Introduction: Rotator cuff tear is one of the most common shoulder ailments and repairing it arthroscopically has gained popularity. Variable factors influence the healing of the tendon to the bone, including contact area, pressure, tissue quality and biomechanical factors. The integrity of the repaired construct after surgery is reported to correlate with post-operative results. Recently, transosseous equivalent technique has received attention, which has been shown in the laboratory that it improves pressurized contact area and mean pressure of the rotator cuff compared to the conventional double-row technique. Although the retear rate of the transosseous equivalent technique has been reported to be lower or comparable to the conventional double-row technique, peculiar retear pattern after the transosseous equivalent technique is becoming a major concern. Several reports have mentioned the medially reruptured tendons with intact footprint. They have insisted that the failure may be caused by the tension overload in the medial suture-tendon interface or possibility of relatively quick necrosis of the cuff at the medial row caused by the strong pressure from the transosseous equivalent construct. These results suggested that transosseous equivalent technique may increase the strain gap between the normal tendon and the repaired tendon, resulting in the concentration of stress along the medial row. The purpose of this study was to compare the strain of the intact rotator cuff tendon and the tendon repaired by transosseous equivalent technique.

Methods: Ten fresh frozen cadaveric shoulders were used (average age of 86.6 years, range 81-96, four male and six female, seven right and three left shoulders). After thawing the shoulders in a room temperature for 24 hours, all the soft tissues and acromion were dissected except for the rotator cuff muscles and the shoulder was set up in a custom made testing machine. To measure the strain of the tendon, micro strain transducer (M-DVRT, MicroStrain, Burlington, VT) was used for all the settings. Four evaluation sites were determined using the infraspinatus tendon: (A) insertion of the tendon, (B) footprint of the tendon, (C) tendon where medial sutures will be passed through, and (D) musculo-tendinous part of the tendon (Figure 1). The average internal rotation angle for all the cadavers was 28°, under the torque of 250 N-mm. Glenohumeral joint was internally rotated from the neutral position to maximum angle and then externally rotated back to the neutral position manually. This motion was repeated twice. To maintain glenohumeral stability while external rotating, each tendon was loaded to the direction of glenoid, 10 N on the subscapularis and 3.5 N on the supraspinatus, referring from the past reports 7. For the infraspinatus, 4 different loads were applied: 0 kg, 0.45 kg, 0.9 kg, and 1.35 kg. These were calculated from the mean electromyographic activation of the infraspinatus activity results according to the past report. Once the evaluation of the strain for the intact tendon was finished, the infraspinatus tear was artificially created at the footprint with the size of 2 cm in width and 1 cm in
length. Two medial anchors (TwinFix 5.0 Ti, Smith & Nephew, Andover, MA) were inserted and the single suture was passed through the tendon in the mattress fashion. Sutures were passed through the tendon approximately 10 mm to 12 mm medial from the tendon edge and separated 4 mm horizontally. Randomly, in 5 shoulders, medial sutures were tied at the medial row (tied single-mattress: TS) and for rest of the 5 shoulders, sutures were untied (untied single-mattress: UTS). Lateral fixation points were placed 1 cm lateral to the lateral edge of the greater tuberosity. Transosseous equivalent repair was completed by fixing the sutures in cross fashion using lateral anchors (Footprint PK 4.5, Smith & Nephew, Andover, MA). Evaluation of the strain was done at the same measurement point with the intact rotator cuff. Differences of the strain during the internal rotation motion were recoded digitally. The most extended point during the internally rotated motion was subtracted from the neutral point and its difference was converted to the displacement length. The average displacement length of all the evaluation points for the intact tendon and transosseous equivalent technique repaired tendon was calculated.

Differences of the displacement length between the intact tendon and the transosseous equivalent repaired tendon at the footprint of the tendon and at the tendon where medial suture were passed through were analyzed using paired t-test. P value of < .05 was considered to be statistically significant. **Results:** At point B, displacement was shortened by 0.047 ± 0.04 mm with 0 kg, 0.054 ± 0.04 mm with 0.45 kg, 0.055 ± 0.04 mm with 0.9 kg, and 0.048 ± 0.03 mm and 1.35 kg. The differences in displacement between the intact and repaired were all significant (P < .05) (Figure 2). However, at point C in the TS group, the displacement length extended 0.155 ± 0.12 mm with 0 kg, 0.27 ± 0.2 mm with 0.45 kg, 0.505 ± 0.21 mm with 0.9 kg, and 0.256 ± 0.26 mm with 1.35 kg. The differences in displacement between the intact and TS groups were significant (P < .05) (Figure 3). The comparison between TS and UTS showed no significant difference.

**Discussion:** The results revealed that the strain at the footprint of the tendon was extremely small, whereas the strain of the tendon where the medial sutures were passed through increased significantly after the transosseous equivalent technique with the medial sutures tied. This increased difference in strain may lead to stress concentration at the site of the medial row, which might be a cause of the medial reruptures observed after the transosseous equivalent technique. Although the differences in the strain of those repaired with tied and untied medial sutures did not reach a significant level, the strain of those with tied medial sutures showed constantly greater strain than those with untied medial sutures. Future analysis of medial retear rate among those with tied and untied medial sutures may support our biomechanical data.

**Significance:** The strain of the tendon repaired with transosseous equivalent technique was significantly smaller than that of the intact tendon at the footprint. However, it was significantly greater than that of the intact tendon at the medial row suture level only when the medial row sutures were tied. Tying the medial row sutures seems to increase the strain difference between the proximal and distal portions of the repaired tendon.
Figure 1. Four evaluation sites: (A) insertion of the tendon, (B) footprint of the tendon, (C) tendon where medial sutures were passed through, and (D) musculo-tendinous part of the tendon.

Figure 2. The comparison of the displacement at point B.
Figure 3. The comparison of the displacement at point C.