Total ankle arthroplasty with ceramic prostheses: A systematic review of medium-term outcomes and failure rates

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Abstract

Introduction
There are few reports for total ankle arthroplasty (TAA) with ceramic implant. We performed a systematic search for relevant articles published in English and other languages between January 1990 and February 2012. We aimed to report the cumulative medium-term outcomes (survivorship/failure rates) for patients treated with ceramic TAA in patients with end-stage arthritis.

Materials and methods
Qualified studies were evaluated using the Coleman methodology score, and data collection was independently implemented by three reviewers.

Results
Four studies qualified for analysis, describing 138 implants (125 TNK, 13 ND-Bioceram). Only one study provided survivorship analysis data as 77% at 14.1 years. The pooled failure rate was 6.3% (95% confidence interval: 6.2–7.1) over a mean follow-up of 5.6 years. Ceramic TAA prostheses currently used in patients with end-stage arthritis achieved satisfactory medium-term outcomes compared with previous non-ceramic TAA studies with a closed length of mean follow-up.

Conclusion
The study showed that the use of ceramic TAA prosthesis had a failure rate of 6.3%, which is a satisfactory result. We call for further studies regarding comparisons between ceramic TAA and ankle arthrodesis to determine the medium- to long-term advantages of ceramic TAA compared with ankle arthrodesis in patients with end-stage arthritis.

Figure 1: The HINTEGRA® (Newdeal SA, Lyon, France) three-component system is characterized by an anatomical shape, which provides high intrinsic stability, low level of bone resection, low contact stress between the prosthesis and the bone, titanium surface in contact with the bone and cobalt-chromium portion articulating with the ultra-high molecular weight polyethylene (UHMWPE) liner (a) tibial component; (b) talar component; (c) polyethylene liner (permission of figures from Phoenix Surgical Equipment Co., Ltd., representative of Newdeal Company in Thailand).
with a polyethylene mobile bearing between the components, were implanted in Japan in the 2000s. However, some studies have reported the results of other type of TAA prosthesis as the ceramic component. Since the 1980s, the TAA system with alumina ceramic component has been developed. The ND-Bioceram was an earlier version that was implanted in Japan. In 1991, the ankle system such as the TNK implant (KYOCERA Medical Corporation, Osaka, Japan) was developed, which consisted of a beaded coating of alumina ceramics on the surface of the tibial and talar components to enhance the affinity between the bone and prosthesis, with polyethylene on a tibial-bearing surface (Figure 3).

There is currently no evidence-based systematic review evaluating the outcomes and failure rates of the ceramic TAA system. We therefore systematically reviewed the literature to determine the outcomes of this TAA system and to provide evidence-based cumulative data of the clinical failure rate, survivorship and the functional outcomes in patients who were implanted with the ceramic TAA.

**Materials and methods**

**Study selection**

Typical systematic review guidelines were used. Initially, a prospective protocol was written to define purposes, search criteria, study selection criteria, elements of interest and plans for analysis.

According to the protocol, a comprehensive search of the literature was performed for studies between January 1990 and February 2012 using the MEDLINE®, Cochrane, EMBASE™ and CINAHL® databases and the following search terms: ‘total’, ‘ankle’ and ‘arthroplasty’ or ‘replacement’.

These electronic searches were supplemented by searching the reference sections of several papers to authenticate the inclusion of all related papers and current reviews. Search results were screened independently by three reviewers (CA, SC and AK) and determined as relevant, irrelevant or
uncertain according to study eligibility criteria. Conflicts regarding study inclusion were resolved by consensus discussions or the decision of the senior author (CA). This study was approved by the ethical committee of the authors’ institution.

**Inclusion and exclusion criteria**
To satisfy inclusion criteria, the study must have (1) reported the outcomes, failure rates and indications or reasons for TAA; (2) included at least 20 ankle joints in the whole study; (3) had a mean follow-up of at least 2 years and (4) the use of ceramic TAA. Studies were excluded if (1) the study used old prosthesis designs implanted before the early 1980s; (2) the ankle arthrodesis or arthroplasty failed or (3) several publications on the same patient population were pooled. All study designs were eligible, including randomized controlled trials, prospective and retrospective non-randomized controlled trials and case series, according to the Journal of Bone and Joint Surgery criteria level I–IV24. The methods used in these studies were assessed by a modified Coleman methodology score (CMS) (Table 1)25, with scores ranging from 0 to 100, where 100 indicated that the study had a perfect design and largely empty of chance, several forms of bias or confounding factors.

**Data collection and statistical methods**
Patient demographics, number of cases, mean follow-up, functional outcome scales and scores, failure rates, causes of failures and rates of prosthesis survivorship were recorded. TAA failure was defined as the necessity to change or remove prosthesis components, convert the TAA to an ankle arthrodesis or TAA-related amputation. The employed studies were reviewed by three orthopaedic surgeons (CA, SC and AK). Protocol-defined data from each eligible study were collected.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Criteria used to calculate the modified Coleman methodology score25</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Criterion</strong></td>
<td><strong>Category</strong></td>
</tr>
<tr>
<td><strong>Part A: only one score to be given for each of the seven sections</strong></td>
<td></td>
</tr>
<tr>
<td>1. Study size</td>
<td>&lt;30 TAA</td>
</tr>
</tbody>
</table>
| &nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&nbsp;&n...
and confirmed by the same three authors. Differences were resolved by consensus discussions or the decision of the senior author (CA) prior to data entry. The rates of survivorship and failure were calculated using a meta-analysis by pooling group results across studies\(^{26}\). Data are shown as median and range or mean and 95% confidence interval (CI). All statistical analyses were performed with Microsoft Excel 2010 (Microsoft Corp., Redmond, WA, USA).

**Results**

We identified four studies\(^{1,22,27,28}\) published from January 1990 to February 2012 that reported the findings of 138 TAA (125 TNK, 13 ND-Bioceram). Only one of the four articles compared the outcomes of TAA (20 cases) with ankle arthrodesis (17 cases)\(^{28}\). There were no randomized trials. In two of the studies, the patient recruitment rate was greater than 90\%\(^{1,22}\). The results of the modified CMS for each study are summarized in Table 2, and demographic data are shown in Table 3. The indications for TAA varied among different studies (Table 3). Rheumatoid arthritis was the most common cause (71.7\%) of arthritis in ankles undergoing ceramic TAA (Table 3).

With revision, arthrodensis or amputation as an endpoint, we identified eight failures among the 138 TAAs [pooled percentage: 6.3\% (95\% CI: 6.2–7.1)]. The weighted follow-up for all implants was 5.6 years (95\% CI: 5.2–5.9). Only one study\(^{27}\) provided survivorship analysis data as 77\% at 14.1 years (Table 4). Two principal complications were reported as the cause of TAA implant failure: aseptic loosening (75\%) and deep infection (25\%) (Table 4). Various functional outcome scales such as American Orthopaedic Foot and Ankle Society (AOFAS)-Hindfoot score\(^{29}\), Evanski and Waugh score\(^{30}\) and authors’ score\(^{1}\) were used to assess ankle function after TAA (Table 5). In most studies, ankle scores improved after TAA; one study did not include a preoperative score to compare with the postoperative score\(^{27}\) and therefore, improvement could not be discerned (Table 5).

All studies evaluated TAA using radiography\(^{1,22,27,28}\). Most studies evaluated the presence of radiolucency and prosthesis loosening or subsidence (Table 4), with variation in methods used and in definitions of component loosening or subsidence. The pooled percentage for radiolucency was 54.8\% (95\% CI: 47.4–59.9) and that for loosening or subsidence was 21.5\% (95\% CI: 19.1–24.9).

### Table 2 Modified Coleman methodology scores for the studies reporting ceramic TAA

<table>
<thead>
<tr>
<th>Study</th>
<th>Study size</th>
<th>Mean follow-up</th>
<th>Number of different versions of the implant used</th>
<th>Type of study</th>
<th>Description of indications/diagnosis</th>
<th>Description of surgical technique</th>
<th>Survivorship analysis</th>
<th>Outcome criteria</th>
<th>Procedure of assessing outcomes</th>
<th>Description of subject selection process</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nishikawa(^{27})</td>
<td>0</td>
<td>7</td>
<td>10</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>10</td>
<td>4</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Takakura(^{1})</td>
<td>7</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>0</td>
<td>4</td>
<td>8</td>
<td>10</td>
</tr>
<tr>
<td>Shinomiya(^{28})</td>
<td>4</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>7</td>
<td>5</td>
<td>0</td>
</tr>
<tr>
<td>Nagashima(^{22})</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>10</td>
<td>5</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>8</td>
<td>10</td>
</tr>
</tbody>
</table>

Values set by consensus among the three reviewers (CA, SC and AK) or the decision of the senior author (CA).

### Discussion

The current study reports the evidence-based cumulative data of clinical failure rates, survivorship and the functional outcomes of ceramic TAA. From four eligible studies, we found only one comparative study between ceramic TAA and ankle arthrodesis that favoured ceramic TAA in terms of postoperative score\(^{29}\). Most studies reported that ankle scores were improved after TAA. However, the functional outcomes for patients treated with ceramic TAA were difficult to determine because of the varied scoring methods used in each study such as AOFAS-Hindfoot score\(^{29}\), Evanski and Waugh score\(^{30}\) and Japanese Orthopaedic Association score\(^{31}\). One group had created their own scoring system\(^{1}\). Consequently, there may be an increased bias caused by the heterogeneity of outcome measures, such that, at this point, it is difficult to compare the different outcomes of ceramic TAA and other designs of TAA studies in this systematic review.

Of the four studies, only one study reported that the pooled mean survival rate of TAA was 77\% at 14.1 years\(^{27}\); these results might have been acceptable if these numbers had been compared with those reported in previous studies\(^{9,25,32}\). TAA survivorship data therefore should...
Table 3  Demographic data on the studies of ceramic TAA

<table>
<thead>
<tr>
<th>Study</th>
<th>Prosthesis</th>
<th>Number of ankle joints</th>
<th>Mean age (range) (years)</th>
<th>Causes of ankle arthritis</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Post-traumatic</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Idiopathic</td>
<td></td>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Autoimmune</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Other</td>
<td></td>
</tr>
<tr>
<td>Nishikawa²⁷</td>
<td>TNK</td>
<td>27</td>
<td>60 (36–75)</td>
<td>—</td>
<td>27 (100%: RA)</td>
</tr>
<tr>
<td>Takakura¹</td>
<td>TNK</td>
<td>70</td>
<td>64.3 (41–87)</td>
<td>36 (51%)</td>
<td>31 (44%: RA) 3 (5%)</td>
</tr>
<tr>
<td>Shinomiya²⁸</td>
<td>TNK/ND AA</td>
<td>7/13</td>
<td>59.8 (43–72) 51.9 (36–68)</td>
<td>—</td>
<td>20 (100%: RA) 17 (100%: RA)</td>
</tr>
<tr>
<td>Nagashima²²</td>
<td>TNK</td>
<td>21</td>
<td>57.9 (42–71)</td>
<td>—</td>
<td>21 (100%: RA)</td>
</tr>
<tr>
<td>All studies</td>
<td>TAA</td>
<td>Mean ± standard deviation AA</td>
<td>138 ± 34.5 ± 17.0 60.5 ± 1.9</td>
<td>36 (26.1%)</td>
<td>99 (71.7%) 3 (2.2%)</td>
</tr>
</tbody>
</table>

AA, total ankle arthroplasty; AA, ankle arthrodesis; RA, rheumatoid arthritis.

Table 4  Failure rates for the ceramic TAA

<table>
<thead>
<tr>
<th>Study</th>
<th>Prosthesis</th>
<th>Mean follow-up (range) (years)</th>
<th>Failures¹</th>
<th>Radiolucencies</th>
<th>Subsidence-migration</th>
<th>Survival rate (mean and 95% CI)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Less than 5 years More than 5 years</td>
</tr>
<tr>
<td>Nishikawa²⁷</td>
<td>TNK</td>
<td>6 (1.25–14.1)</td>
<td>3/27 (11.1%)</td>
<td>Aseptic loosening</td>
<td>18/27 (66.7%)</td>
<td>13/27 (47%)</td>
</tr>
<tr>
<td>Takakura¹</td>
<td>TNK</td>
<td>5.2 (2–11.2)</td>
<td>3/70 (4.3%) 1: deep infection 2: aseptic loosening</td>
<td>—</td>
<td>—</td>
<td>23/67 (34%) NR NR</td>
</tr>
<tr>
<td>Shinomiya²⁸</td>
<td>TNK/ND</td>
<td>8.2 (5–12)</td>
<td>1/20 (5%) Aseptic loosening</td>
<td>20/20 (100%)</td>
<td>1/20 (5%)</td>
<td>NR NR</td>
</tr>
<tr>
<td>Nagashima²²</td>
<td>TNK</td>
<td>2.8 (1.5–4.2)</td>
<td>1/21 (4.8%) Deep infection</td>
<td>11/21 (52.4%)</td>
<td>—</td>
<td>NR NR</td>
</tr>
<tr>
<td>All implants</td>
<td></td>
<td>Meanb Pooled percentageb</td>
<td>5.6 (95% CI 5.2–5.9) —</td>
<td>8/138 6.3% (95% CI 6.2–7.1)</td>
<td>49/138 54.8% (95% CI 47.4–59.9)</td>
<td>37/138 21.5% (95% CI 19.1–24.9)</td>
</tr>
</tbody>
</table>

¹TAA failure was defined as the requirement to change or remove prosthesis components, transform to ankle arthrodesis or TAA-related amputation.

²Calculation using meta-analytic pooling group results across studies²⁶. NR, not reported; CI, confidence interval; TAA, total ankle arthroplasty.

be interpreted with caution. Overall, TAA failure rate was only 6.3% (ranging from 4.3% to 11.1% between centres), with a mean follow-up time of 5.6 years. This failure rate was lower than that in previous non-ceramic TAA studies that were mostly conducted with closed lengths of follow-up³². The most common causes for TAA implant failure in our review were aseptic loosening and infection, which were quite similar with findings reported in previous studies³⁰,³². For the radiographic outcomes, the pooled percentages of radiolucency and loosening or subsidence were a bit higher than outcomes using similar measures outlined in a previous review²⁵; this review had predominantly collected studies from metallic
implants with the closed length of follow-up as those in the present study. However, it may be difficult to conclude anything meaningful in terms of the differences of radiographic outcomes between ceramic and non-ceramic studies because radiolucency and prosthesis loosening or subsidence were determined by different methods using disparate definitions of what constituted component loosening or subsidence. We found several limitations in the literature reviewed. (1) The heterogeneity in study design and outcome measurement did not allow for direct conclusions to be made from many of the ceramic TAA data. (2) Only one comparative study reported the pooled mean sur-

Table 5  Main functional outcomes of the ceramic TAA

<table>
<thead>
<tr>
<th>Study</th>
<th>Prosthesis</th>
<th>Score</th>
<th>Preoperative [mean (range) or ± standard deviation]</th>
<th>Postoperative [mean (range) or ± standard deviation]</th>
<th>Follow-up (years) [mean (range) or ± standard deviation]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nishikawa²⁷</td>
<td>TNK</td>
<td>AOFAS</td>
<td>NR</td>
<td>66.3 (32–90)</td>
<td>6 (1.3–14.1)</td>
</tr>
<tr>
<td>Takakura¹</td>
<td>TNK</td>
<td>Author’s score</td>
<td>OA: 48.7 ± 10.5 RA: 44.3 ± 9.7</td>
<td>OA: 86.1 ± 11.3 RA: 74.2 ± 12.4</td>
<td>5.2 (2–11.2) (all ankles)</td>
</tr>
<tr>
<td>Shinomiya²⁸</td>
<td>TNK/ND AA</td>
<td>JOA</td>
<td>34.4 ± 8.1</td>
<td>71.6 ± 7.8</td>
<td>8.2 (5–12)</td>
</tr>
<tr>
<td>Nagashima²²</td>
<td>TNK</td>
<td>Evanski and Waugh</td>
<td>52.0 ± 8.4</td>
<td>74.1 ± 8.2</td>
<td>2.8 (1.5–4.2)</td>
</tr>
</tbody>
</table>

*One patient died before last follow-up, one patient had prostheses removal due to a deep infection before the last follow-up.

NR, not reported; AOFAS, American Orthopaedic Foot and Ankle Society Ankle–Hindfoot Scale; JOA, Japanese Orthopaedic Association score; Evanski and Waugh, Evanski and Waugh score; AA, ankle arthrodesis.

indicate the clinical utility of ceramic TAA in patients with end-stage arthritis.

Conclusion

The present study showed that currently used ceramic TAA prostheses achieved satisfactory results in terms of failure rate (6.3%) across the medium-term follow-up of 5.6 years. This finding includes the results of only one comparative study that favoured the use of ceramic TAA. Pooled failure rate was lower than that previously reported in studies that mainly comprised non-ceramic TAs with a closed length of mean follow-up. Comparative studies between ceramic TAA and ankle arthrodesis are lacking, and further studies are necessary to determine the medium- to long-term advantages of ceramic TAA compared with ankle arthrodesis in patients with end-stage arthritis.

Acknowledgement

The authors would like to propose special thanks to Professor Masato Takao M.D., D.M.Sc.; Assistant Professor Tanawat Vaseenon, M.D.; Dr. Shingo Masuda (KYOERA Medical Corporation, Osaka, Japan) and Mr. Kittipat Chirungsarpsook (Phoenix Surgical Equipment Co., Ltd., representative of Newdeal Company in Thailand) who provided figures and a part of the data for this report.
Abbreviations list
CI, confidence interval; CMS, Coleman methodology score; JOA, Japanese Orthopaedic Association score; TAA, total ankle arthroplasty

References