The Most-Cited Ankle Arthroplasty Implant Articles

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Abstract
Background: Citation analysis is a useful way of evaluating the impact, importance, and merit of articles within a medical specialty. Our study identified and analyzed the most-cited articles on ankle arthroplasty implants to evaluate their importance in the field of ankle arthroplasty research.

Methods: Using the keywords “ankle arthroplasty” and “ankle replacement” and the search period 1970-2021, we found 3728 articles on ankle arthroplasty implants in the Scopus, Web of Science, and MEDLINE/PubMed databases. We included original articles, reviews, clinical trials, and case reports in the study. We retrieved the 50 most-cited articles published during the time frame and then screened them for studies of specific ankle arthroplasty implants and their postoperative outcomes. We also recorded and analyzed the articles’ subjects, authorship, journals, countries of origin, and years of publication.

Results: The 50 most-cited articles were published between 1983 and 2014, with the majority (33) published between 2000 and 2010. They generated 9012 citations in the literature. The most-cited study accounted for 497 citations; the mean number of citations per article was 180.24 ± 76.24. Twenty-three (46%) of the articles addressed postoperative outcomes following a specific type of arthroplasty implant. Arthroplasty implant studies accounted for 4726 citations, or 52.4% of the citations of the 50 articles. The most frequently studied arthroplasty implant was STAR (15), followed by Agility (7), Buechel Pappas (5), and Salto (4). STAR accounted for 3311 citations, or 37% of the total citations of the 50 articles.

Conclusion: Ankle arthroplasty research has made great progress in the past 2 decades, particularly in the area of postoperative outcomes of specific ankle implants, but continued research and publication on additional arthroplasty implants should become a priority.

Level of Evidence: Level V, Review Article.

Keywords: ankle arthroplasty, ankle replacement, ankle implant, bibliometric analysis, STAR

Introduction
Since the introduction of ankle arthroplasty in the 1970s, several generations of new arthroplasty implants have been developed, each introducing improvements such as hydroxyapatite coating, minimal bone resection techniques, 3-component design, and cementless fixation. These innovations, combined with a growing population in need of ankle replacement, have led to an increase in both procedure volume and research.

In any field, a large and rapidly expanding body of research can obscure the studies that historically have made the greatest impact. Citation analysis is a useful way to highlight the impact and significance of specific publications and to identify research trends. Although several bibliometric analyses of the ankle have been conducted previously, none have examined specific types and generations of ankle arthroplasty implants.

This study identified and analyzed the most-cited research on ankle arthroplasty implants and their outcomes in an effort to understand its impact on the field of ankle arthroplasty.

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Methods

Using the keywords “ankle arthroplasty” and “ankle replacement,” we found 5501 articles on ankle arthroplasty implants in our initial search of the Scopus, Web of Science, and MEDLINE/PubMed databases—2203 in Scopus, 1525 in Web of Science, and 1773 in MEDLINE/PubMed. The studies were published between 1970 and July 2021 and included original articles, reviews, clinical trials, and case reports. From the initial pool of 5501, we retrieved the 50 articles with the most citations. We reviewed the articles from most to least cited, analyzing them for title, authorship, subject, journal, country, and year of publication.

We then conducted full-text reviews of each article to select those that studied specific ankle arthroplasty implants. All ankle arthroplasty implants were included in our assessment. We also conducted a subanalysis of outcomes, survivorship, revisions, arthrodesis, and other reoperation of arthroplasty implants. Revision was defined as replacement of any implant component without removal. Arthrodesis was defined as subsequent fusion of the ankle. Other reoperation was defined as any surgery not including revision or arthrodesis.

Results

Table 1 shows the 50 most-cited articles. The number of citations of each article ranged from 112 to 497, with a mean of 180.24 ± 76.24. In all, the 50 articles were associated with 9012 citations. The average number of citations per article per year from the date of publication through July 2021 ranged from 3 to 36, with a mean of 12 ± 6.20. The 50 articles were published between 1983 and 2014, with a majority (33) published between 2000 and 2010. Eighteen of the articles originated in the United States; 10 in the United Kingdom; 4 in Canada; 3 each in Denmark, France, Sweden, and Switzerland; 2 in Japan; and 1 each in the Netherlands and New Zealand.

Twenty-three studies investigated outcomes of a specific type of arthroplasty implant (Table 1), and 17 of these were published between 2000 and 2010. Other topics included arthroplasty vs arthrodesis (4), biomechanics (4), foot deformity (2), and tissue engineering (1).

Studies of Arthroplasty Implant Devices

Arthroplasty implant studies accounted for 4726 (52.4%) of the 9012 citations of the 50 most-cited articles. Implants in the top-cited arthroplasty implant articles included STAR (Waldemar LINK, Hamburg, Germany; now distributed by Stryker, Kalamazoo, MI), Agility (DePuy, Warsaw, IN), Buechel Pappas (Endotec, South Orange, NJ), Salto (Integra, Plainsboro, NJ), HINTEGRA (Newdeal SA, Lyon, France), TNK (Nerima, Tokyo Prefecture, Japan), Mobility (DePuy, Warsaw, IN), and TPR (Thompson-Parkridge-Richards). The most frequently studied implant device was STAR (15), followed by Agility (7), Buechel Pappas (5), Salto (4), HINTEGRA (3), TNK (3), Mobility (2), and TPR (1) (Table 2). Of these 8 implant types, 5 were second-generation devices and 3 were third-generation implants. Second-generation implants were discussed in 31 total studies, accounting for 7462 citations with a mean of 1492 ± 1202 citations per implant. Third-generation implants were discussed in 9 total studies, accounting for 2330 citations with a mean of 777 ± 315 citations per implant. Studies of the STAR implant accounted for 3311 citations, or 37% of the citations of the 50 most-cited articles.

Studies of Implant Survivorship and Complications

Of the 23 articles on ankle arthroplasty implants, 17 were primary studies assessing implant survivorship and complications, leading to 3508 citations (Table 3). Complications included revision, delayed wound healing, fracture, loosening, periarticular bone formation, osteolytic lesions, talar subsidence, and cysts. Follow-up ranged from 2 to 15 years. Ten of the 17 studies focused on STAR implants, leading to 1947 citations. Eight of the 10 STAR implant primary studies included survival analysis of at least 5 years. There were 41 revisions and 9 removals for 538 Agility ankles; 2 revisions and 0 arthrodesis for 50 Buechel-Pappas ankles, with follow-up ranging from 2 to 16 years; 8 revisions and 0 removals for 122 HINTEGRA ankles, with follow-up of 1.6 years; 18 revisions and 6 arthrodeses for 98 Salto ankles; and 174 revisions and 30 arthrodeses for 1060 STAR ankles. There were 6 revisions or arthrodeses for 32 TPR ankles. There were 230 revisions or arthrodeses for 1471 STAR ankles.

Most-Cited Journal and Authors

The most-cited article, with 497 citations, was an article on arthroplasty vs arthrodesis published by Haddad et al in 2007 in the Journal of Bone and Joint Surgery. The Journal of Bone and Joint Surgery—Series A was the publisher of the greatest share of the 50 articles (13). The most-cited authors were Hintermann and Valderrabano, who coauthored 5 of the 50 articles, including 3 about specific implants. Their articles were associated with 896 citations.

Levels of Evidence

Most of the articles (42 of 50) had a level of evidence of IV. Among the remaining 8 articles, 4 had a level of evidence of V, 2 had a level of evidence of III, 1 had a level of evidence of II, and 1 had a level of evidence of VII. There were 42
Table 1. The 50 Most-Cited Articles on Ankle Arthroplasty and 23 Most-Cited Studies of Implant Devices, by Citation Count, 1970–July 2021.

| First Author (Year) | Title                                                                 | Journal                          | No. of Citations | Implant Device                           |
|---------------------|------------------------------------------------------------------------|----------------------------------|------------------|-------------------------------------------|
| Haddad (2007)²³     | Intermediate and long-term outcomes of total ankle arthroplasty and ankle arthrodesis: a systematic review of the literature | *J Bone Joint Surg Am* | 497 36 | Agility, LCS, Buechel-Pappas, TNK, STAR, Salto |
| Wood (2003)⁶¹       | Total ankle replacement. The results in 200 ankles                     | *J Bone Joint Surg Br*           | 347 19 | STAR                                       |
| Gougoulias (2010)²⁰ | How successful are current ankle replacements? A systematic review of the literature | *Clin Orthop Relat Res*         | 301 27 | STAR, Agility, Buechel Pappas, HINTEGRA, Salto, TNK, Mobility |
| Pyevich (1998)⁹⁹    | Total ankle arthroplasty: a unique design: two to twelve-year follow-up | *J Bone Joint Surg Am*           | 291 13 | Agility                                    |
| Knecht (2004)¹⁴     | The Agility total ankle arthroplasty: seven to sixteen-year follow-up  | *J Bone Joint Surg Am*           | 286 17 | Agility                                    |
| Spirt (2004)¹⁵      | Complications and failure after total ankle arthroplasty               | *J Bone Joint Surg Am*           | 277 16 | Agility                                    |
| Saltzman (2009)⁵³    | Prospective controlled trial of STAR total ankle replacement versus ankle fusion: initial results | *Foot Ankle Int*                | 276 23 | STAR                                       |
| Hinterrmann (2004)²⁷ | The HINTEGRA ankle: rationale and short-term results of 122 consecutive ankles | *Clin Orthop Relat Res*         | 268 16 | HINTEGRA                                  |
| Anderson (2003)¹     | Uncemented STAR total ankle prostheses: three to eight-year follow-up of fifty-one consecutive ankles | *J Bone Joint Surg Am*           | 261 15 | STAR                                       |
| Doets (2006)¹³      | Total ankle arthroplasty in inflammatory joint disease with use of two mobile-bearing designs | *J Bone Joint Surg Am*           | 233 16 |                                           |
| Bolton-Maggs (1985)³ | Total ankle arthroplasty. A long-term review of the London hospital experience | *J Bone Joint Surg Br*           | 228 6 |                                           |
| Wood (2008)⁶²       | Total ankle replacement: medium-term results in 200 Scandinavian Total Ankle Replacements | *J Bone Joint Surg Br*           | 216 17 | STAR                                       |
| Valderrabano (2004)⁵⁸ | Scandinavian total ankle replacement: a 3.7-year average followup of 65 patients | *Clin Orthop Relat Res*         | 214 13 | STAR                                       |
| Kitaoka (1996)²³     | Clinical results of the Mayo total ankle arthroplasty                  | *J Bone Joint Surg Am*           | 211 8  |                                           |
| SooHoo (2007)⁵⁴     | Comparison of reoperation rates following ankle arthrodesis and total ankle arthroplasty | *J Bone Joint Surg Am*           | 210 15 |                                           |
| Henrikson (2007)²⁶   | The Swedish Ankle Arthroplasty Register: an analysis of 531 arthroplasties between 1993 and 2005 | *Acta Orthop*                   | 197 14 | STAR                                       |
| Kofod (2004)¹⁵      | Scandinavian Total Ankle Replacement (STAR)                              | *Clin Orthop Relat Res*         | 194 11 | STAR                                       |

(continued)
| First Author (Year) | Title                                                                                                                                          | Journal                  | No. of Citations | Implant Device       |
|---------------------|------------------------------------------------------------------------------------------------------------------------------------------------|--------------------------|------------------|-----------------------|
| Kofoed (1998)       | Ankle arthroplasty for rheumatoid arthritis and osteoarthritis                                                                          | J Bone Joint Surg Br    | 178              | 8                     |
| Daniels (2014)      | Intermediate-term results of total ankle replacement and ankle arthrodesis a COFAS multicenter study                                             | J Bone Joint Surg Am    | 177              | 25                    |
| Bonnin (2004)       | Midterm results of the Salto Total Ankle Prosthesis                                                                                        | Clin Orthop Relat Res   | 176              | 10                    |
| Buechel (2004)      | Twenty-year evaluation of cementless mobile-bearing total ankle replacements                                                               | Clin Orthop Relat Res   | 167              | 10                    |
| Zaidi (2013)        | The outcome of total ankle replacement: a systematic review and meta-analysis                                                               | Bone Joint J             | 163              | 20                    |
| Valderrabano (2007) | Gait analysis in ankle osteoarthritis and total ankle replacement                                                                            | Clin Biomech             | 163              | 12                    |
| Ohgushi (2005)      | Tissue-engineered ceramic artificial joint—ex vivo osteogenic differentiation of patient mesenchymal cells on total ankle joints for treatment of osteoarthritis | Biomaterials            | 157              | 10                    |
| Easley (2011)       | Results of total ankle arthroplasty                                                                                                        | J Bone Joint Surg Am    | 154              | 15                    |
| Glazebrook (2009)   | Evidence-based classification of complications in total ankle arthroplasty                                                                     | Foot Ankle Int           | 151              | 13                    |
| Conti (2001)        | Complications of total ankle replacement                                                                                                    | Clin Orthop Relat Res   | 142              | 7                     |
| Mann (2011)         | STAR™ ankle: long-term results 257 ankle arthroplasties performed in Norway between 1994 and 2005                                              | Foot Ankle Int           | 141              | 14                    |
| Fevang (2007)       | Ankle replacement versus arthrodesis: a comparative gait analysis study                                                                       | Acta Orthop              | 141              | 10                    |
| Piriou (2008)       | New Jersey Low Contact Stress Total Ankle Replacement: biomechanical rationale and review of 23 cementless cases                               | Foot Ankle Int           | 136              | 10                    |
| Buechel (1988)      | The Salto total ankle arthroplasty: survivorship and analysis of failures at 7 to 11 years                                                  | Foot Ankle Int           | 136              | 4                     |
| Bonnin (2011)       | Ten-year evaluation of cementless Buechel-Pappas meniscal bearing total ankle replacement                                                   | Foot Ankle Int           | 131              | 7                     |
| Valderrabano (2006) | Sports and recreation activity of ankle arthritis patients before and after total ankle replacement                                         | Am J Sports Med          | 130              | 9                     |
| First Author (Year)       | Title                                                                 | Journal                  | No. of Citations | Implant Device |
|--------------------------|----------------------------------------------------------------------|--------------------------|------------------|----------------|
| Myerson (2003)           | Perioperative complications of total ankle arthroplasty              | Foot Ankle Int           | 130              | Agility        |
| Kim (2009)               | Total ankle replacement in moderate to severe varus deformity of the ankle | J Bone Joint Surg Br     | 129              |                |
| Hosman (2007)            | A New Zealand national joint registry review of 202 total ankle replacements followed for up to 6 years | Acta Orthop               | 128              |                |
| Newton III (1982)        | Total ankle arthroplasty. Clinical study of fifty cases              | J Bone Joint Surg Am     | 128              |                |
| Espinosa (2010)          | Misalignment of total ankle components can induce high joint contact pressures | J Bone Joint Surg Am     | 126              |                |
| Haskell (2004)           | Ankle arthroplasty with preoperative coronal plane deformity: short-term results | Clin Orthop Relat Res    | 125              |                |
| Henricson (2011)         | 10-year survival of total ankle arthroplasties: a report on 780 cases from the Swedish Ankle Register | Acta Orthop               | 123              |                |
| Brunner (2013)           | The Scandinavian total ankle replacement long-term, eleven to fifteen-year, survivorship analysis of the prosthesis in seventy-two consecutive patients | J Bone Joint Surg Am     | 121              | STAR           |
| Kofoed (1999)            | Ankle arthroplasty in patients younger and older than 50 years: a prospective series with long-term follow-up | Foot Ankle Int           | 121              |                |
| Hobson (2009)            | Total ankle replacement in patients with significant pre-operative deformity of the hindfoot | J Bone Joint Surg Br     | 116              |                |
| Gougoulias (2009)        | History and evolution in total ankle arthroplasty                   | Br Med Bull              | 115              |                |
| Wood (2009)              | A randomised, controlled trial of two mobile-bearing total ankle replacements | J Bone Joint Surg Br     | 115              | STAR, Buechel-Pappas |
| Kotnis (2006)            | The management of failed ankle replacement                           | J Bone Joint Surg Br     | 115              | STAR, Buechel-Pappas |
| Easley (2002)            | Total ankle arthroplasty                                            | J Am Acad Orthop Surg    | 113              | STAR, Agility, TNK |
| Takakura (1990)          | Ankle arthroplasty. A comparative study of cemented metal and uncemented ceramic prostheses | Clin Orthop Relat Res    | 113              |                |
| Hopgood (2006)           | Ankle arthrodesis for failed total ankle replacement                | J Bone Joint Surg Br     | 112              |                |
original articles, 5 review articles, and 3 systematic reviews. The original articles included 1 randomized controlled trial.

**Discussion**

Since the introduction of ankle arthroplasty, a variety of new ankle arthroplasty implants have been created and researched. The goal of this study was to analyze landmark research on the outcomes of specific types of ankle arthroplasty implants.

Many of the 50 ankle arthroplasty articles we identified were studies of specific ankle arthroplasty implant devices, possibly reflecting the rapid rate of innovation over the past few decades. Ankle arthroplasty was first introduced in the 1970s by Lord and Marotte, who used a ball and socket implant that they based on hip replacement designs. Complication rates were high, and many studies at the time recommended arthrodesis instead of arthroplasty. For decades afterward, arthrodesis was considered the gold standard for treatment of ankle osteoarthritis. In the meantime, however, second-, third-, and fourth-generation ankle replacement devices were developed, with new designs and techniques that required additional research on safety and efficacy. This may explain the finding that the majority of the 50 articles were studies of outcomes of arthroplasty implants and were published between 2000 and 2010.

The most-cited article in our analysis was a systematic review published by Haddad et al in 2007, nearly 3 decades after the introduction of ankle arthroplasty. The article assessed literature on the relative efficacy of ankle arthroplasty vs arthrodesis published during the time when the topic was still heavily debated. The authors reviewed second-generation implants and found that arthroplasty and arthrodesis had similar scores on the American Orthopaedic Foot & Ankle Society (AOFAS) ankle-hindfoot scale, similar meta-analytic mean results, and similar revision rates. Although ankle arthroplasty historically was associated with poorer postoperative outcomes, the review by Haddad et al seemed to support the conclusion that foot and ankle surgeons should favor ankle arthroplasty over arthrodesis because arthroplasty gave patients higher ankle mobility. The authors acknowledged at the time that the data were sparse and that comparative studies were needed to strengthen this conclusion.

A prospective multicenter study by Daniels et al, published in 2014, received the third most citations per year in our review. The study built on the research by Haddad et al and performed a comparative analysis of ankle arthroplasty and arthrodesis based on the Canadian Orthopaedic Foot and Ankle Society (COFAS) Prospective Ankle Reconstruction Database. This study had a level of evidence of II. Before it was undertaken, most of our knowledge of the results of ankle arthroplasty came from level IV evidence. Daniels et al found that the intermediate-term clinical outcomes of arthroplasty and arthrodesis were similar. However, rates of revision and major complications were higher after ankle replacement. The authors suggested that as prosthetic designs improved, revision and complication rates might also improve.

The market landscape of arthroplasty implant devices is continuously evolving. Most of the second-generation ankle implant devices identified in our bibliometric analysis, including the Buechel-Papas, Agility, and Mobility implants, are no longer used, and only the STAR implant continues to be widely used. Among our 50 studies, the ones that mentioned STAR implants were cited 3311 times, receiving 37% of the citations in our analysis. Furthermore, 10 of the 17 primary arthroplasty implant studies assessed STAR implants. Several newer implants, such as the INFINITY and the INBONE, do not appear in our analysis. Future research should assess the influence of studies of these modern implants on the ankle arthroplasty literature.

Our study has several limitations. First, although Scopus, Web of Science, and MEDLINE/PubMed are comprehensive databases, there are other databases such as Embase that might contain works that do not appear in Scopus, Web of Science, and MEDLINE/PubMed. Furthermore, the databases we used contain primarily works written in English, and we may have omitted relevant articles in other languages. Third, this analysis does not account for self-citation. Authors may tend to cite their own articles to increase citation counts, which could skew the analysis. Future study is needed to understand the prevalence of self-citation and its impact on citation counts. Further, citation count is not always the best measure of an article’s impact; level of evidence must also be taken into consideration. Finally, certain well-known journals and authors may have a wider reach than others, leading to higher citation counts for those journals and authors. Higher-quality articles by lesser-known journals and authors may have a deflated citation count.

Despite the limitations of bibliometric analysis, citation counts are used to calculate journal impact factors as well as...
| First Author (Year) | Title                                                                 | Device         | Outcomes (N)                                                                 | N      | No. of Follow-up Years | Surgery Years | No. of Citations | Total | Per Year |
|---------------------|----------------------------------------------------------------------|----------------|-----------------------------------------------------------------------------|--------|------------------------|---------------|------------------|-------|----------|
| Spirt (2004)        | Complications and failure after total ankle arthroplasty             | Agility        | Revision (30); removal for arthrodesis (1); reoperation any reason (85)     | 306    | 2.75                   | 1995-2001     | 277              |       | 16       |
| Knecht (2004)       | The Agility total ankle arthroplasty: seven to sixteen-year follow-up| Agility        | Revision (7); removal for arthrodesis (7); reoperation any reason (46)      | 132    | 7-16                   | 1984-1994     | 286              |       | 17       |
| Pyevich (1998)      | Total ankle arthroplasty: a unique design two to twelve-year follow-up| Agility        | Revision (4); removal for arthrodesis (1); Pain (24); delayed union of syndesmosis (28); component migration (12 tibial, 9 talar); nonunion of syndesmosis (9) | 100    | 2-12                   | 1984-1993     | 291              |       | 13       |
| Buechel (2003)      | Ten-year evaluation of cementless Buechel-Pappas meniscal bearing total ankle replacement | Buechel-Pappas | Revision (2); removal for arthrodesis (0); meniscal bearing wear (1); talar component subsidence (1) | 50     | 2-10                   | 1991-1998     | 131              |       | 7        |
| Hintermann (2004)   | The HINTEGRA ankle: rationale and short-term results of 122 consecutive ankles | HINTEGRA      | Revision (8); removal for arthrodesis (0); talar component migration (2); pain-free (83) | 122    | 1.6                    | 2000-2002     | 268              |       | 16       |
| Bonnin (2004)       | Midterm results of the Salto Total Ankle Prosthesis                  | Salto          | Revision (2); removal for arthrodesis (2); reoperation for any reason (17); survival at 68 mo: 98% | 98     | 2.9                    | 1997-2000     | 176              |       | 10       |
| Bonnin (2011)       | The Salto total ankle arthroplasty: survivorship and analysis of failures at 7 to 11 years | Salto          | Revision (18); removal for arthrodesis (6); Survival any reoperation: 65%; survival of component revision: 85%; Bone cysts (11 patients); fracture of polyethylene (5); unexplained pain (3) | 98     | 7-11                   | 1997-2000     | 132              |       | 13       |
| Wood (2003)         | Total ankle replacement. The results in 200 ankles                   | STAR           | Revision or arthrodesis (14); delayed wound healing (5); fracture of a malleolus (9) | 200    | 6.75                   | 1993-2000     | 347              |       | 19       |
| Anderson (2003)     | Uncemented STAR total ankle prostheses: three to eight-year follow-up of fifty-one consecutive ankles | STAR           | Revision (12); arthrodesis (0); Revision due to loosening (7) and revision due to meniscus fracture (2); Survival at 5 y: 70% | 51     | 3-8                    | 1993-1999     | 261              |       | 15       |
| Wood (2008)         | Total ankle replacement: medium-term results in 200 Scandinavian Total Ankle Replacements | STAR           | Revision (4); arthrodesis (20); Survival at 5 y: 93%; Survival at 10 y: 80% | 200    | 7.3                    | 1993-2000     | 216              |       | 17       |
### Table 3. (continued)

| First Author (Year) | Title                                                                 | Device          | Outcomes (N)                                                                 | N  | No. of Follow-up Years | Surgery Years | No. of Citations | Total  | Per Year |
|---------------------|----------------------------------------------------------------------|-----------------|------------------------------------------------------------------------------|----|------------------------|---------------|------------------|--------|----------|
| Valderrabano (2004) | Scandinavian total ankle replacement: a 3.7-year average followup of 65 patients | STAR            | Revision (14); arthrodesis (0); other reoperation (9); Ballooning bone lysis (3); periarticular hypertrophic bone formation with decreased dorsiflexion and plantar flexion (43) | 68 | 3.7                    | 1994-1998     | 214              | 13     |          |
| Henricson (2007)    | The Swedish Ankle Arthroplasty Register: an analysis of 531 arthroplasties between 1993 and 2005 | STAR            | Revision (101); Survival at 5 y: 78%; Survival at 5 y after first 30 cases: 86% | 531| 5                      | 1993-2005     | 197              | 14     |          |
| Kofoed (2004)       | Scandinavian Total Ankle Replacement (STAR)                          | STAR            | Revision (5); arthrodesis (4); reoperation (9/33 cemented, 1/25 uncemented); Survival at 12 y: 70% cemented, 95% uncemented | 58 | 9.4                    | 1986-1989 (cement) | 1990-1995 (no cement) | 194 | 11       |
| Mann (2011)         | STAR™ ankle: long-term results                                       | STAR            | Revision (9); arthrodesis (5); any complications (21); osteolytic lesions (10); Survival at 5 y: 96%; Survival at 10 y: 90% | 80 | 9.1                    | 1998-2000     | 141              | 14     |          |
| Brunner (2013)      | The Scandinavian total ankle replacement long-term, eleven to fifteen-year, survivorship analysis of the prosthesis in seventy-two consecutive patients | STAR            | Revision (29); arthrodesis (1); aseptic loosening (9); talar subsidence (11); cysts (5); Survival at 10 y: 71%; Survival at 14 y: 46% | 72 | 11-15                  | 1996-2000     | 121              | 15     |          |
| Fevang (2007)       | 257 ankle arthroplasties performed in Norway between 1994 and 2005    | STAR (212) and Cemented TPR (32) | Revision or removal (27); revision or removal STAR (21); revision or removal TPR (6); Survival was same for both prostheses; Survival at 5 y: 89%; Survival at 10 y: 76% | 257| 4                      | 1994-2005     | 141              | 10     |          |
| Wood (2009)         | A randomised, controlled trial of two mobile-bearing total ankle replacements | STAR, Buechel-Pappas | Revision or arthrodesis (12/100 Buechel Pappas, 4/100 STAR); Survival at 5 y: 79% Buechel Pappas, 95% STAR; Difference in survival was not statistically significant (P = .09) | 200| 3                      | 2000-2003     | 115              | 10     |          |
H-index, both widely used measurements for research impact.11 None of these measures are perfect, but they exist to provide an additional objective and quantifiable source of information that can aid in the discussion of what articles, individuals, or topics were most impactful over time. This is the first bibliometric analysis of ankle arthroplasty implants, which have grown in both research and procedure volume over the last few decades. By broadly assessing the literature, our research has identified high-quality articles as well as topics that may be more likely to make an impact within the field.

Conclusion

This study analyzed the most-cited literature on ankle arthroplasty implants according to topic, authors, journals, countries, and citations per year. Ankle arthroplasty research has greatly increased in the past 2 decades, particularly in the area of postoperative outcomes of specific ankle implants, and continued research and publication in additional areas should be a priority in the ankle arthroplasty medical community.

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Ethical approval

Ethical approval was not sought for the present study because the study did not involve patient data.

Declaration of Conflicting Interests

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References

1. Anderson T, Montgomery F, Carlsson A. Uncemented STAR total ankle prostheses. Three to eight-year follow-up of fifty-one consecutive ankles. J Bone Joint Surg Am. 2003;85(7):1321-1329.
2. de Boer S, Tijoe RJC, van der Sijde F, et al. The American Orthopaedic Foot and Ankle Society Ankle-Hindfoot Scale; translation and validation of the Dutch language version for ankle fractures. BMJ Open. 2017;7(8):e017040-e017040. doi:10.1136/bmjopen-2017-017040
3. Bolton-Maggs BG, Sudlow RA, Freeman MA. Total ankle arthroplasty. A long-term review of the London Hospital experience. J Bone Joint Surg Br. 1985;67(5):785-790. doi:10.1302/0301-620X.67B5.405588
4. Bonnin M, Gaudot F, Laurent JR, Ellis S, Colombier JA, Judet T. The Salto total ankle arthroplasty: survivorship and analysis of failures at 7 to 11 years. Clin Orthop Relat Res. 2011;469(1):225-236. doi:10.1007/s11999-010-1453-y
5. Bonnin M, Judet T, Colombier JA, Buscayret F, Graveleau N, Piriou P. Midterm results of the Salto Total Ankle Prosthesis. Clin Orthop Relat Res. 2004;424:6-18. doi:10.1097/01.blo.0000132407.75881.a0
6. Brunner S, Barg A, Knupp M, et al. The Scandinavian Total Ankle Replacement: long-term, eleven to fifteen-year, survivorship analysis of the prosthesis in seventy-two consecutive patients. J Bone Joint Surg Am. 2013;95(8):711-718. doi:10.2106/JBJS.K.01580
7. Buechel FF, Buechel FF, Pappas MJ. Ten-year evaluation of cementless Buechel-Pappas meniscal bearing total ankle replacement. Foot Ankle Int. 2003;24(6):462-472. doi:10.1177/10711007032400603
8. Buechel FF, Buechel FF, Pappas MJ. Twenty-year evaluation of cementless mobile-bearing total ankle replacements. Clin Orthop Relat Res. 2004;424:19-26. doi:10.1097/01.blo.0000132243.41419.59
9. Buechel FF, Pappas MJ, Iorio LJ. New Jersey low contact stress total ankle replacement: biomechanical rationale and review of 23 cementless cases. Foot Ankle. 1988;8(6):279-290. doi:10.1177/107110078800800603
10. Conti SF, Wong YS. Complications of total ankle replacement. Clin Orthop Relat Res. 2001;391:105-114. doi:10.1097/00003086-200110000-00011
11. Cooper ID. Bibliometrics basics. J Med Libr Assoc. 2015;103(4):217-218. doi:10.3163/1536-5050.103.4.013
12. Daniels TR, Younger ASE, Penner M, et al. Intermediate-term results of total ankle replacement and ankle arthrodesis: a COFAS multicenter study. J Bone Joint Surg Am. 2014;96(2):135-142. doi:10.2106/JBJS.L.01597
13. Doets HC, Brand R, Nelissen RGHH. Total ankle arthroplasty in inflammatory joint disease with use of two mobile-bearing designs. J Bone Joint Surg Am. 2006;88(6):1272-1284. doi:10.2106/JBJS.E.00414
14. Easley ME, Adams SBJ, Hembree WC, DeOrio JK. Results of total ankle arthroplasty. J Bone Joint Surg Am. 2011;93(15):1455-1468. doi:10.2106/JBJS.J.00126
15. Easley ME, Vertullo CJ, Urban WC, Nunley JA. Total ankle arthroplasty. J Am Acad Orthop Surg. 2002;10(3):157-167. doi:10.5435/00124635-200205000-00002
16. Espinosa N, Walti M, Favre P, Snedeker JG. Misalignment and stress total ankle replacement: biomechanical rationale and review of 23 cementless cases. Foot Ankle. 1988;8(6):279-290. doi:10.1177/107110078800800603
17. Eyre-Walker A, Stoletzki N. The assessment of science: the relative merits of post-publication review, the impact factor, and the number of citations. PLoS Biol. 2013;11(10):e1001675. doi:10.1371/journal.pbio.1001675
18. Fenvang BTS, Lie SA, Havelin LI, Brun JG, Skredderstuen A, Furnes O. 257 ankle arthroplasties performed in Norway between 1994 and 2005. Acta Orthop. 2007;78(5):575-583. doi:10.1080/17453670701004257
19. Glazebrook MA, Arsenault K, Dunbar M. Evidence-based classification of complications in total ankle arthroplasty. *Foot Ankle Int*. 2009;30(10):945-949. doi:10.3113/FAI.2009.0945

20. Gougoulias N, Khanna A, Maffulli N. How successful are current ankle replacements?: a systematic review of the literature. *Clin Orthop Relat Res*. 2010;468(1):199-208. doi:10.1007/s11999-009-0987-3

21. Gougoulias N, Maffulli N. History of total ankle replacement in North America. In: Roukis TS, Berlet GC, Bibbo C, et al, eds. *Primary and Revision Total Ankle Replacement: Evidence-Based Surgical Management*. Springer International Publishing; 2016:3-13. doi:10.1007/978-3-319-24415-0_1

22. Gougoulias N, Khanna A, Maffulli N. History and evolution in total ankle arthroplasty. *Br Med Bull*. 2009;89(1):111-151. doi:10.1093/bmb/ldn039

23. Haddad SL, Coetzee JC, Estok R, Fahrbach K, Banel D, Nalystnyk L. Intermediate and long-term outcomes of total ankle arthroplasty and ankle arthrodesis: a systematic review of the literature. *J Bone Joint Surg Am*. 2007;89(9):1899-1905. doi:10.2106/JBJS.F.01149

24. Haskell A, Mann RA. Ankle arthroplasty with preoperative coronal plane deformity: short-term results. *Clin Orthop Relat Res*. 2004;424:98-103. doi:10.1097/01.blo.0000132459.64290.52

25. Henriksen A, Nilsson JÅ, Carlsson A. 10-year survival of total ankle arthroplasties: a report on 780 cases from the Swedish Ankle Register. *Acta Orthop*. 2011;82(6):655-659. doi:10.3109/17453674.2011.636678

26. Henriksen A, Skoog A, Carlsson A. The Swedish Ankle Arthroplasty Register: an analysis of 531 arthroplasties between 1993 and 2005. *Acta Orthop*. 2007;78(5):569-574. doi:10.1080/17453670701004248

27. Hintermann B, Valderrabano V, Deremynaeker G, Dick W. The HINTEGRA ankle: rationale and short-term results of 122 consecutive ankles. *Clin Orthop Relat Res*. 2004;424:57-68. doi:10.1097/01.blo.0000132462.72843.e8

28. Hobson SA, Karantana A, Dhar S. Total ankle replacement in patients with significant pre-operative deformity of the hindfoot. *J Bone Joint Surg Br*. 2009;91(4):481-486. doi:10.1302/0301-620X.91B4.20855

29. Hopgood P, Kumar R, Wood PLR. Ankle arthrodesis for failed total ankle replacement. *J Bone Joint Surg Br*. 2006;88(8):1032-1038. doi:10.1302/0301-620X.88B8.17627

30. Hosman AH, Mason RB, Hobbs T, Rothwell AG. A New Zealand National Joint Registry review of 202 total ankle replacements followed for up to 6 years. *Acta Orthop*. 2007;78(5):584-591. doi:10.1080/17453670701004246

31. Jackson MP, Singh D. Total ankle replacement. *Carr Orthop*. 2003;17(4):292-298. doi:10.1016/S0268-0890(02)00195-0

32. Kim BS, Choi WJ, Kim YS, Lee JW. Total ankle replacement in moderate to severe varus deformity of the ankle. *J Bone Joint Surg Br*. 2009;91(9):1183-1190. doi:10.1302/0301-620X.91B9.22411

33. Kitaoka HB, Patzer GL. Clinical results of the Mayo total ankle arthroplasty. *J Bone Joint Surg Am*. 1996;78(11):1658-1664. doi:10.2106/00004623-199611000-00004

34. Knecht SI, Estin M, Callaghan JJ, et al. The Agility total ankle arthroplasty: seven to sixteen-year follow-up. *J Bone Joint Surg Am*. 2004;86(6):1161-1171.

35. Kofod H. Scandinavian Total Ankle Replacement (STAR). *Clin Orthop Relat Res*. 2004;424:73-79. doi:10.1097/01.blo.0000132414.41124.06

36. Kofod H, Lundberg-Jensen A. Ankle arthroplasty in patients younger and older than 50 years: a prospective series with long-term follow-up. *Foot Ankle Int*. 1999;20(8):501-506. doi:10.1177/1071100799020800807

37. Kofod H, Sørensen TS. Ankle arthroplasty for rheumatoid arthritis and osteoarthritis: prospective long-term study of cemented replacements. *J Bone Joint Surg Br*. 1998;80(2):328-332. doi:10.1302/0301-620x.80b2.8243

38. Kotnis R, Pasapula C, Anwar F, Cooke PH, Sharp RJ. The management of failed ankle replacement. *J Bone Joint Surg Br*. 2006;88(8):1039-1047. doi:10.1302/0301-620x.88b8.16768

39. Law TY, Sabeh KG, Rosas S, Hubbard Z, Altajar S, Roche MW. Trends in total ankle arthroplasty and revisions in the Medicare database. *Ann Transl Med*. 2018;6(7):2-2. doi:10.21037/atm.2018.02.06

40. Lawton CD, Butler BA, Dekker RG, Prescott A, Kadakia AR. Total ankle arthroplasty versus ankle arthrodesis—a comparison of outcomes over the last decade. *J Orth Surg Res*. 2017;12(1):76. doi:10.1186/s13018-017-0576-1

41. Lord G, Marotte JH. Prothèse totale de cheville. Technique et premiers résultats. A propos de 12 observations [Total ankle prosthesis. Technic and 1st results. Apropos of 12 cases]. *Rev Chir Orthop Reparatrice Appar Mot*. 1973;59(2):139-151.

42. Lord G, Marotte JH. L’arthroplastie totale de cheville. Expérience sur 10 ans, à propos de 25 observations personnelles [Total ankle replacement (author’s trans)]. *Rev Chir Orthop Reparatrice Appar Mot*. 1980;66(8):527-530.

43. Mann JA, Mann RA, Horton E. STAR™ ankle: long-term results. *Foot Ankle Int*. 2011;32(5):S473-S484. doi:10.3113/FAI.2011.0473

44. Moed HF. New developments in the use of citation analysis in research evaluation. *Arch Immunol Ther Exp (Warsz)*. 2009;57(1):13-18. doi:10.1007/s00005-009-0001-5

45. Myerson MS, Mroczek K. Perioperative complications of total ankle arthroplasty. *Foot Ankle Int*. 2003;24(1):17-21. doi:10.1177/107110070302400102

46. Newton SE. Total ankle arthroplasty. Clinical study of fifty cases. *J Bone Joint Surg Am*. 1982;64(1):104-111.

47. Ohgushi H, Kotobuki N, Funaoa H, et al. Tissue engineered ceramic artificial joint–ex vivo osteogenic differentiation of patient mesenchymal cells on total ankle joints for treatment of osteoarthritis. *Biomaterials*. 2005;26(22):4654-4661. doi:10.1016/j.biomaterials.2004.11.055

48. Pirio P, Culpin P, Mullins M, Cardon JN, Pozzi D, Judet T. Ankle replacement versus arthrodesis: a comparative gait analysis study. *Foot Ankle Int*. 2008;29(1):3-9. doi:10.3113/FAI.2008.0003

49. Pyevich MT, Saltzman CL, Callaghan JJ, Alvine FG. Total ankle arthroplasty: a unique design. Two to twelve-year follow-up. *J Bone Joint Surg Am*. 1998;80(10):1410-1420.

50. Reiley MA. INBONE total ankle replacement. *Foot Ankle Spec*. 2008;1(5):305-308. doi:10.1177/193864008325082

51. Rouhani H, Favre J, Aminian K, Crevoisier X. Multi-segment foot kinematics after total ankle replacement and ankle arthrodesis during relatively long-distance gait. *Gait Posture*. 2012;36(3):561-566. doi:10.1016/j.gaitpost.2012.05.010
52. Rushing CJ, Kibbler K, Hyer CF, Berlet GC. The INFINITY total ankle prosthesis: outcomes at short-term follow-up. Foot Ankle Spec. 2022;15(2):119-126. doi:10.1177/1938640020946199
53. Saltzman CL, Mann RA, Ahrens JE, et al. Prospective controlled trial of STAR total ankle replacement versus ankle fusion: initial results. Foot Ankle Int. 2009;30(7):579-596. doi:10.3113/FAI.2009.0579
54. SooHoo NF, Zingmond DS, Ko CY. Comparison of reoperation rates following ankle arthrodesis and total ankle arthroplasty. J Bone Joint Surg Am. 2007;89(10):2143-2149. doi:10.2106/JBJS.F.01611
55. Spirt AA, Assal M, Hansen STJ. Complications and failure after total ankle arthroplasty. J Bone Joint Surg Am. 2004;86(6):1172-1178.
56. Takakura Y, Tanaka Y, Sugimoto K, Tamai S, Masuhara K. Ankle arthroplasty. A comparative study of cemented metal and uncemented ceramic prostheses. Clin Orthop Relat Res. 1990;252:209-216.
57. Thomas RH, Daniels TR. Ankle arthritis. J Bone Joint Surg Am. 2003;85(5):923-936. doi:10.2106/00004623-200305000-00026
58. Valderrabano V, Hinternann B, Dick W. Scandinavian total ankle replacement: a 3.7-year average followup of 65 patients. Clin Orthop Relat Res. 2004;424:47-56.
59. Valderrabano V, Nigg BM, von Tscharner V, Stefanyshyn DJ, Goepfert B, Hinternann B. Gait analysis in ankle osteoarthritis and total ankle replacement. Clin Biomech (Bristol, Avon). 2007;22(8):894-904. doi:10.1016/j.clinbiomech.2007.05.003
60. Valderrabano V, Pagenstert G, Horisberger M, Knupp M, Hinternann B. Sports and recreation activity of ankle arthritis patients before and after total ankle replacement. Am J Sports Med. 2006;34(6):993-999. doi:10.1177/0363546505284189
61. Wood PLR, Deakin S. Total ankle replacement. The results in 200 ankles. J Bone Joint Surg Br. 2003;85(3):334-341. doi:10.1302/0301-620x.85b3.13849
62. Wood PLR, Prem H, Sutton C. Total ankle replacement. J Bone Joint Surg Br. 2008;90(5):605-609. doi:10.1302/0301-620X.90B5.19677
63. Wood PLR, Sutton C, Mishra V, Suneja R. A randomised, controlled trial of two mobile-bearing total ankle replacements. J Bone Joint Surg Br. 2009;91(1):69-74. doi:10.1302/0301-620X.91B1.21346
64. Zaidi R, Cro S, Gurusamy K, et al. The outcome of total ankle replacement: a systematic review and meta-analysis. Bone Joint J. 2013;95-B(11):1500-1507. doi:10.1302/0301-620x.95b11.31633