



Biomechanical comparison of fixation of two-part osteoporotic neck fracture of the proximal humerus using uni-planar and multi-planar Kirschner wire

Humerus proksimal uç iki parçalı kırıklarının tek yönlü ve çok yönlü Kirschner teli ile tespitinin biyomekanik olarak karşılaştırılması

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Objectives: The stability and effectiveness of uni-planar Kirschner wire (K-wires) was compared to multi-planar K-wires osteosynthesis combined with tension band wiring for fixation of two-part osteoporotic surgical neck fracture of the proximal humerus.

Materials and methods: Two groups each with eight cadaveric elderly (mean age 72.6; range 70 to 80 year) frozen human humeri were used in the study. Transverse osteotomy of the proximal humerus was performed using a thin oscillating saw. The first group (group A) was fixed using two anterograde smooth K-wires, sent from lateral cortex, combined with tension band wiring. The second group (group B) was fixed using multi-planar (anterograde and retrograde) four smooth K-wires combined with tension band wiring on the lateral cortex. Biomechanical tensile properties for 3 mm displacement (gap load) and maximum load were assessed.

Results: The mean value for the gap load was 1045.0±45.4 N (Newton) for group A and 1238.1±115.8 N for group B. Gap load values of groups were similar (p=0.01). The maximum load was 1261.8±52.4 N in group A and 1471.1±107.3 N in group B. The maximum load values were statistically higher in the multiplanar fixation technique (group B) when compared to that of the uniplanar fixation technique (group A), (p=0.004).

Conclusion: Fixation in osteoporotic two-part surgical neck fractures of the proximal humerus using multiplanar K-wires combined with tension band wire provides substantially more effective stability compared to that of uniplanar fixation.

Key words: Proximal humerus; osteoporosis, fracture; biomechanics.

Amaç: Humerus proksimal uç cerrahi boyun iki parçalı kırıklarında tek yönlü Kirschner teli (K-teli) ile tespit yönteminin stabilite ve etkinliği, çok yönlü K-teli ve gergi bandı yöntemi ile biyomekanik olarak karşılaştırıldı.

Gereç ve yöntemler: Çalışma iki grup halinde düzenlendi. Her bir grupta sekizer adet dondurulmuş insan (ort. yaş 72.6; dağılım 70-80 yıl) kadavra humerus kemiği kullanıldı. Humerus proksimalinde ince el testeresi yardımı ile transvers osteotomi yapıldı. Birinci grupta (grup A) gergi bandı yöntemi ile güçlendirilen ve lateral korteksten antegrad olarak gönderilen iki adet düz K-teli ile tek yönlü tespit uygulandı. İkinci grupta ise lateral kortekste gergi bandı yöntemi ile güçlendirilmiş dört adet K-teli ile çok yönlü (antegrad ve retrograd) tespit uygulandı. Üç milimetre aralık oluşturma sırasındaki yüklenme (ayırışma gücü) ve maksimum yüklenme miktarları biyomekanik olarak değerlendirildi.

Bulgular: Ortalama ayırışma gücü, grup A'da 1045.0±45.4 N (Newton) ve grup B'de 1238.1±115.8 N olarak tespit edildi. Ayırışma gücü açısından, iki grup benzerdi (p=0.01). Maksimum yüklenme miktarı grup A'da 1261.8±52.4 N, grup B'de ise 1471.1±107.3 N olarak bulundu. Maksimum yüklenme değerleri, çok yönlü tespit tekniğinde (grup B), tek yönlü tespit tekniğinden (grup A) istatistiksel olarak yüksek bulundu (p=0.004).

Sonuç: Humerus proksimal uç iki parçalı cerrahi boyun kırıklarının sabitlenmesinde, gergi bandı ve K-telleri ile güçlendirilmiş çok yönlü tespit yöntemi, tek yönlü tespit yöntemine göre daha etkilidir.

Anahtar sözcükler: Proksimal humerus; osteoporoz, kırık; biyomekanik.

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Osteoporotic proximal humerus fractures can be fixed by closed reduction and fixation with percutaneous pinning or intramedullary rod, open reduction and fixation with tension band or a plate.^[1-11] One of the serious problems associated with proximal humeral fixation is the potential damage to the blood supply of the humeral head.^[12,13] Standard t-plates and screws require extensive dissection of surrounding soft tissue, periosteal stripping, potentially disrupting major vessels supplying nutrients to the humeral head and shaft.^[7,8-11] Recent trends shifted from open reduction and massive internal fixation towards closed reduction and minimal fixation, which is a less invasive method associated with less damage to the soft tissue and a low rate of avascular necrosis of the humeral head.^[2,6,9,14-18]

Two surgical options for fracture fixation that minimize damage to the muscle, the connective tissue, and the vasculature include pinning (percutaneous or mini open) and intramedullary nailing.^[2,4,9,10,14,17-19] Insufficient fixation, pin tract infection, nerve injuries and pin migration are among the reported complications in pin fixations.^[4,5,14,20-24] The incidence of these complications, particularly the pin migration, is unknown. However, migration to the thorax, and to mediastinal, abdominal and cardiac cavities had been reported.^[5,21,22,24] Percutaneous pinning technique can be used in young patients, with good bone quality, but also in elderly patients with osteoporosis and other pathology associated.^[3,18] In some three or four-part fractures, reduction problems can occur, but these are rare in two-part fractures.

The aim of this study was to improve fixation stability and to prevent pin migration, by using a pinning combined with tension band wiring.

MATERIALS AND METHODS

Sixteen frozen cadaveric humeri (mean age 72.6; range 70 to 80 year), were obtained from the Anatomy Department of Gülhane Military Medical Academy. Two groups each with eight cadaveric humeri were used in the study. X-rays of all humeri were taken to exclude any pathology or previously treated fractures. Two-part surgical neck fractures were created using a thin oscillating saw. The first group was fixed with two (2.5 mm) antero-grad smooth Kirschner-wires (K-wires) combined with the tension band technique (Figure 1).

The second group was fixed with four K-wires (2.5 mm) combined with tension band between K-wires on the lateral cortex as described by Jaberg et al.^[5] the proximal two wires were directed distally through the greater tuberosity to engage the medial cortex inferior to the surgical neck (anterograde pins), the distal two wires were directed proximally (retrograde) from the distal lateral cortex of the shaft into the humeral head and between these wires end figure eight tension band techniques were performed (Figure 2). One of the inferior K-wires was inserted into the anterior-inferior location, the second K-wires inserted in a postero-inferior location on to humeral head.

Mechanical testing

For mechanical testing, a material testing machine (model TIRA test 24500; Demgen, Werkzeugbau, GmbH) was used to apply axial tensile load on each specimen. The load was applied on each specimen at a rate of 40 mm/min. Tests were done at Mustafa Kemal University, Faculty of Engineering laboratory. Both groups of specimens were tested under the same conditions. Axial tension test was performed by applying constantly increasing load. The load value (Newton: N) versus distal fragment displacement in millimeter (mm) was constantly measured using data acquisition system. Failure of the fixation was defined as 3 mm displacement of the distal fragment in respect to proximal humerus.

The following values were recorded:

- 1) Load value (N) when there is 3 mm displacement at the site of the osteotomy.
- 2) Maximal load (N) tolerated by the construct and the deformation at this load.
- 3) Fracture load (N) when there is complete failure of the construct (fracture at the distal or at the proximal fragment) and the deformation at this load.

Statistical analysis

Results analysis were performed with SPSS 11.5 (SPSS Inc., Chicago, IL, USA) statistical package. Descriptive statistics were presented as the mean \pm standard deviation (SD). The uniplanar osteosynthesis (group A) and multiplanar osteosynthesis (group B) groups compared with the Mann Whitney U-test; *p* value was set at *p*=0.05.



Figure 1. Fixation of the osteotomy site using uniplanar Kirschner wire fixation plus tension band osteosynthesis.

RESULTS

The mean value for the gap load was 1045.0 ± 45.4 N for group A and 1238.1 ± 115.8 N for group B. No statistically significant differences in gap load values were found between the two groups ($p=0.1$; Table I).

The maximum load was 1261.8 ± 52.4 N for group A and 1471.1 ± 107.3 N for group B. The maximum load values were statistically higher in the multiplanar fixation technique when compared to the uniplanar fixation technique ($p=0.004$).

Fracture load was 1516.3 ± 104.3 N for group B and 1295.0 ± 46.1 N for group A. The fracture load values were statistically higher in the multiplanar fixation technique when compared to the uniplanar fixation technique ($p=0.002$).

DISCUSSION

The mechanical stability of pin fixation is doubtful in clinical practice. Some authors^[1,5,25] suggest that, with an additional 1 or 2 anterograde pins through the greater tuberosity to the medial cortex, the



Figure 2. Multiplanar fixation method using four wires plus tension technique.

whole construct will have better stability. In this study satisfactory stability can be achieved with 2 retrograde and 2 anterograde pins combined with tension band wiring.

Naidu et al.^[25] also suggested that an additional 2 anterograde pins stabilizing the greater tuberosity to the medial cortex will improve both axial and rotational stability. In their study of two part proximal humerus fractures using ten fresh frozen humeri, they determined that the addition of two bicortical tuberosity pins or two bicortical tuberosity pins and one anterior pin to two lateral pins significantly increased rotational and bending rigidity. They concluded that multiplanar pins are needed to augment torsional stiffness, and that the addition of two bicortical tuberosity pins enhances bending rigidity. Our study were similar to their study in that we compared the uniplanar to multiplanar fixation, however we used unthreaded pins while they used terminally threaded pins to fix the fracture and we tested the construct in axial load while they tested the specimens in both torsion and bending.

TABLE I
Statistical results

	Group A-Uniplanar (n=8)		Group B-Multiplanar (n=8)		<i>p</i>
	Mean±SD	Minimum-maximum	Mean±SD	Minimum-maximum	
Length of humeri/mm	24.0±1.7	21-26.5	23.7±1.6	21-26	0.873
Maximum load/N	1261.8±52.4	1160-1320	1471.1±107.3	1250-1600	0.004
Displacement at max. load/mm	12.5±1.0	11-14	7.4±1.1	6-9	0.001
3 mm displacement load/N	1045.0±45.4	980-1120	1238.1±115.8	980-1380	0.1
Fracture load/N	1295.0±46.1	1210-1355	1516.3±104.3	1310-1640	0.002

N: Newton.

The limitations of this study were; (i) we did not measure the bone mineral density of the specimens and we measured the displacement at the fracture site visually instead of using more accurate camera systems, (ii) lack of simulation of the biologic repair process as this was a cadaveric study, (iii) all specimens were tested to failure in a single loading fashion. The effects of surrounding musculature and soft tissues were not taken into account. Peri-articular forces around the shoulder joint are in different directions, which results in a complex load distribution at the fracture site.^[26] It is difficult to create all these forces during the laboratory tests. Understanding the exact contribution of the supporting ligaments to the functional integrity is crucial for the diagnosis and treatment.^[25,27]

Our results are in accordance with those of Koval et al.^[1] as we found that multiplanar fixation provided better fixation than uniplanar fixation. Koval et al.^[1] showed that the best mechanical stability is achieved in osteoporotic bone with 3 retrograde pins in a convergent construct combined with 1 anterograde pin. In their study, they compared ten different fixation methods used in surgical neck fractures of humerus and found that four pins with one pin placed through the greater tuberosity provide statistically stronger fixation than four parallel pins in both fresh frozen and embalmed specimens. These results showed that different methods of tension banding alone provided less stability than other methods. Similarities between their study and ours included the creation of a reproducible oblique osteotomy of the surgical neck, fixation with uniplanar and multiplanar technique and loading of the specimens to failure. The primary differences were the orientation of loading and the number of constructs tested.

Jiang et al.^[27] suggested that parallel configuration of pin fixation has better torsional stability compared with the convergent configuration when 1 cm is used as the pin-to-pin distance. They suggest that parallel pin fixation should be applied whenever possible, and a specially designed parallel drill sleeve with a 1 cm pin-to-pin distance is recommended during clinical application.

A two-dimensional finite element study may be of great help to overcome certain limitations of cadaver studies.^[28] In the future more prospective and retrospective studies are needed to evaluate the clinical results of this technique.

In conclusion, multiplanar fixation combined with tension band technique provided better stability and prevented pin migration compared to that of uniplanar fixation which allowed early rehabilitation. This combination technique is cost effective and readily available which can be applied through minimal invasive method.

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