Deadman Angle

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1. **What is Deadman?**
   
   A heavy plate, wall, or block buried in the ground that acts as an anchor for a retaining wall, sheet pile, etc, by a tie connecting the two (*From Dictionary.com*)

2. **Deadman Theory**

   Burkhart et al 1995\(^1\): The Deadman Theory of Suture Anchors

   \( \theta_1 \): pullout angle \( \leq 45^\circ \)  \( \Rightarrow \) Anchor inclination = deadman (rock)

   \( \theta_2 \): tension reduction angle \( \leq 45^\circ \)  \( \Rightarrow \) Suture inclination = deadman wire

   "Ideally, \( \theta_1 \) and \( \theta_2 \) should both be less than or equal to 45°."

3. **Biomechanical studies on \( \theta_1 \)**

   - Reed et al 1996\(^6\): Comparison between transosseous suture vs suture anchor.
     Failure load: 194 N (TO) vs 261 N (anchor)  Recommend that anchors be inserted perpendicular to the line of pull (although tested only one angle of insertion)

   - Liporace et al 2002\(^4\): Comparing barbed anchors inserted at 90°, 75°, 45°, 30° into human cadaveric humeri, no significant difference in the failure load pulling in 135° direction: 171 N at 90°, 219 N at 75°, 169 N at 45°, 192 N at 30°
- Strauss et al 2009\textsuperscript{6}: Cyclic loading in the anatomic direction of the supraspinatus muscle-tendon unit repaired with an anchor inserted at 90° or 45° to the footprint of cadaveric shoulders: Cycles at complete failure: 90° (avg 443 cycles) > 45° (avg 334 cycles)

- Sano et al 2013\textsuperscript{7}: equivalent stress under 100-N pulling force: 90° < 45° in the physiological range of pull (35° - 60°) → risk of anchor pullout: 90° < 45°

- Green et al 2014\textsuperscript{1}: Pullout strength using polyurethane foam: greatest when the pulling angle was similar to the insertion angle. Pullout strength of anchor inserted at 90°: 182 N (0° angle of applied load), 199N (30°), 243 N (60°), 306 N (90°)

- Clevenger et al 2014\textsuperscript{2}: For threaded metallic suture anchors inserted into polyurethane foam, an obtuse insertion angle of 90° and 135° withstands a greater load to failure (375 N, 415 N) than the more acute insertion angle of 45° (< 240 N)

- Nagamoto et al 2014\textsuperscript{5}: pullout strength in the direction of 135°:
  - 711 N (90°) > 599 N (45°) using polyurethane foam
  - 265 N (90°) > 182 N (45°) using the porcine humeri

4. Interpretation

4-1. $\theta_2$

$\theta_2$ is related to the inclination of the sutures through the rotator cuff tendon. As $\theta_2$ decreases, less force to the suture is required to resist the retraction of the cuff tendon. $\theta_2$ was very well described, discussed, and well understandable.\textsuperscript{1}

4-2. $\theta_1$

$\theta_1$ is related to the inclination of the suture anchors in the bone. As $\theta_1$ decreases, more force is required to pullout the anchor. Theoretically, there is 41% more resistance to pullout at $\theta_1 = 45°$ than at $\theta_1 = 90°$.\textsuperscript{1} This is true under the condition that the bony construct does not deform. In other words, when the
suture anchor moves only in the direction of insertion, this mathematical calculation is correct. However, pullout tests using cadaveric bones and polyurethane foam have revealed that this is not the case because the bone deforms and crashes by the rotation of the suture anchor caused by the inclination of the pulling force. The pullout strength decreased by 7% using porcine bones and by 19% using high density polyurethane foam. Finite element model analysis showed that stress was equally distributed without great concentration when the anchor was pulled in the direction of 90°, whereas there was a great stress concentration on the pulling side of the proximal anchor, which would contribute to the rotation of the anchor. The description of $\theta_1$ was very limited in the original paper, and accordingly, all the biomechanical studies thereafter focused on $\theta_1$ issue.

5. Clinical application

5-1. $\theta_2$

$\theta_2$ is related to the inclination of the sutures through the rotator cuff tendon. Once the sutures are passed through the tendon and tied securely, the tendon may retract a little until the force balance comes to the equilibrium. During surgery, we do not need to worry about $\theta_2$.

5-2. $\theta_1$

$\theta_1$ depends on the shape of the anchor. As long as we use the threaded anchors, 135° or closer to it would be more resistant to pullout. In the clinical setting, however, 135° may not be recommended for the medial row anchors because 1) it may not be feasible due to the acromion, and 2) it may penetrate the lateral cortex of the greater tuberosity. Thus, for the medial anchor, inserting it as perpendicular to the facet as possible would be recommended. On the other hand, inserting a footprint anchor to the lateral cortex at 135° (45° caudally) is possible and it is stronger than inserting it at 90°. In addition, it may help to avoid the
butting of the medial-row and footprint anchors. Therefore, closer to 90° for the medial-row anchors and 135° for the footprint anchors seem to be the best angles.

References


