Suture Capsulorrhaphy Versus Capsulolabral Advancement for Shoulder Instability

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Purpose: The purpose of this study was to test the strength of a suture capsulorrhaphy repair versus a capsulolabral repair with knotless suture anchors in a cadaveric model with anteroinferior shoulder instability. **Methods:** Fourteen cadaveric shoulders were tested with either a suture capsulorrhaphy to the intact labrum or a capsulolabral advancement using a knotless suture anchor into the glenoid. Specimens were translated with the shoulder in an abducted, externally rotated position to failure. **Results:** The capsulolabral advancement showed a significantly higher load to failure than did the suture capsulorrhaphy group (P = .030). **Conclusions:** Capsulolabral advancement with suture anchors may offer greater initial strength when compared with a suture capsulorrhaphy. In the setting of shoulder instability without evidence of a labral tear, the capsulolabral advancement technique may be considered biomechanically superior. **Clinical Relevance:** In the setting of shoulder instability due to capsular insufficiency, the capsulolabral advancement may be considered biomechanically superior to a traditional suture capsulorrhaphy.

With advances made in arthroscopic surgery, more surgeons are treating unstable shoulders arthroscopically. Proper tensioning of the glenohumeral ligaments and surrounding capsule is the goal in both open and arthroscopic repairs.[1] Results have been mixed, because initial outcomes show similar dislocation rates to open procedures, but long-term results were less reliable.[2] In fact, in 1 study with 5-year follow-up, only 40% of arthroscopic repairs had no instability, although they were not performed with modern repair techniques.[3]

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Many failures of arthroscopic repair often result from inadequate treatment of capsular laxity or injury. Patients with shoulder instability due to excessive capsular laxity and without a concomitant labral tear are not uncommon. In addition, patients with anterior labral tears may have more global laxity beyond the area of the torn labrum. Capsulorrhaphy has been shown to aid in reduction of instability during surgery. A study by Alberta et al.[4] showed that anterior translation could be reduced with the use of suture plication stitches, and the reduction was similar to open methods. Thermal capsulorrhaphy aimed to address this laxity, and although immediate postoperative results were encouraging,[5] recent literature does not support this treatment because of the risk of chondrolysis, capsular thinning, high failure rate, and axillary nerve damage.[6-11] Many surgeons perform a capsulorrhaphy by suturing the capsule to the labrum, whereas others prefer advancing the capsulolabral complex and securing this with suture anchors. Provencher et al.[12] tested the strength of capsular plication to an intact labrum versus using suture anchors and found that suturing to an intact labrum provided similar fixation strength to repair with glenoid bone anchors when loaded under direct tension to the capsule. Other recent studies in instability surgery show trends in failure with suture capsulorrhaphy when compared with repair with suture anchors. Bradley et al.[13] found in their review of 100 patient shoulders that the 8 patients requiring revision surgery all had capsular laxity and 87.5% had initially undergone only suture capsulorrhaphy. Van Oostveen et al.[14] retrospectively reviewed 267 patients who had undergone arthroscopic stabilization, and the rate of recurrent dislocations was significantly higher in their transglenoid suture group compared with the anchor group (34% *v* 8.7%). Overall, it appears that the trends in these studies show inferiority of a standard suture capsulorrhaphy when compared with the use of bone anchors, yet no cadaveric or biomechanical study has shown this effect.

Limited information is available detailing the relative initial strength or healing capacity of these constructs. Capsulolabral advancement has the potential advantages of soft tissue–to–bone healing and the use of strong suture anchors that do not necessarily rely on knot security if a knotless suture anchor is used. The capsulorrhaphy capitalizes on the strength of the labrum but relies purely on soft-tissue capsular healing and knot strength. We have observed clinically that high–tensile strength suture can cut through labrum or capsule, particularly when a simple suture configuration is used. In addition, even a well-placed knot may migrate toward the articular surface under repetitive loads.

We sought to examine the strength of a suture capsulorrhaphy to an intact labrum versus the capsulolabral advancement after partial labral detachment in resisting anteroinferior humeral head translation in a cadaveric specimen. We also looked at the modes in which the constructs failed and their effects on surrounding tissues. We hypothesized that the capsulolabral advancement would provide a stronger biomechanical construct.

METHODS

Specimens

To determine the necessary sample size to detect a difference between the 2 groups of interest, a power analysis with the failure load as the primary variable was performed. With an expected difference in means of 90 N and an expected SD of 55 N, 7 specimens were necessary to achieve 80% power at $\alpha = .05$. Thus 14 fresh-frozen cadaveric forequarter shoulder specimens (7 matched pairs) (age range at time of death, 30 to 69 years; mean age, 55 years) were prepared for testing by thawing at room temperature and were kept moist with saline solution during testing. Four of the pairs were female cadaveric donors, whereas the remaining 3 were male cadaveric donors. All shoulders were examined and found to be normal, without damage to the rotator cuff or capsule. We removed the skin, bulk musculature, rotator cuff muscles except the subscapularis, and portions of the posterior superior capsule. Most of the capsule was left intact for the procedure to replicate arthroscopic techniques. All 14 shoulders were potted with polyester resin. Wood screws were drilled into the humerus orthogonal to its length to ensure rigidity and position in potting. The humerus was potted in a 5-in section of 2-in-diameter polyvinyl chloride (PVC) pipe. The potting material was kept at least 2 cm away from the origin and insertion of the capsule to prevent damage during epoxy polymerization. The humerus was exposed distal to the capsular attachment and was potted so that the humeral head was centralized over the pot.

The medial border and inferior tip of the scapula were resected, allowing the potting material to remain 2 cm away from the capsule. Wood screws were drilled into the scapula to increase potting rigidity. The scapular remnant was potted in a 1-in section of 4-in-diameter PVC pipe. While the polyester resin set, the specimen was fixed so that the articulating surface of the glenoid was parallel to the base of the PVC mold (Fig 1).

Creation and Repair of Labral Damage

The initial specimen for each matched pair was randomized to either capsulorrhaphy or capsulolabral advancement repair, with the other specimen receiving the companion procedure. After this, all soft tissues except the capsule from the superior border of the anterior band of the inferior glenohumeral ligament position (roughly the 3-o'clock position) in the right shoulder to the 6-o'clock position were removed to isolate the anteroinferior portion, including the anterior band of the inferior glenohumeral ligament, which is the most commonly injured area clinically.[15,16] This allowed us to accurately test only the tissue repaired and isolate the anteroinferior capsule as a variable. Both procedures were performed using arthroscopic instrumentation in an effort to best represent the clinical procedures, although the procedure was theoretically an open repair.

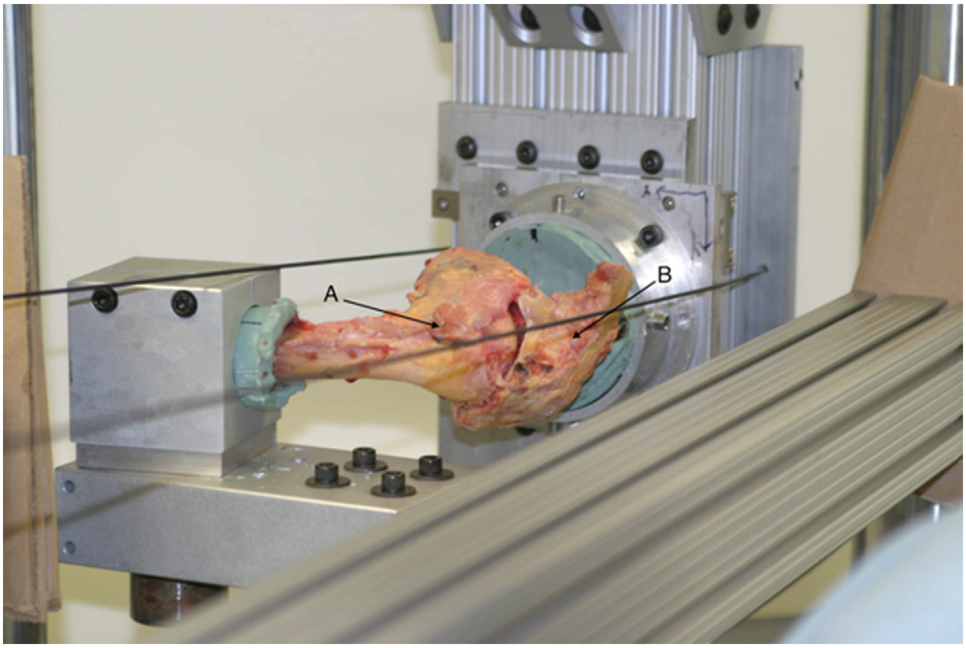

Figure 1. Cadaveric humerus (A) and scapula (B) mounted in MTS machine.

For the capsulorrhaphy group, sutures (No. 2 FiberWire; Arthrex, Naples, FL) were passed through the capsule 1 cm from the glenoid and brought up through the labral-chondral junction. The sutures were tied with a Weston knot such that the knot was placed outside the capsule away from the articular surfaces. These were placed at the 4- and 5-o'clock positions in reference to right shoulder specimens.

For the suture anchor group, a labral detachment was performed between the 3:30 and 5:30 positions to allow for the advancement. Sutures (No. 2 FiberWire) were passed through the capsule 1 cm from the glenoid, around the labrum, and advanced between the labrum and glenoid. Pilot holes for a 2.9-mm PushLock anchor (Arthrex) were created at the 4- and 5-o'clock positions, 1 mm onto the glenoid surface, and angled to simulate drilling through anterior portals.[12] The capsulolabral complex was advanced (6-o'clock tissue into 5-o'clock hole and 5-o'clock tissue into 4-o'clock hole) onto the face of the glenoid as the anchor was pounded into the pilot hole, forming a larger buttress anteriorly than would be present when only an intact labrum is present. This model also mimics the clinical scenario where surgeons want to create soft tissue–to–bone healing.

Shoulder Testing Machine

Each specimen was mounted in a custom testing machine, with the scapular tray parallel to the floor. The design of this construct allowed the shoulder to be positioned throughout a full range of abduction and external rotation. Uniaxial bearings allowed motion in both the mediolateral and superoinferior directions. Motion in the anteroposterior direction was semiconstrained by the actuator. Once mounted, the fixture was adjusted so that the specimens would have 60° of glenohumeral abduction, which corresponds to 90° of shoulder abduction, where most instability occurs.[17] External rotation was determined by aligning the bicipital groove with the supraglenoid tubercle.[18] Once mounted, the specimen was rigidly locked in place to the testing frame. Motion was only allowed in the unconstrained direction described previously.

A joint compression force of 22 N was placed on the joint by suspending weights from platforms supporting the humerus and scapula. This load stimulated standard resting muscle forces on the joint, creating mechanical stability to ensure testing reproducibility.[19] The jig was mounted to an 858 Mini-Bionix II (MTS Systems, Eden Prairie, MN) load frame. The scapular side of the specimen was mounted to the actuator arm, whereas the humeral side was mounted to the load cell.

Testing Protocol

The anatomic axes were defined with respect to the scapula. All translations of the humeral head were measured with respect to the scapula. The reference position was determined by centering the humeral head on the glenoid face. Each specimen was conditioned before load-to-failure testing. The conditioning protocol consisted of loading the joint construct from 0 to 44 N 10 times at a rate of 0.25 Hz. After conditioning, each specimen was loaded to failure with a constant displacement rate of 1 mm/s. A displacement of 30 mm was tested on all specimens to ensure failure. Axial force, displacement, and time to failure were all measured.

Data Analysis

Load-to-failure, stiffness, and translation data for capsulorrhaphy and capsulolabral advancement specimens were compared by use of a Student *t* test, with the significance level determined by $P < .05$. Data analysis was performed with SigmaPlot software (SigmaPlot 11.0; Systat Software, San Jose, CA).

RESULTS

Table 1 details the results for each matched shoulder pair during testing. Mean load to failure for the anchor capsulolabral advancement (210.2 ± 64.5 N) was significantly higher than that for the suture capsulorrhaphy group (134.3 ± 49.7 N) ($P = .030$) (Fig 2, Table 2). In 2 of the 7 anchor specimens, failure occurred with anchor pullout, and in the remaining 5, the sutures tore through the capsule. For the suture capsulorrhaphy group, 5 of the 7 specimens failed when the sutures tore through the capsulolabral complex, whereas in the remaining 2, the sutures failed at their knots.

The stiffness data (Fig 3) showed that the mean was higher for the anchor group (23.9 ± 10.6 N/mm) than it was for the suture group (19.5 ± 12.7 N/mm), but these values were not significantly different ($P = .50$). Mean translation distance to failure (Fig 4) was also higher for the anchor group (11.6 ± 7.6 mm) when compared with the suture group (8.4 ± 5.9 mm), but again, this difference was not significant ($P = .40$).

DISCUSSION

A gold-standard treatment for shoulder instability caused by capsular laxity with an intact glenoid labrum has not been fully elucidated. In this biomechanical study, a significantly higher load to failure occurred with the use of suture anchors when compared with a standard capsulorrhaphy stitch. These results differ from the previously referenced study by Provencher et al.,[12] where they found no statistically significant difference in load to failure between suture anchors and suture repair, although differences in their testing and ours certainly exist. Similar to their study, though, no difference was seen in stiffness.

Careful examination of failure modes during testing showed that when placing a capsulorrhaphy stitch through the capsule and around the labrum, pullout through the labrum resulted in 5 of the 7 specimens. In a clinical setting, this would suggest that a patient who had a repeat episode of instability after suture capsulorrhaphy could damage his or her labrum to an extent that could make revision arthroscopic labral reconstruction more complex. For the anchor group, 2 of the 7 failures occurred with anchor failure, and the other 5 were soft-tissue failures. Barber et al.[20] studied the failure modes of various suture anchors and found that the soft tissue–suture interface is typically the weakest part of the repair and that the anchor itself is normally

Table 1. *Study Results for 7 Matched Shoulder Pairs*

Specimen Pairs	Side	Suture/Anchor	Failure Load (N)	Translation (mm)	Stiffness (N/mm)
1	Left	Anchor	179.157	24.600	7.282
	Right	Suture	131.821	16.980	7.757
2	Left	Anchor	286.976	19.250	14.875
	Right	Suture	93.102	4.370	19.886
3	Left	Suture	69.553	15.300	5.927
	Right	Anchor	121.200	5.950	24.752
4	Left	Suture	206.726	11.110	23.151
	Right	Anchor	241.715	10.620	32.033
5	Left	Anchor	255.810	5.110	36.522
	Right	Suture	184.826	3.740	43.490
6	Left	Suture	104.345	4.780	22.872
	Right	Anchor	136.052	4.460	32.815
7	Left	Anchor	250.740	11.650	19.140
	Right	Suture	39.673	2.810	14.039

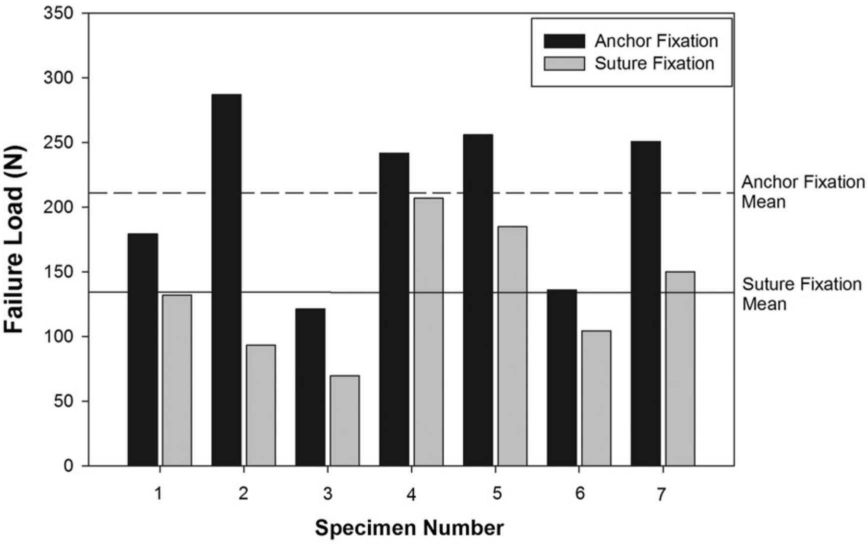

FIGURE 2. Failure loads (in Newtons) of anchor versus suture fixation in 7 matched pairs of cadaveric shoulders.

not the area of failure. Similar studies examining the anchor–to–suture–to–soft tissue interface also suggest that the weak link for failure is at the soft tissue–suture interface.[21,22] Our results showed similar mean loads to failure due to anchor pullout and soft-tissue injury for the capsular advancement group, which is related to the inability of suture anchors to properly achieve fixation in cadaveric bone, which may have inadequate bone density compared with living tissue. Although we saw similar frequencies of soft-tissue versus suture/anchor failures in the 2 groups, the importance of creating the strongest repair available is of utmost importance. Soft-tissue failure can be considered detrimental to subsequent labral repair, and revision surgeries after these failures may force the surgeon to debride large amounts of labral tissue. Thus the strength of the construct is of upmost importance in preventing recurrence of glenohumeral instability.

In contrast to prior studies on the strength of labral and capsular repairs, the specimens in our study were tested to failure by translating an intact humerus along the glenoid in a manner such that the shoulder would move biomechanically and in a manner similar to methods used to diagnose instability clinically.[23] The ability to translate the humeral head against the repair may better model the actual clinical loads applied. In addition, the labrum itself was detached in the capsulolabral advancement group to advance the labrum to a more prominent position on the glenoid face. Ideally, a third treatment group would have been included wherein the labrum was left intact, but it would not have been possible to advance the capsulolabral complex into a position where we consider that it could better resist recurrent subluxation events. We believed that many clinicians would prefer a more substantial advancement, and thus we created an environment for soft tissue–to–bone healing, modeling an actual clinical scenario. In addition, if the labrum was not mobilized, this may have been a study where the only difference between treatment groups was the addition of an anchor. In the setting of patients with multiple instability issues and recurrent surgical failures, this labral advancement offers an option for the surgeon to attempt before pursuing an open procedure.

Many studies have examined risk factors for recurrence of shoulder instability after arthroscopic Bankart repair, which include improper restoration of labral height, a large percentage of glenoid bone loss, cap-

TABLE 2. *Aggregate Data and Statistical Significance*

	Failure Load	Translation	Stiffness
Aggregate data (mean ± SD)			
Suture fixation	134.3 ± 49.7 N	19.5 ± 12.7 mm	8.4 ± 5.9 N/mm
Anchor fixation	210.2 ± 64.5 N	23.9 ± 10.6 mm	11.6 ± 7.6 N/mm
Statistical significance	.03	.496	.397

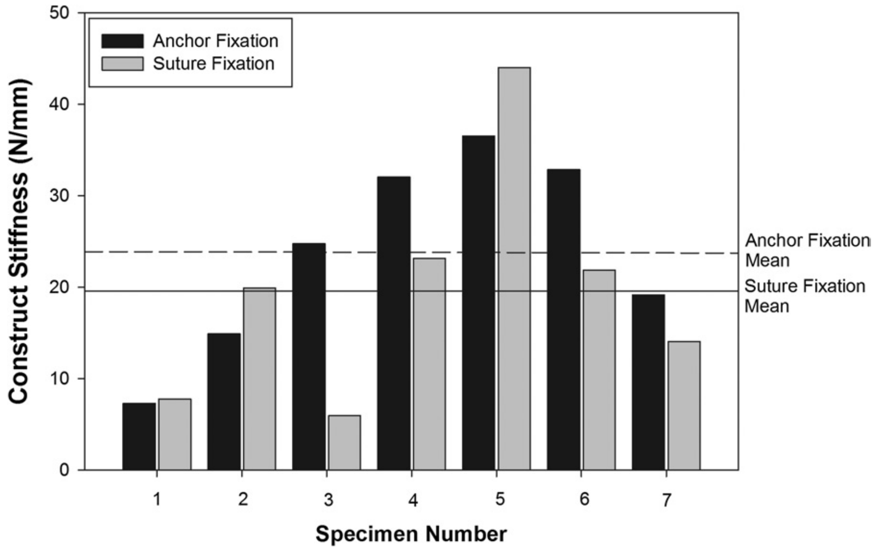

Figure 3. Construct stiffness (in Newtons per millimeter) of anchor versus suture fixation in 7 matched pairs of cadaveric shoulders.

sular redundancy, and periosteal sleeve avulsion lesions (anterior labroligamentous periosteal sleeve avulsion), although a Bankart lesion does not always account for the presence of instability.[24-27] Stefko et al.[28] found that significant stretching occurred in the anterior band of the inferior glenohumeral ligament with acute Bankart lesions. It stands to reason that addressing a stretched capsule during an arthroscopic repair for a Bankart lesion would decrease the incidence of recurrent instability. Ahmad et al.[29] have advocated a double-row repair of the glenoid to better increase the insertional footprint of the capsulolabral complex, although research for this is limited. Our clinical experience shows that patients with shoulder instability may not have obvious damage to the glenoid labrum, and instead, they require repair of the surrounding soft tissues. Results of this study suggest that a capsulolabral advancement using suture anchors may be superior to suture capsulorrhaphy stitches around the labrum.

Limitations of our study include the inability to account for variations in the strength of the cadaveric shoulder tissues across the specimens; bone densitometry may have revealed issues with glenoid bone stock. This may account for the variations in failure load that occurred across each specimen. Second, as mentioned earlier in the "Discussion" section, the labrum was detached in the capsulolabral advance-

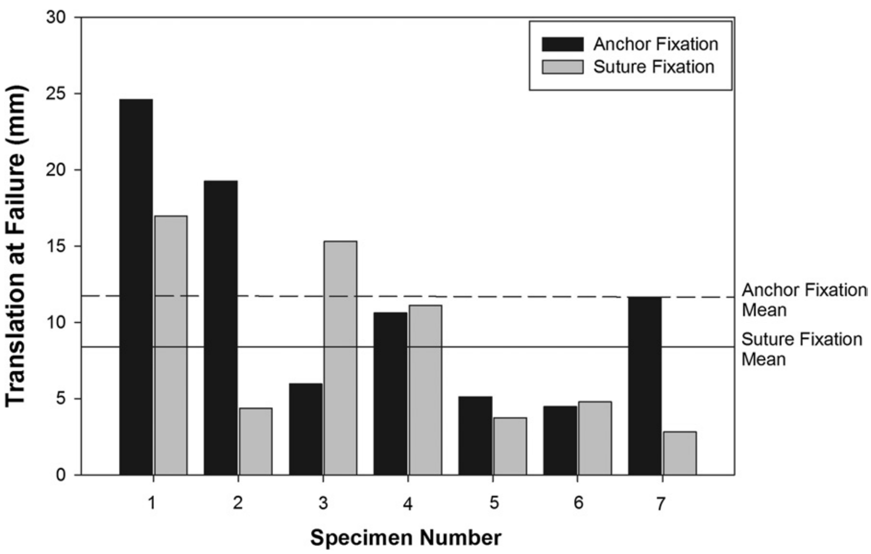

Figure 4. Translation at failure (in millimeters) of anchor versus suture fixation in 7 matched pairs of cadaveric shoulders.

ment group, though not in the suture capsulorrhaphy group. Thus no true control group exists, and testing an intact labrum to failure or detaching the labrum and repairing it without advancement would have given data to compare results between groups. In addition, although the rotator cuff was removed, the main focus of our study was to show the differences in failure load and strength with different labral repairs. The study of Provencher et al.[12] is most similar to our study in terms of methodology, except that the labrum was loaded by translating the humeral head on the glenoid, whereas they directly pulled on the labrum to failure. However, a model with an intact rotator cuff and simulated active motion could yield further information. When we were designing this study, the importance of the labral advancement is a factor that we hoped the study would reveal—our results showed that even with partial detachment, the construct was still biomechanically superior. In addition, the specimens were not cyclically loaded during testing. A cyclic load would better replicate repetitive shoulder motion and could show larger differences in testing between the 2 testing groups. However, cyclic loading of cadaveric tissues that cannot respond biologically to these loads may also be of limited value. Procedures were performed using arthroscopic instrumentation in an effort to best represent the clinical procedures, although the procedure was theoretically an open repair. Lastly, this cadaveric biomechanical study is used to deliver information for a clinical problem normally treated arthroscopically, so the results do not directly correlate; randomized, prospective clinical control trials could be performed to examine outcomes in patients.

CONCLUSIONS

In this study we compared the strength of suture capsulorrhaphy versus capsulolabral advancement as it related specifically to humeral head translation and rotation in an abducted, externally rotated position of a cadaveric model. Capsulolabral advancement with suture anchors may offer greater initial strength when compared with a suture capsulorrhaphy. In the setting of shoulder instability without evidence of a labral tear, the capsulolabral advancement technique may be considered biomechanically superior.

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