallest diameter (5 mm) in osteoporotic patients.

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