Comparative Study of the Pullout Strength of the 2.4-mm AO Locking Screw, 2.0-mm AO Cortical Screw and Herbert Screw in Sawbones: A Biomechanical Study

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Background: *Headless screw is a standard implant for an osteochondral fragment fixation. With a threaded design, the screw head can be buried under the articular cartilage to prevent a post-traumatic arthritis. However, the screw is expensive and maybe not available in the emergency situation. The 2.4-mm AO locking screw also has a threaded head which is able to advance underneath the cartilage. This has been used for fixation of the osteochondal fracture clinically. We compared the pullout strength of 2.4-mm AO locking screw with those of Herbert screw and 2.0-mm AO cortical screw.*

Material and Method: *The studies performed by using Instron 4502 to measure the pullout strength in 12 models for each type of the screw. The pullout strength of the 2.4-mm AO locking screw from a corticocancellous bone model was compared with the pullout strength of the Herbert screw from a cancellous bone model and the 2.0-mm AO cortical screw from the corticocancellous bone model. The differences in pullout strength between the 2.4-mm AO locking screw and the other two screws were determined by independent t-test.*

Results: *The pullout strength of the 2.4-mm AO locking screw, Herbert screw and 2.0-mm AO cortical screw were 143.49$\pm$46.18 N, 72.83$\pm$16.64 N, and 80.38$\pm$1.42 N, respectively. The pullout strength of 2.4-mm AO locking screw was significantly higher than those of Herbert screw and 2.0-mm AO cortical screw ($p<0.001$).*

Conclusion: *According to the recent biomechanical study, the 2.4-mm AO locking screw in the corticocancellous bone model had pullout strength higher than the Herbert screw in the cancellous bone model and the 2.0-mm AO cortical screw in corticocancellous bone model. The 2.4-mm AO locking screw may use instead of headless screw for intra-articular fixation in a specific situation, such as when the headless screw is unavailable.*

Keywords: *Pullout strength, AO screw, Locking screw, Herbert screw*

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Anatomical reduction and rigid internal fixation is indicated in an intra-articular fracture to prevent post-traumatic osteoarthritis. Various implants for fixation of this kind of fracture have been described(1). Headless screw, such as the Herbert screw, is one of the most commonly used implant for fixation of a small intra-articular fracture because the screw can be applied directly through and buried under the articular surface, so post-traumatic arthritis from the prominent implant is less likely(2,3). However, the screw has high cost and it is unavailable during the emergency situation in our institute.

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We confronted the situation of a comminuted distal humerus fracture with a small osteochodral fragment of the capitellum. The headless screw was not available at that time. Thus we used a 2.4-mm AO locking screw instead of headless screw and found that the conical fully thread-head of the screw could be buried into the articular part of the osteochondral fragment (Fig. 1A).The outcome of treatment is excellent with full range of motion and there is no evidence of osteoarthritis change at 3-year-follow-up (Fig. 1B).

Because the 2.4-mm AO locking screw has never been use as an interfragmentary device so we conducted a biomechanical study to compare this application with the other standard methods.The pullout strength of the 2.4-mm AO locking screw was measured and compared with the pullout strength of the Herbert screw and the 2.0-mm AO cortical screw. The synthetic bone was used to create a uniform model for biomechanical study[4].

Material and Method

Three types of screw were used in our study; the Herbert screws (Zimmer, Warsaw, IN), the 2.4-mm AO locking screw (Synthes USA, Paoli, PA) and the 2.0-mm AO cortical screw (Synthes USA, Paoli, PA) (Fig. 2).

Cellular rigid polyurethane foam (Sawbones with density of 0.16 g/cc) represents the cancellous bone[2,3,5]. The cortical bone was simulated with short fiber filled epoxy sheet with density of 1.64 g/cc. To create a cortico cancellous model for the biomechanical study of 2.4-mm AO locking screw and 2.0-mm AO cortical screw, 10-mm-thick polyurethane foam was combined with 1-mm-thick epoxy sheet into 11-mm-thick laminated test block by manufacturer. The laminated test block was divided into model blocks with dimension of 20 x 20 mm (Fig. 3A).

Fig. 1 (A) Fixation of the capitellar fragment was done with the 2.4-mm AO locking screw. The screw head was buried under the cartilage (arrow). (B) The anteroposterior and lateral radiographs revealed united of the capitellar fracture. There is no screw head prominent in the lateral radiographic view and no osteoarthritic change at the radiocapitellar joint.

Fig. 2 From left to right: 2.4-mm AO locking screw (Synthes, Paoli, PA), Herbert screw (Zimmer, Warsaw, IN) and 2.0-mm AO cortical screw (Synthes, Paoli, PA). A pitch different between the head and the shank of the 2.4-mm AO locking screw resemble to the different in pitch between proximal and distal end of Herbert screw.

Because the Herbert screw was designed to place within the cancellous bone[6], for this reason, in biomechanical study of the Herbert screw, the polyurethane foam with thickness of 20 mm was used as a cancellous model[2,3,5] (Fig. 3B). Each model was drilled at the center. The screws insertion performed following the manufacturers' instructions. The 2.4 mm AO locking screw and 2.0 mm AO cortical screw were inserted from the cancellous part to the cortical part of the model. The 2.4-mm AO locking screw was driven until the cutting flute at the screw tip past the outer cortex of the model[7] (Fig. 3A). The Herbert screw was introduced 11 mm deep into the cancellous model (Fig. 3B). Twelve models were tested for each type of screw.

The pullout test was performed with Instron 4502 material testing system (machine model 4502, Instron, Singapore Pte Ltd) (Fig. 3C). The screw was loaded with a velocity of 5 mm per minute until the load dropped. Ultimate load to failure of each model was collected and analyzed with independent t-test.

Results

The mean pullout strength of the 2.4-mm AO locking screw, Herbert screw and 2.0-mm AO cortical screw were 143.49$\pm$46.18 N, 72.83$\pm$16.64 N and 80.38$\pm$1.42 N, respectively. Statistical analysis showed the 2.4-mm AO locking screw had pullout strength significantly higher than those of the Herbert screw and the 2.0 mm-AO cortical screw (p<0.001).

Discussion

Anatomical reduction is the principle for

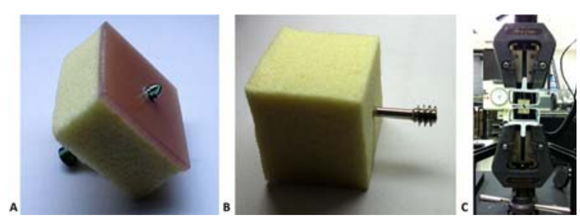

Fig. 3 (A) The 2.4-mm AO locking screw was driven until the cutting flute at the screw tip past the outer cortex of the laminated test block model. (B) The Herbert screw was introduced 11 mm deep into the cancellous model. (C) Biomechanical testing with Instron 4502.

treatment of the intraarticular fracture, thus, open reduction and internal fixation is the mainstay of treatment. Fixation of a small osteochondral fragment is a challenging problem. In many situations, such as a capitellum fracture, talus fracture and comminuted distal humeral fracture, the implant has to be applied directly through the articular surface. Various implants can be used to fix these kinds of fracture, such as minifragment plates, headless compression screws, small diameter screws, threaded K-wires, and bioabsorbable pins(1).

A small diameter screw are the basic and most efficient for fixation of a small fragment as a lag screw or in cooperated with plate for fixation a small diaphyseal fracture. However, in the treatment of osteochondral fracture, the implant should not be left inside the joint or it can be harmful to the articular cartilage. To solve the problem, the screw should be inserted in a retrograde fashion or countersunk underlying articular cartilage(1,2). However, countersinking can further destroy the cartilage and some part of the implant still remains in the joint space.

The Herbert screw is one of the most commonly used headless screw. As a headless designed, it has an ability to bury screw head completely below the articular surface, which eliminates exposes hardware and the potential of cartilaginous damage(2,3).

The 2.4-mm AO locking screw has a thread head that engages with the thread of the plate hole(8). We confronted the situation of a comminuted distal humerus fracture with a small osteochondral fragment of the capitellum (Fig. 1). At that time the headless screw was not available. Moreover, the cartilaginous damaging from the screw prominent and the countersinking were our concerned. We decided to use a 2.4-mm AO locking screw as a headless screw and found that it can be inserted through articular cartilage and head of the screw can be buried below cartilage surface. Furthermore, the patient has a very good long term postoperative result. This application of such a screw has never been reported in the literature.

The present study showed that the average pullout strength of the 2.4 mm AO locking screw was significantly higher than those of the Herbert screw and the 2.0 mm AO cortical screw. This finding may cause by size and cortical purchase of the screw. And this property may allow using this screw instead of the Herbert screw to fix a small osteochondral fragment in some situation.

The 2.4-mm AO locking screw has been designed to insert in the bone cortex. The depth of insertion through the cortex affects the pullout strength. There has been reported that, the pullout strength is decreased 10% to 30% if the cutting flute is left in the cortex(7). However, the prominent of screw tip can bring the problem(9,10) as in a volar plate fixation for distal radius fracture. Extensor tendon injury from the dorsal screw prominent after volar locking plate fixation for the distal radius fracture is a well-known complication(11).

Schoenfeld et al(12) suggests that the pullout strength increases significantly when the screw was inserted 1 mm past outer cortex. However, in their study, bigger screws were used and screws were inserted through two cortices so this recommendation may not appropriate to apply with our technique. To gain the maximal pullout strength as in the present study, the screw should be inserted until the cutting flute of the screw tip past the outer cortex.

So, application of the 2.4-mm AO locking screw as our technique should be done with extremely caution. If the 2.4-mm AO locking screw is used for fixation the osteochondral fragment, the opposite cortex should be free of highly mobile structure such as tendon or the contact area of the articular surface otherwise the attritional injury of the tendon or posttraumatic osteoarthritis can occur.

Interfragmentary compression is an important factor for fracture healing(13,14). Many studies compared the compressive force between various screws. In the 2.0 mm AO cortical screw, the interfragmentary compression can create by lag-screw principle(1). The Herbert screw creates compression force by its design. The different in pitch between proximal and distal end of the Herbert screw produces the compression force between two bone fragments(15).

We neither investigate nor compare the compression force between the screws that used in our study. However, a good correlation between the compressive test and the pullout test has been reported(2,3). A pitch difference between the head and the shank of the 2.4-mm AO locking screw may generate interfragmentary compression, more or less (Fig. 2). With the limitation of data, the interfragmentary compression should be achieved with another technique before insertion of the 2.4-mm AO locking screw.

Conclusion

From our biomechanical study, the 2.4 mm AO locking screw may be used instead of the headless screw in a specific situation. However, with the lacking of clinical studies, any possible technique should be considered before application of this technique.

Potential conflicts of interest

None.

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การเปรียบเทียบแรงดึงของ 2.4-mm AO locking screw, 2.0-mm AO cortical screw และ Herbert screw ในวัสดุจำลองกระดูก

อรรคพัฐ โกสิยตระกูล, สูรย์ สอนปาน, สุริยา ลือนาม

วัตถุประสงค์: *สกรูชนิดปราศจากหัวเป็นอุปกรณ์หลักที่ใช้ยึดตรึงชิ้นกระดูกหักขนาดเล็กที่มีส่วนของผิวข้อ รวมอยู่โดยเฉพาะอย่างยิ่งหากจำเป็นต้องใส่อุปกรณ์ดังกล่าวผ่านทางผิวข้อของชิ้นกระดูกนั้น การออกแบบสกรูที่ปราศจากหัวทำให้สกรู lk, ki5 ถูกฝังเข้าไปใต้กระดูกอ่อน ปัญหาการเกิดข้อเสื่อมจากอุปกรณ์เสียดสีกับผิวข้อจึงหมดไป อย่างไรก็ตามสกรูดังกล่าวมีราคาสูงและไม่สามารถนำมาใช้ในการผ่าตัดฉุกเฉินในสถาบันของเรา สกรูชนิด 2.4-mm AO locking screw มีเกลียวที่ส่วนหัว ทำให้สกรูสามารถถูกคันจนจมเข้าไปใต้กระดูกอ่อนได้ การศึกษานี้จะทำการเปรียบเทียบแรงดึงของ Herbert screw, 2.4-mm AO locking screw และ 2.0-mm AO cortical screw*

วัสดุและวิธีการ: *ทำการทดสอบวัดแรงดึงของสกรูด้วยเครื่อง Instron 4502 ที่ห้องปฏิบัติการของศูนย์เทคโนโลยีโลหะและวัสดุแห่งชาติ (MTEC) โดยสกรูแต่ละชนิดจะถูกยึดกับวัสดุจำลองกระดูกหรือ Sawbone จำนวน 12 ชิ้น ดังนี้ Herbert screw จะถูกยึดกับวัสดุจำลองกระดูกฟองน้ำ ส่วนสกรูชนิด 2.4-mm AO locking screw และ 2.0-mm AO cortical screw จะถูกยึดกับวัสดุจำลองที่มีทั้งกระดูกทึบและฟองน้ำอยู่ด้วยกัน ค่าความแตกต่างของแรงดึงจะถูกวิเคราะห์โดยใช้ independent t-test*

ผลการศึกษา: *ค่าแรงดึงเฉลี่ยของ Herbert screw คือ 72.83±16.64 นิวตัน ค่าแรงดึงเฉลี่ยของ 2.4-mm AO locking screw คือ 143.49±46.18 นิวตัน และค่าแรงดึงเฉลี่ยของ 2.0-mm cortical screw คือ 80.38±1.42 นิวตัน โดยค่าแรงดึงของ 2.4-mm AO locking screw มีค่ามากกว่า Herbert screw อย่างมีนัยสำคัญทางสถิติ ($p<0.05$)*

สรุป: *ผลจากการศึกษาทางชีวกลศาสตร์แสดงให้เห็นว่าการใช้ 2.4-mm AO locking screw ยึดกับวัสดุจำลองที่มีทั้งกระดูกทึบและฟองน้ำอยู่ด้วยกันมีแรงดึงมากกว่าการใช้ Herbert screw ยึดกับวัสดุจำลองกระดูกฟองน้ำดังนั้นสกรูชนิด 2.4-mm AO locking screw อาจนำไปใช้แทนสกรูชนิดปราศจากหัวในการยึดกระดูกแตก ผิวข้อได้ในบางกรณี*