Minimal Clinically Important Difference and the Effect of Clinical Variables on the Ankle Osteoarthritis Scale in Surgically Treated End-Stage Ankle Arthritis

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Background: There is much debate regarding the best outcome tool for use in foot and ankle surgery, specifically in patients with ankle arthritis. The Ankle Osteoarthritis Scale (AOS) is a validated, disease-specific score. The goals of this study were to investigate the clinical performance of the AOS and to determine a minimal clinically important difference (MCID) for it, using a large cohort of 238 patients undergoing surgery for end-stage ankle arthritis.

Methods: Patients treated with total ankle arthroplasty or ankle arthrodesis were prospectively followed for a minimum of two years at a single site. Data on demographics, comorbidities, AOS score, Short Form-36 results, and the relationship between expectations and satisfaction were collected at baseline (preoperatively), at six and twelve months, and then yearly thereafter. A linear regression analysis examined the variables affecting the change in AOS scores between baseline and the two-year follow-up. An MCID in the AOS change score was then determined by employing an anchor question, which asked patients to rate their relief from symptoms after surgery.

Results: Surgical treatment of end-stage ankle arthritis resulted in a mean improvement (and standard deviation) of 31.2 ± 22.7 points in the AOS score two years after surgery. The MCID of the AOS change score was a mean of 28.0 ± 17.9 points. The change in AOS score was significantly affected by the preoperative AOS score, smoking, back pain, and age.

Conclusions: Patients undergoing arthroplasty or arthrodesis for end-stage ankle arthritis experienced a mean improvement in AOS score that was greater than the estimated MCID (31.2 versus 28.0 points).

Level of Evidence: Therapeutic Level IV. See Instructions for Authors for a complete description of levels of evidence.

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Determining the degree of disability and the success of treatment for musculoskeletal conditions remains a challenge. Outcomes scores are an attempt to determine clinically relevant, measurable factors that can be used to determine the success of treatment or the impact of disease. Outcomes scores allow practitioners to (1) objectively evaluate functional status; (2) measure differences in functional status before and after treatment, over time, or between treatment groups; and (3) determine how functional status affects the lives of patients[1]. Outcomes scores are generally global (pertaining to the overall health of the whole person), regional (pertaining to one area of the body), or disease-specific (pertaining to one disease process). Ideally, outcomes scores should be reliable (i.e., repeatedly producing the same results when

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measuring the same thing), valid (i.e., measuring what they purport to measure), and responsive (i.e., able to detect meaningful clinical change)[2].

There are a limited number of validated, reliable, responsive outcomes tools in the orthopaedic foot and ankle subspecialty[3]. The Ankle Osteoarthritis Scale (AOS) was created in 1998 from the previously established Foot Function Index, with the goals of creating a disease and region-specific score that accurately measured the self-reported disability of ankle arthritis, was easy to administer, and was valid and reliable[4]. The AOS has been examined for reliability, validity, and responsiveness[4,5]. It is composed of the average of two scales filled out by the patient: one measuring pain and one measuring activity (see Appendix). Scores increase as pain or impairment increase. The highest (i.e., worst) score possible is 100, and the lowest (i.e., best) possible score is zero. The AOS score has been used extensively in the literature to determine the effects of end-stage ankle arthritis and its treatment.

Determining the most informative questions to ask patients, and how to meaningfully interpret the results, remains a challenge[6]. Despite being one of the few reliable, valid, and responsive foot and ankle outcomes scores available, questions remain as to the clinical performance of the AOS score. Is the AOS measuring the "correct" things in the population of patients dealing with end-stage ankle arthritis? Do independent clinical variables affect the change in the AOS score that accompanies treatment? What is a minimal clinically important difference (MCID) in the AOS?

The purpose of this retrospective review of a comparative study was to help answer these questions by examining AOS scores in a cohort of patients undergoing surgical treatment for end-stage ankle arthritis. Our hypotheses were that improvement in the AOS score after surgery for end-stage ankle arthritis would be greater than the MCID and that clinical variables would affect improvement in the AOS score.

Materials and Methods

This was a retrospective analysis of data that were previously collected in a prospective cohort study. Institutional review board approval was granted from the participating site, and informed consent was obtained from all study participants. Patients undergoing surgical treatment for end-stage ankle arthritis (with either total ankle arthroplasty or arthroscopic or open ankle arthrodesis) between 2002 and 2010, at a single academic institution, were considered for inclusion in the study; potential subjects were identified and invited to participate in the study only after they had committed to total ankle arthroplasty or arthrodesis. All patients were enrolled in the Canadian Orthopaedic Foot and Ankle Society (COFAS) Prospective Ankle Reconstruction Database. This database includes data on patients with symptomatic end-stage ankle arthritis of various etiologies. Inclusion in the current study required skeletal maturity, a complete preoperative data set, and the ability and willingness to give informed consent. Exclusion criteria were substantial osteonecrosis of the talus that precluded the use of an ankle replacement prosthesis or resulted in the loss of a large amount of bone, compromising the ability to achieve ankle fusion; a prior ankle arthrodesis or arthroplasty; an active or prior infection; Charcot arthropathy; and severe or morbid obesity (a body mass index [BMI] of >35 kg/m^2). For our analysis, we defined the MCID as the smallest change in an outcome that a patient would perceive as meaningful, either beneficial or harmful[7].

The primary outcome measure in the present study was the change in the AOS score from baseline to a minimum of two years postoperatively. The pain and disability components were used to calculate the total score. Patients filled out the questionnaire on paper forms for the entirety of the study.

Secondary outcome measures were also collected as part of the Musculoskeletal Outcomes Data Evaluation and Management System (MODEMS) questionnaire from the American Academy of Orthopaedic Surgeons[8], which includes questions regarding demographics, comorbidities, Short Form-36 (SF-36) items[5], and expectations of the operation and satisfaction with the outcome in addition to the AOS score.

Patients were administered the MODEMS questionnaire preoperatively and at six and twelve months postoperatively and then yearly thereafter.

When the effect of clinical variables on the AOS was examined, only the patients who completed the entire AOS questionnaire in relation to the involved side both prior to (or on the same day as) surgery and at a minimum follow-up of two years were included. Baseline comorbidities were recorded at the first administration of the questionnaire.

In a second phase of the analysis, an MCID in the change of the AOS score was determined by employing an anchor question that asked patients to rate their relief from symptoms after surgery. The inclusion criteria were as above, with the addition that preoperative and postoperative SF-36 data from the MODEMS questionnaire were also required. The anchor question stated: "Are the results of your treatment what you expected [in terms of] relief from symptoms (pain, stiffness, swelling, numbness, weakness, instability)?" Response options were "definitely yes," "probably yes," "not sure," "probably not," "definitely not," and "not applicable." As relief from symptoms is one of the primary clinical benefits of surgery for end-stage ankle arthritis, those who answered "probably yes" or "probably not" were considered to represent the subgroup of patients who had the smallest measurable clinically important change as a result of surgery, which allowed calculation of an MCID as described below[7,9,10].

Statistical Analysis

The primary objective of the present study was to calculate the AOS change score, which was defined as the AOS score at baseline minus the AOS score at follow-up. In the analysis, the change in the AOS score between baseline and follow-up was calculated for each patient. If two-year follow-up data were unavailable, the data from the next follow-up examination were used, up to a maximum of five years after surgery.

A multivariate linear regression model examined the variables affecting the change in the AOS scores between baseline and follow-up, controlling for demographic information collected at baseline from patients. Demographic variables for chronic conditions were included in the regression model only if their prevalence exceeded 10% of the study sample. The goodness-of-fit of the linear regression model was evaluated by examining the residuals.

The secondary objective of the present study was to calculate an MCID for the AOS change score, as this had not previously been determined[11]. The mean of the absolute value of the AOS change score for the patients who had answered "probably yes" or "probably not" to the anchor question was selected as the MCID for the AOS change score. To provide supporting data that the differences detected by the anchor question resulted from the surgery, changes in the SF-36 domain scores between baseline and follow-up were also tested.

Source of Funding

Indirect research funding support was received from the Providence Health Care Research Institute (Vancouver, British Columbia, Canada) for this study.

Results

Of the 298 eligible patients meeting the inclusion criteria, 238 were available at a minimum follow-up of two years and had no missing data (see Appendix). The mean length of follow-up for the questionnaire used for calculating the AOS

TABLE I Summary Statistics of Change in AOS Scores from Baseline to Follow-up for 238 Patients

Measure	AOS Change Score* *(points)*
Mean	31.2
Median	29.0
Standard deviation	22.7
99th percentile	84.5
1st percentile	−20.0

*The AOS baseline score minus the AOS follow-up score.

change score was 2.74 years. The AOS change score demonstrated a mean improvement (and standard deviation) after surgery of 31.2 ± 22.7 points (Table I).

Several demographic factors had a significant impact on the AOS change score. Table II demonstrates the relationship between the regression effects and the change in the AOS score from the preoperative to the postoperative evaluation. (Higher AOS scores reflect poorer performance.) The column labeled "Value" represents the degree to which the regression parameter affects the change in the AOS score; a value that is larger in magnitude indicates that the parameter has a greater effect, and a positive value indicates that the parameter is associated with an improvement.

The baseline AOS score significantly affected the AOS change score ($p < 0.01$). Starting with a worse (higher) AOS score preoperatively was associated with a greater AOS change score at the time of follow-up.

The patients who had quit smoking more than twelve months prior to entering the study had greater improvement than the patients who had never smoked ($p < 0.01$). Interestingly, those who were current smokers or had quit smoking less than twelve months prior to their intake survey also showed greater improvement than those who never smoked, although this did not reach significance ($p = 0.08$ for current smokers and $p = 0.05$ for those who had quit less than twelve months earlier).

The presence of back pain negatively and significantly affected the AOS change score ($p = 0.03$). Patients without back pain had a greater improvement in the AOS score—and therefore a larger AOS change score—than those with back pain.

The patient's age at the time of surgery significantly affected the AOS change score ($p = 0.03$). Older patients showed a greater improvement than younger patients.

The following variables did not significantly affect the AOS change score: sex, BMI, high blood pressure, depression, the presence of osteoarthritis or rheumatoid arthritis, or the nature of the surgery (arthrodesis versus total ankle arthroplasty).

Seventy-eight of the 238 patients who met the inclusion criteria answered either "probably yes" (fifty-seven patients) or "probably not" (twenty-one patients) to the question: "Are the results of your treatment what you expected [in terms of] relief from symptoms (pain, stiffness, swelling, numbness, weakness, instability)?" The mean of the absolute value of the AOS change score for this subgroup was 28.0 ± 17.9 points. This value provides one estimate of the MCID for the AOS.

To provide supporting data that the differences detected by the anchor question were the result of surgery, the preoperative and postoperative responses on the SF-36 questionnaire were contrasted (Table III). For each domain, positive values representing differences between preoperative and postoperative scores were consistent with improvement. Improvements in the patient's physical function, role physical, bodily pain, vitality, social function, and role emotional domains were

TABLE II Parameter Values for Linear Regression Model of Change in AOS Score from Baseline to Follow-up

Variable*	Value	Standard Error	P Value
Intercept	−26.3	13.55	0.05
Baseline AOS score	0.74	0.08	<0.01†
Age at time of surgery	0.28	0.13	0.03†
Sex (female)	0.44	2.72	0.87
Body mass index	−0.42	0.26	0.11
High blood pressure (false)	−0.70	2.84	0.80
Depression (false)	−0.48	3.73	0.89
Osteoarthritis (false)	−0.16	2.92	0.95
Back pain (false)	5.59	2.60	0.03†
Rheumatoid arthritis (false)	2.30	3.65	0.53
Smoking (those who had quit >12 mo earlier compared with nonsmokers)	7.43	2.76	<0.01†
Surgery (arthrodesis)	−0.93	3.00	0.75

*Answers in parentheses in the variable column represent the dichotomous response. †The difference was significant.

TABLE III Change in the SF-36 Domain Score for the Seventy-eight Patients Who Met the Criteria*

SF-36 Domain	Estimated Change	Standard Error	P Value
Physical function	8.1	1.07	<0.01
Role physical	8.8	1.23	<0.01
Bodily pain	7.2	1.07	<0.01
General health	0.2	1.18	0.87
Vitality	3.6	1.35	<0.01
Social function	5.1	1.64	<0.01
Role emotional	5.9	1.49	<0.01
Mental health	2.8	1.35	0.04

*The change in the score was the SF-36 score at follow-up minus the baseline score.

observed and may have been associated with surgery ($p < 0.01$). There was some evidence of improvement in mental health ($p = 0.04$), although there was no evidence of an improvement in the patients' self-reported general health.

Discussion

Outcomes scores are objective, comparable means by which we determine how debilitated our patients are and how successful our treatments are. These scores allow surgeons to move beyond anecdote and biased interpretation toward more scientific rigor. Despite the importance of such scores, there are a limited number of outcome scoring systems in foot and ankle surgery that are reliable, valid, and responsive.

Global scores, such as the SF-36 and EuroQol 5D (EQ-5D)[12], record general health, and while often insensitive to small changes in disease or region-specific health, they provide a measure of how overall health and function are affected by musculoskeletal disease. Disease and/or region-specific scores, such as the Disabilities of the Arm, Shoulder and Hand (DASH)[13] and AOS, provide a more focused lens with which to examine the effects of nonsystemic disease or interventions. While a disease and/or region-specific score may reveal differences in pain or function associated with a process or procedure affecting a small area of the body, if global health scores are unaffected, we are left with two questions: (1) Are the right questions being asked, and (2) How much does the process or procedure actually affect a patient's general state of being?

There is compelling evidence that ankle arthritis and its treatment significantly affect patients' general health. Ankle arthritis is at least as disabling as hip arthritis, with SF-36 scores two standard deviations below age-adjusted norms for both[14]. The two primary procedures used to treat end-stage ankle arthritis, ankle arthrodesis and total ankle arthroplasty, have been shown to substantially improve general quality-of-life scores[15,16] and disease and region-specific scores[15-17]. The current study was undertaken to better understand the clinical performance of a disease and region-specific score, the AOS, and ultimately to determine whether the AOS is asking the most appropriate questions for the patients it examines.

In analyzing the clinical performance of the AOS, this study examined the change from preoperative baseline for a group of patients being treated for end-stage ankle arthritis. Our goal was not to differentiate between the patients undergoing ankle arthrodesis and those having total ankle arthroplasty, but rather to look at the overall effect of two proven treatment methods on the score. We chose not to differentiate between arthrodesis and arthroplasty because the treatments have similar outcomes as measured by the AOS[17]. In our study, the AOS change score showed a large improvement after treatment, with an average decrease of 31.2 points, and there was no difference in the AOS change score between those treated with arthroplasty and those treated with arthrodesis.

The AOS was affected by comorbidities in some clinically intuitive ways that have yet to be fully defined elsewhere in the literature. Regression analysis showed that the change in AOS score was significantly affected by the preoperative AOS score, as well as by back pain and age, as follows: (1) patients with a higher (worse) preoperative AOS score improved more after surgery than those with a lower baseline score ($p < 0.01$); (2) patients without back pain improved more than those with back pain ($p = 0.03$); and (3) older age at the time of surgery led to more improvement from surgery ($p = 0.03$). These findings support the long-held belief that a patient's baseline state prior to surgery significantly affects his or her subjective improvement from surgery.

Less intuitive was the effect of smoking on the AOS change score. Patients who were current smokers, those who had quit smoking more than twelve months prior to entering the study, and those who had quit less than twelve months earlier were compared with nonsmokers. Current and previous smokers had larger AOS change scores (i.e., greater improvement) than did nonsmokers, although the difference reached significance only for those who had quit more than twelve months prior to entering the study. While it is possible that this finding was spurious, it is also possible that the psychological state of patients who had successfully quit smoking positively affected their response to surgery.

An important aspect of understanding the clinical performance of the AOS was the development of an MCID in the score. Statistical differences are relatively easy to measure, but may not correspond to clinically meaningful change. Defining clinically meaningful change is challenging, and numerous methods exist to achieve this goal[18]. An "anchor question" to help define an MCID has been used in the orthopaedic literature to develop clinically meaningful thresholds for the WOMAC and the SF-36 in hip and knee arthritis[19,20]. The basic concept relies on identifying a question that asks directly about subjective clinical change and linking this response with changes in an outcome score. We chose part of the expectation and satisfaction portion of the MODEMS questionnaire, which asked patients about their clinical improvement after surgery as related to their preoperative expectations. We chose the smallest unit of change from neutral as a measure of the MCID—essentially, the change in patients who identified themselves as minimally better or minimally worse as a result of surgery. The patients with the smallest unit of change from neutral had a mean change in the AOS of 28.0 points, whether this was an improvement or decline from baseline. This provides one estimate of the MCID of the AOS, and could be considered when determining the response to treatment for ankle arthritis.

The estimate of the MCID that we identified was relatively large, indicating that large changes in the AOS must be seen before they become clinically important. It is also possible that the large MCID and standard error mean that a more sensitive anchor question would produce a smaller MCID. We did not split our group into an exploratory and a validation population, and that may have had some effect on the sensitivity of the anchor question. Interestingly, the mean change in the AOS with treatment in our group was larger than the MCID, lending credence to the idea that treating end-stage ankle arthritis surgically leads to substantial and clinically meaningful improvement. However, this large MCID indicates that the AOS may not be particularly sensitive in this patient population, and its ability to distinguish between two procedures for end-stage ankle arthritis may therefore be limited. Further investigation of how each of the eighteen questions in the AOS contributes to the total AOS score is warranted.

There are several limitations to the present study. Twenty percent (sixty) of 298 eligible patients withdrew, declined, were lost to follow-up, died, or had incomplete data, and this could introduce bias into our results (see Appendix). We required a two-year follow-up period, but used the questionnaire closest to two years if the exact two-year follow-up data were not available. While this does not capture all patients at the exact same time, our goal was to examine as many patients as possible at a relatively consistent time point. The list of comorbidities examined in the regression analysis is not exhaustive. In addition, our COFAS database imparted exclusion criteria and this adds bias to the study group; specifically, it excluded the patients with severe or morbid obesity (a BMI of >35 kg/m^2), and this may mask the effect of BMI on the AOS change score (although only seventeen patients were excluded because of BMI).

Our estimate of the MCID must also be interpreted cautiously. Our anchor question was relatively specific, but did include an element of patient expectation, which can influence the perception of treatment success. As well, no single definitive manner of determining the MCID has been established, and anchor question methods are not without flaws related to the specificity and subjectivity of the anchor question.

Appendix

eA Figures showing the AOS questionnaire and a flowchart of patient enrollment, exclusion, and loss to follow-up are available with the online version of this article as a data supplement at jbjs.org. ■

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