The Impact of Obesity on the Outcome of Total Ankle Replacement

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Background: Obese patients have a slightly higher proportion of revision and infection following knee or hip replacement, but functional improvement is equivalent to that of normal-weight patients. We compared outcomes of total ankle replacement for end-stage ankle arthritis in obese and normal-weight patients.

Methods: This retrospective cohort study compared thirty-nine obese patients (those with a body mass index of ≥30 kg/m²) at a mean follow-up time of 3.76 years and forty-eight non-obese patients (those with a body mass index of <30 kg/m²) at a mean follow-up time of 3.92 years after total ankle replacement. Outcome measure scores (Ankle Osteoarthritis Scale [AOS] and Short-Form 36 [SF-36]) were collected preoperatively and at least two years postoperatively. Complication and revision data were collected by manual chart audits. Statistical analyses were performed with use of t tests, Wilcoxon signed-rank tests, and Mann-Whitney U tests. Survival analysis was conducted with use of the Kaplan-Meier method.

Results: The two cohorts had similar demographic characteristics. Ten (26%) of thirty-nine patients in the obese group were morbidly obese (having a body mass index of >40 kg/m²). There were thirty-nine patients in the obese group and forty-eight patients in the non-obese group. The mean body mass index (and standard deviation) was 36.28 ± 5.43 kg/m² for the obese group and 25.84 ± 3.00 kg/m² for the non-obese group. The obese group had significantly worse preoperative SF-36 Physical Component Summary scores (p = 0.01) than the non-obese group. Preoperatively to postoperatively, both obese and non-obese patients demonstrated significant improvements (p < 0.001) in AOS pain, AOS disability, and SF-36 Physical Component Summary scores, and the changes in these scores were similar for both groups. The SF-36 Mental Component Summary scores did not change significantly (p = 0.30) in either group. There was no significant difference (p = 0.48) in the proportion of complications or revisions between the groups.

Conclusions: Although obese patients had increased disability and worse function preoperatively, total ankle replacement significantly and similarly improved pain and disability scores in both obese and non-obese patients, with no significant difference in the proportion of complications. We therefore maintain that total ankle replacement is a reliable treatment option for patients with end-stage ankle arthritis, including those who are obese.

Level of Evidence: Prognostic Level III. See Instructions for Authors for a complete description of levels of evidence.

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As the prevalence of obesity continues to rise, its influence on outcomes of orthopaedic procedures, particularly arthroplasty, has been of increasing importance. The World Health Organization defines a normal body mass index (BMI) to be <25 kg/m², an overweight BMI to be 25 to 29.9 kg/m², and an obese BMI to be ≥30 kg/m². Adult obesity is a known risk factor for many chronic diseases, including type-II diabetes, cardiovascular disease, hypertension, osteoarthritis, some cancers, and

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gallbladder disease. It is also associated with psychosocial problems, functional limitations, and disability. It might therefore be hypothesized that performing total ankle replacement surgery in obese patients with end-stage ankle arthritis could lead to an increased prevalence of adverse outcomes.

Evidence addressing the impact of BMI on the outcomes of total ankle replacement surgery is lacking. Conversely, extensive studies have been conducted on the effect of obesity on the outcomes of total knee replacement and total hip replacement. Two systematic reviews and a joint registry study of total knee arthroplasty and a review and a meta-analysis of total hip arthroplasty showed several observations that are consistent across both procedures. Obese patients (those with a BMI between 30 and 40 kg/m²) have slightly higher prevalences of revision, infection, and deep infection than non-obese patients (those with a BMI of <30 kg/m²). Postoperative functional outcomes are slightly lower in obese patients compared with non-obese patients, but improvement is often equivalent and is substantial, significant, and sustained over the long term. Morbidly obese patients (those with a BMI of >40 kg/m²) have higher prevalences of complications and infection, lower implant survivorship, and lower postoperative function than obese or non-obese patients following hip or knee replacement.

The purpose of this study was to compare validated patient outcomes of total ankle replacement in patients with end-stage ankle arthritis between an obese cohort (patients with a BMI of ≥30 kg/m²) and a non-obese cohort (patients with a BMI of <30 kg/m²). Revisions and complications for the two cohorts were assessed.

Materials and Methods

In this retrospective cohort study, all consecutive patients who underwent total ankle replacement between May 2002 and November 2010 at an academic hospital in a large, urban center were identified from the surgeon's patient database. Patients completed the Ankle Osteoarthritis Scale (AOS) and the Short Form-36 (SF-36) preoperatively and at least once at a minimum of two years postoperatively. Manual chart audits were performed to record complications and revisions, as well as any demographic data not recorded in the patient database.

Patients were included in this study if they were eighteen years of age or older, had a diagnosis of end-stage ankle arthritis, and had undergone primary total ankle replacement. Patients were excluded from the study if they had coronal plane deformity of >10°, Charcot arthropathy, postinfectious arthritis, a comorbidity such as a neurologic disorder that could affect function or gait, other ipsilateral lower limb surgery in the twelve months preceding the total ankle replacement, or a total ankle replacement converted from an ankle arthrodesis.

Research ethics approval was obtained from the hospital's internal review board.

Surgical Procedures

All surgeries were performed by a single foot and ankle fellowship-trained surgeon (T.R.D.). Three cobalt-chrome, mobile-bearing, second-generation implants were used: the Mobility (DePuy Synthes, Leeds, United Kingdom), the HINTEGRA (Integra LifeSciences, Plainsboro, New Jersey), and the STAR (Scandinavian Total Ankle Replacement) (Waldemar Link, Hamburg, Germany). The recommendation for total ankle replacement was based on a combination of the surgeon's preoperative clinical examination, radiographic findings, and patient preference, in addition to intraoperative assessments. The surgeon evaluated medical comorbidities, vascular status, skin integrity, bone stock, ligamentous stability, and arthritis and performed adjunctive ligament reconstruction, osteotomies, and/or arthrodeses as needed to achieve a balanced ankle, plantigrade foot, and stable construct.

Outcomes Measured

The primary outcome measures were the pain and disability scores of the AOS, a self-reported, ankle-specific, validated functional outcome measure. Secondary outcome measures included the SF-36 Physical Component Summary (PCS) and Mental Component Summary (MCS) scores (a generic measure of general health status) and the prevalence of complications and revisions, which were coded according to the Canadian Orthopaedic Foot and Ankle Society (COFAS) Ankle Arthritis Research Group complications grading system (see Appendix). The AOS and SF-36 have been validated in the patient population with end-stage ankle arthritis.

Statistical Analysis

Patients were divided into two groups based on BMI for analysis purposes: obese and non-obese. All continuous demographic and outcome measure variables were examined for normal distribution of data with use of three methods (skewness and kurtosis, Kolmogorov-Smirnov test, and normal and detrended probability plots) and were treated as normally distributed if at least two of these methods categorized them as such. For normally distributed variables, a paired sample t test was used to compare clinical changes from preoperatively to postoperatively within each group. Independent sample t tests were used to compare continuous demographic and outcome measure variables at each time point (preoperative and postoperative) between the groups. For non-normally distributed variables, data within each group were compared with use of the Wilcoxon signed-rank test, and the two groups were compared with use of the Mann-Whitney U test. The chi-square test for independence was used to assess differences in categorical demographic variables between groups. Tests were two-sided, and significance was set at p ≤ 0.05. To account for the multiple testing (four tests), we used the Bonferroni correction and only considered those comparisons for which p ≤ 0.05/4 (i.e., p ≤ 0.01) to be significant. To determine the implant metal component survivorship at five years, a Kaplan-Meier estimate of the survival function was plotted. We used each patient's latest follow-up date (if less than five years) or five years following the surgery (if the latest follow-up was more than five years) as the censor date, as the sample size provided more precise survival estimates at this shorter time span. A log-rank (Mantel-Cox) test of equality of survival distributions for the two groups was used to determine significance.

Source of Funding

One author of this study (T.R.D.) received a grant and personal fees for this study from Integra LifeSciences, which is the manufacturer of the HINTEGRA implant that was used in this study. Funds were used to pay for research staff salaries and maintenance of the ankle arthritis database.

Results

Cohort Demographic Characteristics

From 2002 to 2010, 211 total ankle replacements performed by a single surgeon (T.R.D.) were reviewed for eligibility for this study. Nineteen patients were excluded from the study because they had undergone other lower-limb surgery in the previous twelve months. Three patients for whom the BMI could not be accurately determined were excluded. A review of preoperative radiographs indicated that fifty-four patients had a coronal plane deformity of >10°, and they were excluded from the study. One patient died for reasons not related to the surgery, and one patient moved and was lost to follow-up. Forty-six patients had a final follow-up of less than two years and were excluded from the study. Thus, thirty-nine patients who qualified as obese and forty-eight patients who qualified as non-obese
were included in this retrospective review; the mean BMI (and standard deviation) was 36.28 ± 5.43 kg/m² for the obese group and 25.84 ± 3.00 kg/m² for the non-obese group (p < 0.001). Of the thirty-nine patients in the obese group, ten (26%) had a BMI of >40 kg/m² and were considered morbidly obese and nine (23%) weighed more than 113.5 kg (250 lb); of these nine patients, two had a BMI of ≤40 kg/m² and seven had a BMI of >40 kg/m².

The demographic characteristics of the eighty-seven patients included in the study are summarized in Table I. There were eighteen male patients (46.2%) in the obese cohort and twenty-one male patients (43.8%) in the non-obese cohort (p = 0.82).

### TABLE I Demographic Characteristics at Baseline

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Obese Cohort (N = 39)</th>
<th>Non-Obese Cohort (N = 48)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male sex*</td>
<td>18 (46.2%)</td>
<td>21 (43.8%)</td>
</tr>
<tr>
<td>Arthritis etiology*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Posttraumatic arthritis</td>
<td>26 (66.7%)</td>
<td>32 (66.7%)</td>
</tr>
<tr>
<td>Degenerative arthritis</td>
<td>6 (15.4%)</td>
<td>7 (14.6%)</td>
</tr>
<tr>
<td>Rheumatoid arthritis</td>
<td>6 (15.4%)</td>
<td>7 (14.6%)</td>
</tr>
<tr>
<td>Other</td>
<td>1 (2.6%)</td>
<td>2 (4.2%)</td>
</tr>
<tr>
<td>Implant*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>STAR</td>
<td>2 (5.1%)</td>
<td>7 (14.6%)</td>
</tr>
<tr>
<td>HINTEGRA</td>
<td>26 (66.7%)</td>
<td>32 (66.7%)</td>
</tr>
<tr>
<td>Mobility</td>
<td>11 (28.2%)</td>
<td>9 (18.8%)</td>
</tr>
<tr>
<td>BMI † (kg/m²)</td>
<td>36.28 ± 5.43 (34.52 to 38.04)</td>
<td>25.84 ± 3.00 (24.97 to 26.71)</td>
</tr>
<tr>
<td>Age † (yr)</td>
<td>62.44 ± 8.42 (59.71 to 65.16)</td>
<td>62.07 ± 10.35 (59.06 to 65.07)</td>
</tr>
<tr>
<td>Length of follow-up † (yr)</td>
<td>3.76 ± 1.73 (3.20 to 4.32)</td>
<td>3.92 ± 1.75 (3.41 to 4.42)</td>
</tr>
</tbody>
</table>

*The values are given as the number of patients, with the percentage in parentheses. †The values are given as the mean and the standard deviation, with the 95% CI in parentheses.

### TABLE II Clinical Outcome Scores Following Total Ankle Replacement

<table>
<thead>
<tr>
<th>Outcome Score</th>
<th>Obese Cohort*†</th>
<th>Non-Obese Cohort*‡</th>
</tr>
</thead>
<tbody>
<tr>
<td>AOS pain</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>55.88 ± 18.00 (49.96 to 61.79)</td>
<td>52.92 ± 19.41 (47.28 to 58.55)</td>
</tr>
<tr>
<td>Postoperative</td>
<td>19.59 ± 18.50 (13.50 to 25.67)</td>
<td>19.00 ± 16.80 (14.07 to 23.93)</td>
</tr>
<tr>
<td>Change</td>
<td>35.68 ± 23.09 (27.98 to 43.38)</td>
<td>33.75 ± 20.20 (27.82 to 39.68)</td>
</tr>
<tr>
<td>AOS disability</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>68.64 ± 14.09 (63.94 to 73.34)</td>
<td>59.79 ± 19.57 (54.11 to 65.48)</td>
</tr>
<tr>
<td>Postoperative</td>
<td>28.21 ± 21.51 (21.14 to 35.28)</td>
<td>27.20 ± 19.33 (21.46 to 32.94)</td>
</tr>
<tr>
<td>Change</td>
<td>40.46 ± 22.13 (32.97 to 47.95)</td>
<td>32.61 ± 20.74 (26.45 to 38.77)</td>
</tr>
<tr>
<td>SF-36 PCS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>29.54 ± 6.92 (27.23 to 31.84)</td>
<td>34.48 ± 9.05 (31.80 to 37.17)</td>
</tr>
<tr>
<td>Postoperative</td>
<td>39.21 ± 10.30 (35.83 to 42.60)</td>
<td>40.30 ± 9.84 (37.38 to 43.22)</td>
</tr>
<tr>
<td>Change</td>
<td>9.19 ± 9.24 (6.11 to 12.27)</td>
<td>5.82 ± 8.56 (3.25 to 8.40)</td>
</tr>
<tr>
<td>SF-36 MCS</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Preoperative</td>
<td>50.86 ± 12.72 (46.62 to 55.10)</td>
<td>53.70 ± 11.24 (50.37 to 57.04)</td>
</tr>
<tr>
<td>Postoperative</td>
<td>50.51 ± 13.37 (46.12 to 54.91)</td>
<td>54.05 ± 9.27 (51.29 to 56.80)</td>
</tr>
<tr>
<td>Change</td>
<td>0.55 ± 14.58 (−5.41 to 4.31)</td>
<td>1.16 ± 9.81 (−1.78 to 4.11)</td>
</tr>
</tbody>
</table>

*The values are given as the mean score and the standard deviation, in points, with the 95% CI in parentheses. †In the obese cohort, the number of patients ranged from thirty-six to thirty-eight for individual questions. ‡In the non-obese cohort, the number of patients ranged from forty-five to forty-eight for individual questions.
mean age at the time of surgery was 62.44 ± 8.42 years in the obese group and 62.07 ± 10.35 years in the non-obese group (p = 0.86). The mean follow-up length was 3.76 ± 1.73 years (range, 1.92 to 9.92 years) in the obese cohort and 3.92 ± 1.75 years (range, 1.92 to 9.25 years) in the non-obese cohort (p = 0.73).

In the obese group, 66.7% of patients had posttraumatic arthritis, 15.4% had degenerative arthritis, 15.4% had rheumatoid arthritis, and 2.6% were classified as “other,” which included psoriatic and other polyarticular arthritides. The distribution of arthritis etiologies in the non-obese cohort was similar (Table I). Arthritis etiology and type of implant could not be compared statistically because of small patient numbers in some of the categories; however, the numbers in each group appeared similar.

Outcome Measures
AOS and SF-36 scores are summarized in Table II. There was no difference in preoperative AOS pain scores (p = 0.47) or postoperative AOS pain scores (p = 0.93) between the obese and non-obese cohorts. Each cohort showed significant improvement (p < 0.001) in AOS pain scores from preoperatively to postoperatively, with a mean score change of 35.7 ± 23.1 points for the obese group and 33.8 ± 20.2 points for the non-obese group; this change was similar (p = 0.62) in each cohort.

The difference in preoperative AOS disability scores between the obese and non-obese cohorts approached but did not reach significance when applying the Bonferroni correction (p = 0.02), and there was no significant difference in postoperative scores between the cohorts (p = 0.82). Both cohorts showed significant improvement (p < 0.001 for both) in AOS disability scores following total ankle replacement, with a mean change of 40.5 ± 22.1 points in the obese group and 32.6 ± 20.7 points in the non-obese group; this change was similar in each cohort (p = 0.10).

The mean preoperative SF-36 PCS score was significantly worse (p = 0.01) for the obese patients (29.5 ± 6.9 points) than for the non-obese patients (34.5 ± 9.1 points). However, at the time of

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**Fig. 1**

Kaplan-Meier analysis of operation-free survivorship at five years following total ankle replacement in obese patients (n = 39) and non-obese patients (n = 48). One patient in the non-obese group had a complication (revision surgery) at five months postoperatively and was deducted from the number of patients at risk in the first year.
the latest follow-up, the mean scores for the two groups were similar ($p = 0.62$) at $39.2 \pm 10.3$ points for the obese group and $40.3 \pm 9.8$ points for the non-obese group. The preoperative to postoperative changes in SF-36 PCS scores were significant ($p < 0.001$ for both the obese and non-obese groups) and similar ($p = 0.09$) between the two groups.

The SF-36 MCS scores of the obese and non-obese groups were similar preoperatively ($p = 0.32$) and at the time of the latest follow-up ($p = 0.30$). No significant difference in the change from preoperative to postoperative scores was observed in either the obese group ($p = 0.98$) or the non-obese group ($p = 0.98$), nor was the change in either group significantly different from the other ($p = 0.55$).

**Complications and Revisions**

Thirty-two obese patients (82.1%) and forty-three non-obese patients (89.6%) had good outcomes and did not experience any adverse events (see Appendix). The proportion of complications or revisions in each group was similar ($p = 0.48$). The revision of metal components was performed in four obese patients (10.3%); two cases were due to aseptic loosening of a Mobility implant, and two morbidly obese patients required revision of a fractured mobile bearing (see Appendix). One non-obese patient (2.1%) required metal component revision of a Mobility implant due to aseptic loosening. Three obese patients (7.7%) and three non-obese patients (6.3%) underwent a polyethylene liner exchange. There were no deep infections in the obese group and only one deep infection (2.1%) requiring metal component revision in the non-obese group.

**Survival Analysis**

The mean operation-free survival time was 4.5 years (95% confidence interval [95% CI], 4.1 to 5.0 years) for the obese group and 4.6 years (95% CI, 4.3 to 4.9 years) for the non-obese group ($p = 0.47$) (Fig. 1).

**Discussion**

This study found that total ankle replacement provided similar relief of pain and disability and a low prevalence of complications both in obese patients at a mean follow-up time of 3.76 years and in non-obese patients at a mean follow-up time of 3.92 years following surgery, despite the worse preoperative function observed in obese patients.

To our knowledge, few studies have examined the effect of increased BMI on outcomes of total ankle replacement. Barg et al. performed a retrospective chart review of 118 patients (123 ankles) with a minimum BMI of 30 kg/m² who underwent total ankle replacement for end-stage ankle arthritis. At a mean follow-up of 67.7 months, all patients demonstrated significant pain relief and functional improvement. In a retrospective survey of twenty-seven patients with a mean preoperative BMI of 28.3 kg/m² who had undergone total ankle replacement, Baker et al. found that elevated BMI did not affect subjective outcome scores at a mean follow-up of sixty months. In contrast, Lagaay and Schuberth found a significant association among patient satisfaction, a BMI of <30 kg/m², and a patient age of more than sixty years in a cohort of ninety-five patients who underwent total ankle replacement. The mean BMI of this group was 27.7 kg/m², and 68% of patients had a BMI of >30 kg/m².

A biomechanical study has suggested that increased patient weight could lead to premature total ankle replacement implant failure. Dunbar et al. radiographically assessed migration and displacement of the Mobility total ankle replacement implant in twenty-three patients. They concluded that implants subside into bone over time and under load, corresponding to the direction of primary loading during standing or walking. They inferred that this motion may be clinically important and may correspond to premature implant failure in overweight and obese patients undergoing total ankle replacement. In our study, two obese patients and one non-obese patient required revision of Mobility implants because of aseptic loosening less than two years after ankle replacement.

In the obese cohort of our study, of the thirty-nine implants, four (10.3%) required revision of metal components and three (7.7%) required exchange of the polyethylene liner. Barg et al. reported a 4.9% prevalence of revisions at sixty-eight months in 123 ankles of obese patients. These proportions are comparable with those of the general population undergoing total ankle replacement.

The prevalence of complications in our study is also comparable with that reported in the literature for the general population undergoing total ankle replacement. Only two studies have specifically shown complications in obese patients who underwent total ankle replacement. Barg et al. described eight cases (6.5%) of delayed wound-healing, but no deep infections, and the total prevalence of secondary surgical procedures was 18.7%. Baker et al. found that one (14.3%) of seven obese patients and four (20.0%) of twenty non-obese patients required additional surgery. Two patients (one obese and one non-obese) required wound debridement for superficial infections.

The hip and knee replacement literature provides more information on the effects of increased BMI. On the basis of multiple systematic reviews and meta-analyses and a national joint registry study that evaluated a combined total of more than 62,000 patients, the prevalence of revision, infection, or deep infection is slightly higher in obese patients following total knee replacement or total hip replacement. Functional outcomes at the time of the latest follow-up were found, on average, to be slightly lower in obese patients compared with non-obese patients. However, when improvement from baseline to the latest follow-up was calculated, it was found to be substantial and significant, equivalent to that in non-obese patients in most cases, and sustained over the long term. The findings of our study and others that evaluated the effect of obesity on total ankle replacement indicate no differences in the prevalence of revisions or complications and no differences or only slight differences in the functional outcomes between obese and non-obese patients. However, sample sizes were small, and more studies are needed to determine whether outcomes are consistently equivalent following total ankle replacement, or whether trends similar to those following total knee replacement and total hip replacement will be observed. The effect of morbid
obesity, which has been shown to increase the prevalences of complications and infection, lower implant survivorship, and lower postoperative function following total knee arthroplasty and total hip arthroplasty\(^{1,7}\), is as yet unknown for total ankle replacement. Although our study included some morbidly obese patients, the numbers were too small to permit separate analysis.

It is debatable whether BMI, rather than absolute weight, is the appropriate criterion for the evaluation of outcomes, particularly component wear, following total ankle replacement. Two of ten morbidly obese patients in our study required revision of metal components; one of nine patients who weighed more than 113.5 kg (250 lb), an arbitrary cutoff considered a contra-indication by some U.S. insurers, underwent metal component revision. A larger cohort study with longer follow-up will be required to elucidate any differential effects of BMI compared with absolute weight on total ankle replacement.

A potential clinical association of obesity and total ankle replacement under debate is whether the surgery enables future weight loss. The pain and disability associated with end-stage ankle arthritis hypothetically render it difficult for overweight and obese patients to achieve weight loss prior to joint replacement surgery. Several studies have explored this issue; however, most have shown that no significant weight loss occurs after surgery. Penner et al.\(^{17}\) conducted a retrospective study of 145 patients with a preoperative BMI of >25 kg/m\(^2\) and assessed BMI for up to five years following total ankle replacement. Although pain and disability were significantly improved, the mean BMI remained unchanged after surgery. In contrast, Barg et al.\(^{11}\) reported significant weight loss in 12% of obese patients (predominantly male patients) at one year after total ankle replacement. In the total knee replacement and total hip replacement literature, several studies have shown no significant reduction in BMI in overweight patients following surgery\(^{19-20}\). Studies have concluded that obesity was related to factors other than inactivity due to arthritis\(^{17,18}\).

The limitations of this study included the uneven number of patients in the two cohorts, which precluded certain analyses that may have helped to identify confounding variables, and the short to intermediate-term follow-up. The precision of survival estimates in the Kaplan-Meier curve decreased over time because of the small patient numbers at risk for metal revision in later years, necessitating a five-year cutoff for survivorship analysis. Longer follow-up with larger patient numbers in each group will be needed to more definitively determine any differences in clinical outcomes or the prevalence of revision between the groups as the prostheses approach the end of their lifespan or to assess the development of any long-term effects on the ankle from obesity.

In conclusion, although obese patients have increased disability and worse function preoperatively, total ankle replacement significantly and similarly improved pain and disability scores in both obese and non-obese patients, with no significant difference in the prevalence of complications. We therefore maintain that total ankle replacement is an effective treatment option for patients with end-stage ankle arthritis, including those patients who are obese.

### Appendix

#### Tables showing the Canadian Orthopaedic Foot and Ankle Society (COFAS) Ankle Arthritis Research Group complication classification system for total ankle replacement and ankle arthrodesis, complications and revisions, and a description of complications following total ankle replacement are available with the online version of this article as a data supplement at jbjs.org.

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### References


