SCIENTIFIC ARTICLE

Arthrodesis Versus Arthroplasty in Thumb Carpometacarpal Osteoarthritis: Impact on Maximal Voluntary Force, Endurance, and Accuracy of Pinch

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Purpose To investigate differences in pinch strength recovery among patients with first carpometacarpal joint osteoarthritis treated with either arthrodesis or suspension arthroplasty.

Methods Thirty-seven subjects who underwent arthrodesis or suspension arthroplasty for carpometacarpal osteoarthritis were included. Force exerted during maximal voluntary contraction (MVC) in a pinch task was measured. Maximal voluntary contraction was recorded using a haptic device equipped with a load cell from which an analog signal was acquired and digitized for visual feedback. Dynamic force was assessed by a task consisting of 10 repetitions, with a target of 70% of MVC. Endurance was assessed by the length of sustained pinch task at 30% of MVC. Task performance was quantified by mean distance and offset error from the target force as error indices, and standard deviation of force was used as index of force steadiness.

Results The arthrodesis group obtained considerably higher MVC values than the arthroplasty group. No notable differences were found for pinch endurance. The standard deviation for dynamic force was lower for arthroplasty, indicating greater force steadiness.

Conclusions Arthrodesis is associated with greater pinch strength. Arthroplasty is associated with better pinch precision. *(J Hand Surg Am. 2022;47(1):90.e1-e7. Copyright © 2022 by the American Society for Surgery of the Hand. All rights reserved.)*

Type of study/level of evidence Therapeutic IV.

Key words Arthrodesis, arthroplasty, carpometacarpal, osteoarthritis, pinch.

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STIFFNESS, LOSS OF GRIP, and loss of pinch strength, along with pain at the base of the thumb are the most common symptoms of first carpometacarpal (CMC) joint osteoarthritis (OA).[1] These impairments have an important impact on hand functioning and on the ability to perform tasks of daily life such as clipping nails, turning keys, or opening tight jars and food packages.[2]

Nonsurgical treatment should be considered as the first approach for the management of CMC OA disease; however, if that fails, surgical treatment may be an option.[3] The 2 main surgical techniques used for

the treatment of thumb CMC OA are arthrodesis and suspension arthroplasty. Yet, it remains unclear which surgical approach leads to better results in terms of strength recovery and hand function.[4–6] Pinch strength has been widely used as an objective measure of thumb function.[2] Although maximal static pinch force is a well-established measure, it cannot quantify the sensorimotor integration necessary to perform most of the activities of daily living that require submaximal forces and the ability to maintain and adapt pinch strength.[7,8] Force control assessment testing has recently been improved; it is no longer limited to maximal static force measurement and also allows for a more accurate evaluation of all force components.[9–14] Furthermore, the employment of visual feedback during the assessment can challenge conventional methods of evaluation; recent studies have demonstrated the positive psychologic impact of the new tool interfaces.[12–14]

The purpose of our study was to investigate and compare the effects of arthrodesis and arthroplasty surgical procedures on hand force control, combining an innovative visual feedback-based system for pinch assessment.

METHODS

Study design

This was a retrospective study conducted on a convenience sample of subjects who underwent thumb CMC surgery between February 2011 and October 2018.

Patient inclusion criteria were established as follows: age between 40 and 70 years; previous diagnosis of CMC OA radiographic grade III/IV on the Eaton-Littler classification; surgical treatment with arthrodesis or suspension arthroplasty; and minimum of 1 year after undergoing surgery. Subjects were excluded if one of the following conditions was present: concurrent musculoskeletal hand/wrist pathologies (carpal tunnel syndrome or de Quervain tenosynovitis); systemic inflammatory diseases (rheumatoid arthritis, psoriatic arthritis, gout, or scleroderma); complex regional pain syndromes or neurologic pathologies; acute inflammatory state of the CMC joint during the week before the assessment (local edema or swelling, increased temperature, local tenderness, or limiting pain); and medication usage (anticonvulsants, narcotics, opioids, or muscle relaxant drugs). A cohort of 227 patients met the eligibility criteria and was asked to participate in the study. From this cohort, 149 patients were not contactable, and 41 patients decided not to participate. Thirty-seven subjects agreed to participate and were enrolled in the study. A total of 42 hands were assessed, 22 of which were treated with arthrodesis and 20 with suspension arthroplasty. All patients underwent surgery in the same surgery center and from the same chief surgeon. The choice of surgical procedure was determined by a clinical decision shared between the patients and the surgeon, taking into account complaints and the functional demands of each patient.

For an arthrodesis, the articular surfaces were removed using an oscillating saw, and the fusion was performed using the insertion of a memory staple. The thumb position of fusion was determined by positioning the joint structures in a 45° angle between the thumb and index metacarpals and in opposition to the third metacarpal bone. The suspension arthroplasty was performed in accordance with the Weilby-Ceruso technique.[15,16] A dorsal incision was made in the joint capsule, and trapeziectomy was performed. After that, the arthroplasty was performed by suturing the abductor pollicis longus to the flexor carpi radialis by sectioning the tendon at the myotendinous junction and forming a double loop, first across a buttonhole made in the distal part of the flexor carpi radialis and then around the flexor carpi radialis tendon.

Data collection

Data regarding sex (M/F), age (years), body mass index, dominant hand (right/left), site of surgery (right/left), surgical approach (arthrodesis/arthroplasty), occupation (blue/white collar or other), comorbidities, and drug therapies were collected.

Force transducer

The pinching force was assessed by an acquisition system consisting of a load cell made of AISI 630 steel with a measuring range of ±250 N and a nominal offset of ±0.075 mV/V (EMAC s.r.l.), which converted analog signal into digital, providing a visual feedback of the exerted force to the participant.

Procedures

The subject was seated on a height-adjustable chair in front of a table, with a computer monitor positioned at a distance of 60 cm. The subject was asked to keep the trunk in an erect posture, with a natural head position and the feet well placed on the floor (90° of hip, knees, and ankle flexion). The subject was asked to maintain the forearm of the arm being tested on the table up to the elbow (three-fourths of the forearm on

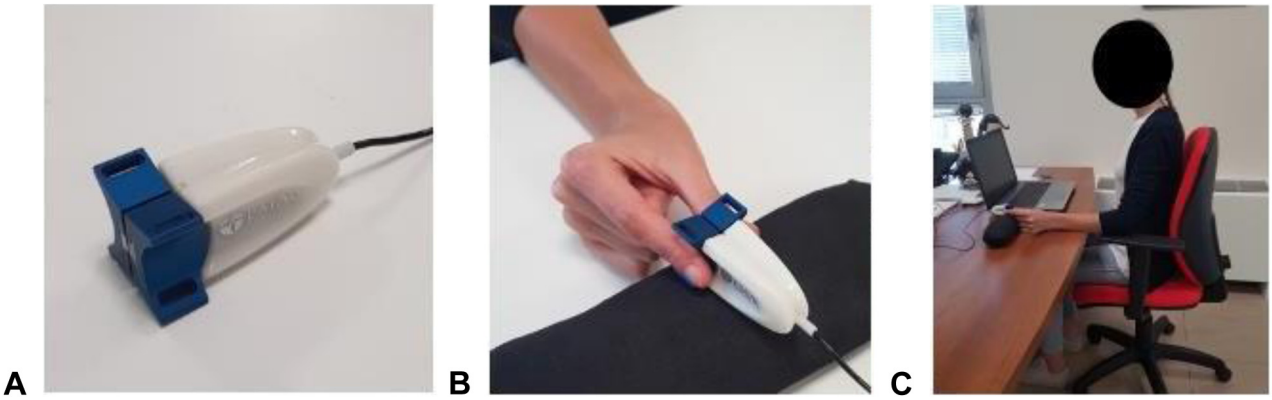

FIGURE 1: Pinch assessment. **A** Pinch assessment device. **B** Pinch assessment position. **C** Patient position.

the table and the elbow off) in a neutral position of pronation-supination and with slight extension of the wrist (approximately 30°). The subject was asked to maintain the sensor with a pulp-to-pulp pinch between thumb and index finger, maintaining the interphalangeal joints extended and the middle, ring, and little fingers flexed against the palm of the hand. The signal of the force delivered by the subject's pinch grip was directly acquired by the computer that generated the relative visual feedback displayed on a monitor (Fig. 1).

For the measurement of maximal voluntary contraction (MVC), the subject pinched the device with his maximal available strength. The subject was able to visualize the force via the visual feedback displayed on the computer screen and was encouraged to get the maximal value. Two tests were performed, with an interval of 30 seconds in between, and the highest value was recorded as the reference value.[17] In the dynamic force (DF) assessment, the task consisted of reaching and holding the position of the cursor displayed on the monitor at a target level of 70% of the MVC. A total of 10 targets were administered to the subject, each one of 5 seconds duration, with a resting interval of 10 seconds. In the pinch endurance assessment, the task consisted of reaching and maintaining the position of the cursor at 30% of the MVC for as long as possible. The task was stopped if the cursor exited from a tolerance range of 10% of the initial MVC for more than 2 seconds.

Force measures

The maximal pinch force, time duration for the endurance task, precision, and steadiness obtained during pinch tasks were recorded for each subject. Individual performance was assessed in terms of precision, by mean distance (MD) and offset error (OE), and in terms of steadiness by standard deviation (SD).

Mean distance represented the average cursor-target distance, OE was calculated as the distance between the average cursor position and the target, and SD was calculated as the standard deviation of the subject's force despite the target force.[17] These 3 indices were normalized over the target force value and therefore were expressed as percentage error. While the indices were mutually dependent, they provided a different functional meaning. Standard deviation was considered as an indicator of force unsteadiness, displayed by the spread of the cursor trajectory around the target and was assumed to be a measure of precision. This index represented the force signal oscillations and so reflected the subject's ability to recruit motor units involved in the task in a synchronized and stable way. A lower value of SD corresponded with a lower variability of the force signal; this was the result of a more controlled force exertion during the pinch task. Offset error indicated whether there was an offset between the average cursor position and the target, and it was a measure of accuracy. Mean distance was an overall matching error index that depended on both OE and SD.[13] This represented the average cursor-target distance and provided clinically useful information about the precision and accuracy of the motor performance.

Data analysis

Nonparametric statistical analyses were performed to account for the relatively small size of the sample. The Mann-Whitney U test was applied to evaluate the differences between the groups (arthrodesis and arthroplasty) for all force variables (MVC, MD, OE, and SD). Results are reported as mean and SD. Linear regression analysis was performed for mean strength value (in kilograms) in the DF assessment for the last

TABLE 1. Baseline Characteristics*

Characteristic	Arthrodesis (n = 22)	Arthroplasty (n = 20)
Age (y)	57.95 ± 6.43	57.40 ± 4.86
Sex (% female)	63.6	80.0
Body mass index	23.89 ± 4.47	25.89 ± 4.05
Site of surgery (% dominant hand)	40.9	50.0
Time from surgery (mo)	42.05 ± 27.84	26.50 ± 15.77
Current pain intensity (numerical rating scale)	0.91 ± 2.00	0.65 ± 1.57

*Values given as mean ± SD unless otherwise stated.

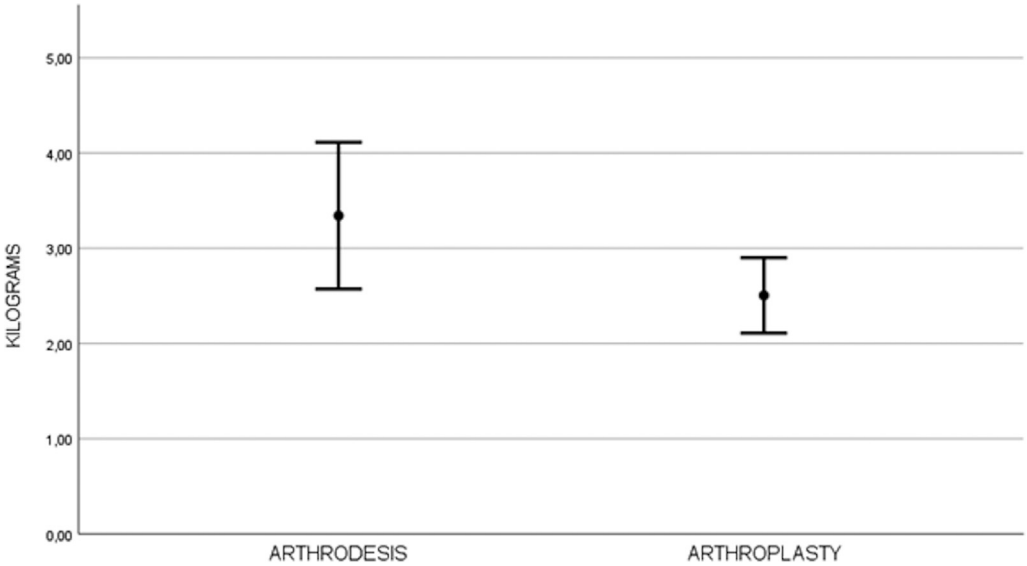

FIGURE 2: Maximal voluntary contraction. The arthrodesis group showed a mean value of 3.34 kg (95% confidence interval [CI] 2.57−4.11), whereas arthroplasty group showed a mean value of 2.50 kg (95% CI 2.10−2.90).

5 targets to assess the development of the fatigue trend between groups.

RESULTS

Baseline characteristics of the subjects are presented in Table 1. In the force assessment, the MVC task showed differences in the favor of the arthrodesis group (Fig. 2), whereas the DF task showed lower SD for the arthroplasty group, indicating greater precision, but no differences were found in MD and OE (Fig. 3). The pinch endurance task showed no differences between the groups (Fig. 4).

In addition, the arthrodesis group showed a minor fatigue trend (b = −0.002; y = −0.002*x + 1,954) compared with the arthroplasty group (b = −0.010; y = −0.010*x + 1,429) (Fig. 5). This linear regression analysis confirmed that fatigue developed in both groups and therefore allowed us to exclude biases due to potential differences during pinch exertion effort.

DISCUSSION

The aim of our study was to investigate the potential differences between subjects who underwent arthrodesis or arthroplasty surgery for thumb CMC OA in terms of strength recovery. Strength level and force control were assessed by an innovative system for pinch force evaluation, which converted the measured pinching force to visual feedback and provided an objective assessment by engaging the subjects in an intuitive "reach-and-hold" type of task. There is growing evidence that the employment of digital devices in combination with visual feedback can provide additional value in the clinical assessment of various musculoskeletal conditions,

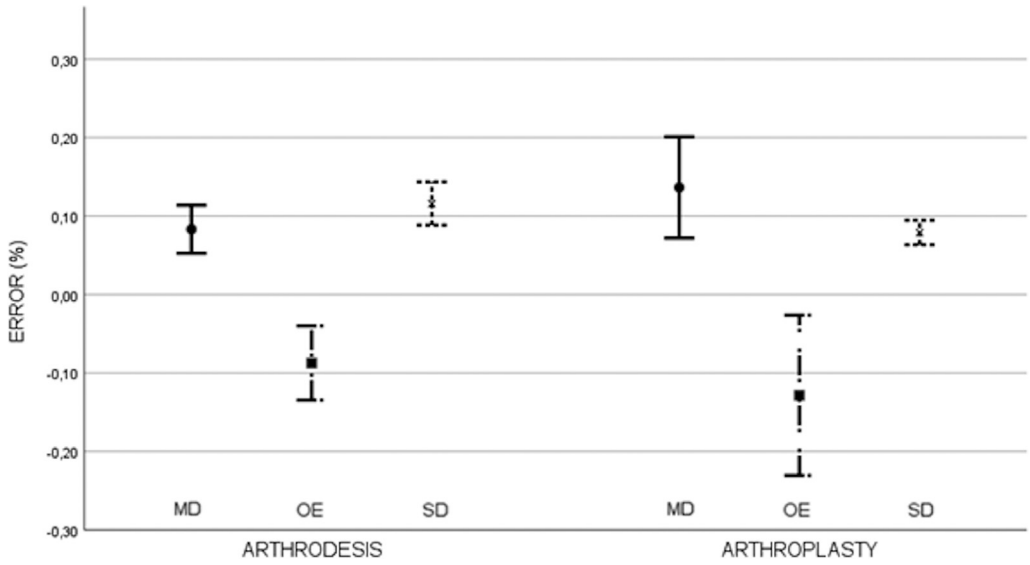

FIGURE 3: Dynamic force assessment. For the variable MD, the arthrodesis group showed a mean value of 8.32 (95% CI 5.25−11.39), whereas the arthroplasty group showed a mean value of 13.65 (95% CI 7.20−20.10). For the variable OE, the arthrodesis group showed a mean value of −8.73 (95% CI −13.46 to −4.00), whereas the arthroplasty group showed a mean value of −12.85 (95% CI −23.06 to −2.64). For the variable SD, the arthrodesis group showed a mean value of 11.59 (95% CI 8.84−14.34), whereas the arthroplasty group showed a mean value of 7.90 (95% CI 6.33−9.47).

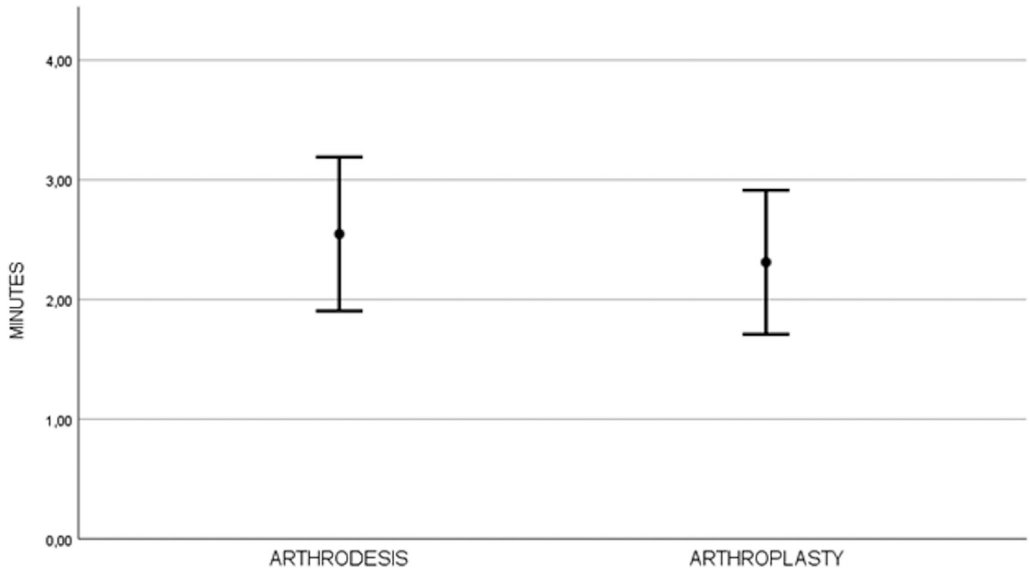

FIGURE 4: Pinch endurance assessment. The arthrodesis group showed a mean value of 2.55 min (95% CI 1.91−3.19), whereas the arthroplasty group showed a mean value of 2.31 min (95% CI 1.71−2.91).

particularly regarding pinch and grip hand strength testing.[9−14]

Our findings indicate that people who underwent arthrodesis surgery showed better results in the MVC task, although other studies demonstrated no statistically significant differences among groups.[4,18−21] The study of Hartigan et al,[18] found significant differences in favor of the arthrodesis group in lateral and chuck pinch but not for pulp-to-pulp tip-pinch strength. More recent evidence provided by Vermeulen et al[20] and Spekreijse et al[21] found similar results for tip pinch. In contrast, Raven et al[19] reported no significant differences between groups in terms of strength. The pinch strength assessment in their study relied exclusively on qualitative methods, without clear indications on how the procedure was performed; therefore, no comparison could be made between their findings and ours.[19] Accordingly,

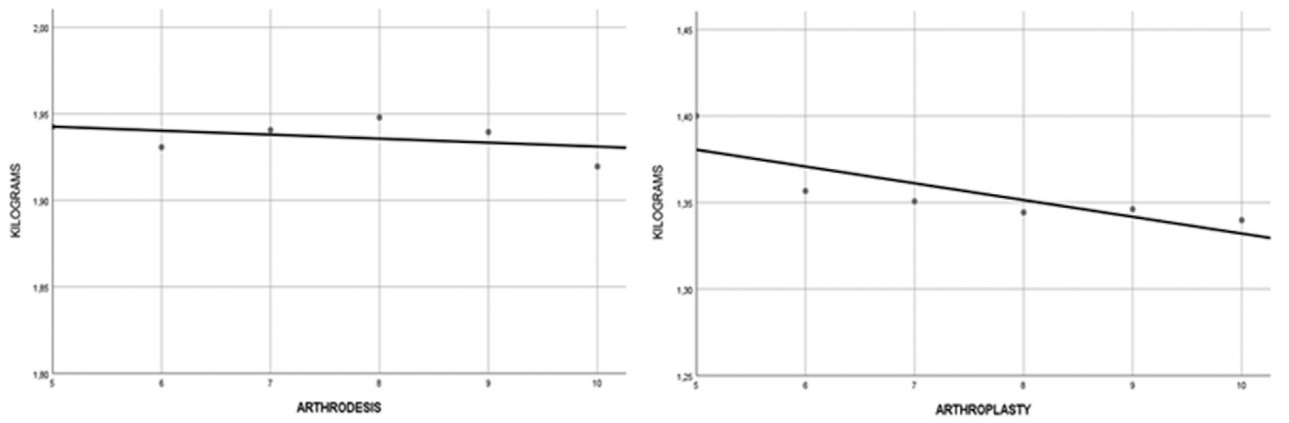

FIGURE 5: Fatigue trend. The arthrodesis group showed a minor fatigue trend (b = −0.002; y = −0.002*x + 1,954) compared with the arthroplasty group (b = −0.010; y = −0.010*x + 1,429).

Mureau et al[4] did not find significant differences for tip-pinch strength between the arthrodesis and arthroplasty groups. The discrepancy between our results and those of these previous studies could be due to different factors. First, our study measured pinch strength by the means of a digital device with visual feedback, whereas previous studies employed analog dynamometers; this methodological difference could at least partially explain the differences between the findings.[4,18,20,21] Second, we investigated tip-pinch position because this allowed us to evaluate the different parameters of motor control associated with strength modulation, precision, and endurance. Since the majority of the available studies have focused on the assessment of maximal strength only, pinch positions better suited for this type of task, such as lateral and tripod pinch grips, were used.[4,18,20,21] Differences between pinch position modes offer a further explanation for the discrepancy between our findings and those reported in the previous literature. Specifically, in our study, in order to focus distribution of joint stress at the CMC joint and to guarantee a suitable distribution of the joint loads, the CMC joint was maintained at a neutral position during the exertion of the pinching force, limiting the involvement of the metacarpophalangeal and interphalangeal joints.[22] We can therefore speculate that the difference in MVC results could be due to a gain in joint stability obtained by the arthrodesis approach, resulting in less force dissipation during the task than with the arthroplasty approach.[23]

In the assessment of the DF, the arthroplasty group showed better results in terms of SD, meaning that this approach may provide a better steadiness of the pinch strength. To exclude a bias introduced by a lower MVC depending on a lower effort level of the patients in the arthroplasty group, we analyzed the fatigue trend during the DF task in the last 6 targets by a linear regression model. The results (Fig. 5) demonstrate that fatigue developed in both the groups, more strongly so in the arthroplasty group. This confirmed that maximum force has likely been exerted by the patients in both the groups while performing the MVC assessment. The fact that both the groups exerted their maximal force allows us to assume that all the patients had an appropriate development of fatigue in all the strength performances. This excludes bias due to potential differences related to effort and suggests that the differences we found between the groups were not compromised by different levels of engagement in the MVC task.

The study has some limitations. First, there could be selection bias due to the method of convenience sampling that we employed to enroll the patients in our study, and the sample size was small, with less than 20% of the total number of eligible cases. Participants were recruited in the same hand surgery center where the choice of the surgical procedure was determined by a decision shared between the patients and the surgeon. Because all the procedures were performed by the chief surgeon, this could have also led to a selection bias. Although the sample had a high prevalence of women (72%), it is well established that CMC OA is more common in females[24–26]; thus, a higher ratio of women to men was expected.

Another limitation of this study is that only 1 type of pinch was assessed, for which normative data were not available; thus, our results could not be compared with the strength level among the unaffected population. Moreover, during the strength analysis it was not possible to assess and compare the contralateral

side because CMC OA is typically a bilateral disorder, and our intent was to evaluate the long-term functionality of the hands that underwent surgery.[18]

These results could help surgeons choose the surgical approach based on the consideration of patient goals. To conclude, our findings suggest that arthrodesis could be advantageous in cases in which the functional need is characterized by a higher requirement for strength.[27] Otherwise, in cases in which the requirement is more based on precision abilities, arthroplasty might be preferred.

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