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Introduction: Advancement of arthroscopic technique has increased the popularity of arthroscopic repair of the rotator cuff. To accomplish the repair, suture anchors are widely used with many kinds being distributed, differentiating themselves by its design, materials, and structure. Fixation strength relies on the design of the anchor, density of the bone, insertion depth, and insertion angle. In 1995, Burkhart introduced the deadman’s angle theory, proposing by trigonometric calculation that anchors should be inserted 45 degrees from the insertion surface to increase the pullout strength (1). Recent researches have shown that deadman’s angle does not necessarily display strongest pullout strength. Sano et al. reported that the stress distribution on the anchor was lower in 90 degrees insertion compared to 45 degrees insertion using a three-dimensional finite element method model (2). This result suggested that inserting the anchor 90 degrees to bone surface may demonstrate higher pullout strength compared to inserting the anchor 45 degrees as a result of less stress distribution occurring around its threads. Nevertheless, the study was done by computer calculation with no biomechanical testing to substantiate the results. The purpose of the study was to compare the pullout strength of anchor insertion between 90 degrees and 45 degrees to the bone surface and reveal its relationship with bone mineral density.

Methods: Pullout tests were performed using Instron 5566 (Instron, Norwood, MA) universal testing machine. Synthetic sawbones (Pacific Research Laboratories, Vashon, WA) of three different densities with 2 mm-thick cortical bone model attached on one side were used. The densities of the sawbones were 0.08 g/cm2, 0.16 g/cm2, and 0.24 g/cm2 (defining as low density, medium density and high density, respectively) referring from the past reports (3). TwinFix 5.0 Ti anchor (Smith & Nephew, Andover, MA) was used for all the biomechanical testing. Originally double loaded sutures were switched to braided polyethylene lines to bear the load of testing and the test was investigating only the performance of the bone-to-anchor interface. Sawbones were predrilled using 2.5 mm drill and the anchor was inserted 90 degrees or 45 degrees to the bone surface. Sutures were pulled in two different angles from the bone surface, 90 degrees (load applied parallel to the axis of anchor insertion) representing the worst-case scenario for failure strength as previously described (4) and 45 degrees (load applied 135 degrees to the axis of the anchor insertion) resembling the physiologic pull of supraspinatus (5). This totaled to 4 conditions per each density sawbones block. Sawbones block was set up in a special jig for holding and braided polyethylene lines were tied to custom-made pulling jig by Fisherman’s knot fashion followed by addition of half-hitch for 8 times to each end of the suture to resist the load and prevent the knot from loosening. The anchor was preloaded to 10 N and pulled at a crosshead speed of 1 mm/s (3, 6). The load prior to sudden testing cessation or gradual load decrease was recorded as maximum load to failure and they were digitally recorded. The mode of failure for each specimen was recorded by a video camera. Total of 6 pullout tests were performed for each conditions.

Differences in pullout strength between insertion angle, pulling angle, and bone density were analyzed using Student’s t-test. P value of <.05 was considered to be statistically significant.

Results: Pullout strength of anchor inserted 90 degrees was significantly higher than anchor inserted 45 degrees for low and medium density sawbones regardless of pulling angle (P < .05). For high density sawbones, pullout strength of anchor inserted 90 degrees was significantly higher than anchor inserted 45 degrees when the suture was pulled 90 degrees from the bone surface (P < .01). However, when the suture was pulled 45 degrees, the pullout strength was lower in 90 degrees insertion compared to 45 degrees insertion using a three-dimensional finite element method model (2). Sano summarized that when the anchors were inserted in 45 degrees, the stress distribution around the proximal anchor threads were highly concentrated compared to 90 degrees (2). By our biomechanical testing results, it may support this simulation that as the stress distribution is lower, the pullout strength is stronger. The pullout strength became stronger as the bone density increased. Pietschmann reported that pullout strength of anchors correlated to trabecular bone mineral density (5), which supports our results of relationship between pullout strength and bone density. The
anchors inserted to high density sawbones block and pulled 45 degrees from the bone surface never pulled out and all the sutures were cut at the eyelet. It is documented in the past that anchor eyelet is a critical point and depends on its design as the sharp edge created at the eyelet may cut the sutures (7). We consider the bone density was stronger than the pullout strength leading to cutout at the sharp edge of the eyelet.

**Significance:** Pullout strength of anchor inserted 90 degrees from the bone surface is stronger than anchor inserted 45 degrees in any density bones. The results may suggest that placing the suture anchors at 90 degrees from the bone surface is desirable rather than the deadman’s angle.

**Acknowledgments:**

**References:****
3. Poukalova M. J of Biomech 2010; 43: 1138-1145

![Graph showing pullout force compared to sawbone density and angle of insertion](image)

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