Total ankle arthroplasty and coronal plane deformities

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Summary
Introduction: There is no consensus regarding total ankle replacement (TAR) in case of arthritis associated with coronal plane deformities. The purpose of this study was to determine, based on clinical and radiographic outcomes, the technical requirements and additional procedures that should be performed in such indications.
Hypothesis: Coronal deformities greater than 10° are not a contraindication to TAR if a stable and aligned ankle can be obtained after surgery.
Materials and methods: Of a total of 131 TAR, 21 were performed on coronal plane deformities greater than 10°. Only cases of osteoarthritis secondary to fracture or chronic instability were included. Inflammatory ankles were excluded. Twenty-one patients (15 men and 6 women), mean age 57 years old (±12) were reviewed retrospectively with a mean follow-up of 38 months (±26). Patients were divided into four groups, categorizing first, congruent and incongruent ankles, and second varus and valgus deformities. Associated procedures were performed from proximal to distal, correcting perarticular malunions first, ligament imbalances, associated deformities of the foot and equinus deformity. Revision arthrodesis and implant changes due to loosening or progressive instability were considered to be failures.
Results: Surgery resulted in improved functional outcome and durable correction of the deformity, passing from 16.5° (±4.9) to 2.5° (±3.9) for varus, and from 16.7° (±5.6) to 1.4° (±2.1) for valgus. Six varus ankles required revision surgery for further corrections. Three incongruent ankles failed.
Discussion: Correction of osteoarticular deformities and ligament imbalance in case of frontal deformities requires a significant number of associated procedures. Residual defects are detrimental to implant longevity and warrant further correction. Short-term results are satisfactory even for severe deformities, but require longer-term monitoring.
Level of evidence: Level IV. Retrospective study.
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Introduction

Treatment of arthritis of the ankle associated with coronal plane deformities by total ankle replacement (TAR) remains controversial [1–4]. For some authors, satisfactory short-term results are possible, [5–11] however, numerous authors prefer arthrodesis [2–4,12,13]. There are numerous causes for these deformities: bone malunion, ligament imbalance or associated deformities of the foot. Obtaining a stable, balanced ankle on an aligned foot is the guarantee of success. Although there are numerous indications of additional procedures to be associated with TAR in these cases, they have not been well defined. [5,6,14].

The aim of this retrospective study was to define the clinical and radiographic results of a series of TAR implanted for coronal deformities greater than 10°, and identify the problems of each type of deformity.

Materials and methods

Inclusion criteria

Only ankles presenting with preoperative post-traumatic arthritis secondary to fracture or instability, associated with a coronal plane deformity of the tibiotalar axis of more than 10° were included in the study (Fig. 1). Secondary deformities due to inflammatory diseases were excluded. A total of 21/131 replacements were included (16 AES® Biomet®, 4 Salto® Tornier®, 1 New-Jersey® DePuy®) (Table 1). TAR was performed between February 1993 and April 2009 in 21 patients (15 men and 6 women), mean age 57 years old (± 12 years) by the same surgeon (GA). Mean follow-up was 38 months (± 26 months) with a minimum follow-up of 12 months. None of the patients were lost to follow-up. One patient died of a disease that was not related to TAR.

In order to differentiate between the role of osteoarticular anomalies and ligament imbalance in the deformity, the distinction was made between congruent and incongruent ankles, with incongruence defined as a gape in the talocrural joint space (talar tilt) of more than 10° [1,5] on weight-bearing X-rays. Most incongruent ankles were secondary to instability, with ligament imbalance causing the gape in the joint space, but not affecting the tibial plafond. On the other hand, congruent ankles were secondary to periarticular fracture malunion, causing an oblique joint space with no significant talocrural gaping. Four groups were then defined depending on the type of deformity: valgus or varus congruent ankles, and valgus or varus incongruent ankles. Out of 21 ankles, nine were congruent, five associated with a varus deformity and four with a valgus deformity. Ten of the 12 incongruent ankles had a varus deformity and two a valgus deformity.

Surgical technique

An anterior approach was used for all surgical procedures. Bone cuts were performed according to the specific characteristics of each type of implant using appropriate material. There were numerous different associated procedures (Table 1) to obtain a stable, balanced ankle on an aligned foot [15,16].

Generally, extraarticular deformities resulting in an oblique joint space were corrected by supramalleolar osteotomies associated with placement of a tibial implant perpendicular to the diaphyseal axis. Articular deformities were corrected to obtain a balanced, rectangular talocrural space with a horizontal joint space. For this, malunions of the malleolus were corrected with malleolar

Figure 1 Radiographic assessment. On the left, measurement of the tibiotalar axis. In the center, measurement of ankle joint incongruence (talar tilt); to the right illustration of edge-loading (failure in an incongruent varus ankle with the development of bone cysts).
Table 1  Summary according to joint congruence and type of deformity.

<table>
<thead>
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<th>Congruent ankles</th>
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<tr>
<td></td>
<td>Varus (n = 5)</td>
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<td></td>
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<td></td>
<td>1 fracture</td>
<td>1 instability</td>
</tr>
<tr>
<td><strong>Ratio M/W</strong></td>
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<td>2/2</td>
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<tr>
<td></td>
<td>8/2</td>
<td>2/0</td>
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<tr>
<td><strong>Mean age</strong></td>
<td>49 years old (±7)</td>
<td>55 years old (±10)</td>
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<td></td>
<td>59 years old (±13)</td>
<td>63 years old (±11)</td>
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<td><strong>Mean deformity</strong></td>
<td>15.7° (±5°)</td>
<td>14.7° (±2.5°)</td>
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<td>16.3° (±5°)</td>
<td>19° (±6°)</td>
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<td><strong>Mean tilt</strong></td>
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<td>13.3° (±2.7°)</td>
<td>17.5° (±5°)</td>
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<td><strong>Mean follow-up</strong></td>
<td>24.4 months</td>
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<td>1 LCL</td>
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<td><strong>Interventions</strong></td>
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<tr>
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<td><strong>Foot correction</strong></td>
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<td>osteotomy</td>
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<td></td>
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<td></td>
<td>1 loosening</td>
<td>valgus dislocation</td>
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a Emslie-Vidal ligamentoplasty procedure.
b Calcaneal osteotomy with lateral translation.
c Dorsiflexion osteotomy of the first metatarsal.

lowering or shortening osteotomies (Figs. 2 – 4). Joint incongruence due to laxity was treated by ligamentoplasties [17] (Figs. 4b, 5b). In case of previous unsuccessful ligamentoplasties, the ligament was tightened by malleolar shortening osteotomy. In cases of varus pes cavus foot deformities, calcaneal osteotomies with lateral translation were performed with, if necessary, osteotomies to raise the first metatarsal (M1). Significant irreducible deformities of the triple joint
complex or associated with posterior tibial or fibular musculotendinous failure were treated with triple arthrodeses. Finally, sural-Achilles-plantar retractions causing residual equinus at the end of surgery were treated by lengthening of the gastrocnemius bundle or the Achilles tendon according to the Banks and Green technique.

All patients in the group of congruent varus ankles \( (n = 5) \), presented with fracture sequellae. Fourteen procedures were associated with implant placement or a mean 2.8 per TAR \( (\pm 1.6) \). One preoperative supramalleolar osteotomy was performed. Eighty percent of patients \( (4/5) \) required corrective malleolar osteotomies (2 medial malleolar osteotomies for lowering, and three lateral malleolar osteotomies for shortening) associated with lengthening of the Achilles tendon (Fig. 2). No additional procedure was necessary in one case as the osteotomy cuts resulted in a balanced ankle with no associated hindfoot deformities. Early revision surgery was performed in two patients \( (40\%) \) including a calcaneal osteotomy for valgisation and dorsiflexion osteotomy of the first metatarsal (M1).

In the group of congruent valgus ankles \( (n = 4) \), deformities were all secondary to fracture. Correction was obtained in two cases with a lateral malleolar lowering osteotomy (Fig. 3) associated with lengthening of the Achilles tendon and in one case by simple treatment of equinus. One patient did not require any associated procedures. None of the patients required revision surgery.

In the group of 10 incongruent varus ankles, nine were secondary to instability and one to fracture. Twenty-seven procedures were associated with arthroplasty or a mean 2.7 procedures per TAR \( (\pm 2.1) \). In 90% of the cases lateral ligamentoplasty \( (n = 5) \) or ligament tightening by lateral malleolar shortening osteotomy was performed \( (n = 3) \) to correct ligament imbalance (Fig. 4). One medial malleolar lowering osteotomy was also performed. Five cases \( (50\%) \) also required realignment of the hindfoot with three
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Figure 3  a. Osteoarticular procedures in congruent valgus deformities: lateral malleolar lowering osteotomy. b. Correction of a congruent valgus deformity by lateral malleolar lowering osteotomy.

calcaneal osteotomies for valgisation and four dorsiflexion osteotomies of M1. Early revision surgery was necessary in four patients (40%) to correct residual laxity or malalignment of the hindfoot with three lateral malleolar shortening osteotomies, one release of the deltoid ligament, two repositioning of the implant, one arthrolysis and one calcaneal valgisation osteotomy.

Only one of the two cases of incongruent valgus ankles required associated procedures with stabilization of the triple joint complex by arthrodesis and medial ligamentoplasty using the plantaris muscle (Fig. 5b).

Evaluation of results

The overall evaluation was based on preoperative and final postoperative AOFAS scores. Radiographic evaluation was based on weight-bearing AP (mortise) and lateral view X-rays of the ankle as well as Meary-type views [1,18]. Several parameters were evaluated (Fig. 1):

- the tibiotalar axis which defined overall ankle alignment, by measuring the angle formed by the anatomical tibial axis and the perpendicular line to the tangent of the talar dome [1,5];
- talocrural joint incongruence or talar tilt, by measuring the angle formed by the tangent to the distal tibial joint space and the talar dome;
- loss of parallelism of the tibial and talar implant joint surfaces, causing asymmetric mechanical overloading, or edge-loading [1,2].

Final values were the mean of two measurements obtained 1 month apart by an examiner who was not the primary surgeon.

Criteria for failure

Late revisions to replace implants or arthrodeses due to incapacitating pain, loosening or progressive instability were considered failures. Early surgical revisions due to
residual instability of the ankle or insufficient correction of the foot were not considered failures, but were considered additional secondary procedures.

Statistical methods
The clinical and radiographic evaluation was analyzed in relation to congruence and type of deformity (varus or valgus). The AOFAS scores and the different radiographic parameters were compared for each of these groups preoperatively and at the final postoperative follow-up using the Wilcoxon test ($p < 0.05$). Survival was calculated by the Kaplan-Meier method. Patients who died were included in the series in the calculation of survival, based on the last date of contact.

Results

Details of the series are presented in Table 1.

Congruent varus ankles

For congruent varus ankles ($n = 5$), surgery resulted in significant improvement from $15.7^\circ (\pm 5^\circ)$ to $2.6^\circ (\pm 2.6^\circ)$ in mean coronal plane deformity with no significant change at the final follow-up (Table 2). The AOFAS score improved from $31 (\pm 8)$ to $69 (\pm 9)$. One case of early infection of the surgical site was identified which resolved after lavage. There were no failures.

Congruent valgus ankles

For congruent valgus ankles ($n = 4$), surgery resulted in significant improvement from $14.7^\circ (\pm 2.5^\circ)$ to $0^\circ (\pm 2.5^\circ)$ in mean coronal plane deformity with no significant change at the final follow-up (Table 2). The AOFAS score improved from $51 (\pm 16)$ to $89 (\pm 7)$. There were no complications or failures.

Incongruent varus ankles

For incongruent varus ankles ($n = 10$), surgery resulted in improvement from $16.3^\circ (\pm 4.5^\circ)$ to $1.5^\circ (\pm 1^\circ)$ in mean coronal-plane deformities and mean talar tilt from $13.3^\circ (\pm 2.7^\circ)$ to $1.2^\circ (\pm 1.2^\circ)$ (Table 2). The mean functional score improved, increasing from $36 (\pm 16)$ to $74 (\pm 16)$. Complications included two medial malleolar fractures discovered perioperatively. Union was obtained without
Total ankle arthroplasty and coronal plane deformities

Figure 5  

Table 2  Radiographic criteria.

<table>
<thead>
<tr>
<th></th>
<th>Preoperative</th>
<th>Post-operative</th>
<th>p</th>
<th>Final follow-up</th>
<th>p'</th>
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<tr>
<td>Tibiotalar axis</td>
<td>15.7° ± 5° (11° to 25°)</td>
<td>2.6° ± 2.6° (−2° to 6°)</td>
<td>0.04</td>
<td>2.4° ± 2.9° (−2 to 5°)</td>
<td>0.68</td>
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<td>Talar tilt</td>
<td>2.2° ± 2° (0° to 7°)</td>
<td>0.6° ± 0.8° (0° to 2°)</td>
<td>0.36</td>
<td>1.2° ± 1.1° (0 to 3°)</td>
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<tr>
<td>Tibiotalar axis</td>
<td>14.7° ± 2.5° (12° to 18°)</td>
<td>−0.2° ± 2.5° (−4° to 3°)</td>
<td>0.06</td>
<td>1.5° ± 2.3° (−2° to 4°)</td>
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<td>1.5° ± 1.6° (0° to 4°)</td>
<td>0.10</td>
<td>1.5° ± 1.6° (0 to 4°)</td>
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<td><strong>Incongruent varus (n = 10)</strong></td>
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<tr>
<td>Tibiotalar axis</td>
<td>16.3° ± 4.5° (11° to 25°)</td>
<td>1.5° ± 1.0° (0° to 3°)</td>
<td>0.008</td>
<td>2.6 ± 4.2° (−2 to 13°)</td>
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<td>Talar tilt</td>
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<td>2° ± 4.2° (−1° to 5°)</td>
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<tr>
<td>Talar tilt</td>
<td>17.5° ± 5° (14° to 21°)</td>
<td>2° ± 2.8° (0° to 4°)</td>
<td>0.18</td>
<td>0° a</td>
<td>0° a</td>
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</table>

p: Wilcoxon test comparing pre- and postoperative criteria; p’: Wilcoxon test comparing post-operative criteria and at final follow-up. 

1 patient died.
sequella using pins. Pseudarthrosis developed on a lateral malleolar shortening osteotomy because of recurrent edge-loading resulting in TAR failure. The same patient developed progressive tibial bone cysts (Fig. 1). A second non-progressive tibial cyst was identified in another patient. A second failure was observed due to implant loosening on defective correction of the hindfoot.

**Incongruent valgus ankles**

For incongruent valgus ankles \( (n=2) \), surgery resulted in correction of the mean tibiotalar axis from 19° \((\pm 5.5^\circ)\) to 2° \((\pm 4.2^\circ)\) and of mean talar tilt from 17.5° \((\pm 5^\circ)\) to 2° \((\pm 2.8^\circ)\) (Table 2). The first patient presented with arthritis on a 15° deformity secondary to overtightening of a lateral ankle ligamentoplasty. No additional procedures were necessary. Union was obtained in a perioperative fracture of the medial malleolus with no complications. The early outcome was favourable, with an improvement in the AOFAS score from 45 to 91, correction of the tibiotalar axis from 15° to 1° and of talar tilt from 14° to 0°, but the patient died the next year. A failure occurred in the second patient. This patient presented with a 23° deformity secondary to a bimalleolar equivalent fracture, with collateral medial ligament and posterior tibial tendon dysfunction (Fig. 5a). A triple arthrodesis and medial ligamentoplasty using the plantaris muscle (Fig. 5b) only resulted in partial correction of the deformity with persistent 5° valgus and 4° talar tilt. A fracture of the medial malleolus occurred at 36 months with recurrent dislocation and conversion to talocrural arthrodesis.

Nine (43%) out of the 21 ankles in the series underwent revision including six for additional correction (29%). Three failures (14%) occurred, if late revisions with implant replacement or arthrodeses are considered failures, resulting in 91% survival at 35 months and 57% at 5 years (Fig. 6a). If all revision surgeries are included, survival was 67% at 3 years and 43% at 5 years (Fig. 6b).

**Discussion**

The short-term results of ankle replacements for coronal plane deformities of more than 10° are encouraging. These deformities are not a contraindication for arthroplasty, as long as a stable, balanced ankle can be obtained on an aligned foot.

Nevertheless, there is no consensus on the indications for TAR in significant coronal-plane deformities, although this entity is not rare. According to the literature between 33 and 44% of arthritic ankles present with a coronal plane deformity of more than 10° \([1,2,5]\). Wood and Deakin \([3]\) identified deformities greater than 15° in 20% of cases.

Our study is interesting because it specifically analyzed the results of TARs performed in case of arthritis associated with a coronal plane deformity of more than 10°. The exclusion of inflammatory ankles and the inclusion of the idea of joint congruence associated with the dichotomy of varus and valgus, provided a more detailed analysis of the specific problems of each type of deformity. The main biases in this study are the small number of patients and the discontinuous, retrospective design of the study.

The difficulties of correction were due to the type of deformities. Incongruent varus ankles were the most difficult to treat. Associated procedures were necessary in all cases to correct ligament or hindfoot imbalances. Certain authors have also discussed transferring the peroneus longus onto the peroneus brevis for these incongruent varus ankles \([5,8]\). Congruent varus ankles also required numerous associated procedures including in 80% of corrective malleolar osteotomies and hindfoot corrections. In many cases, these congruent varus ankles could be corrected by the tibial cut associated with deltoid ligament release \([5,11,19,20]\). Like Doets and van der Plaat \([9]\), we preferred a medial malleolar lowering osteotomy. Congruent valgus ankles are the simplest entity to correct with few associated procedures. Valgus instabilities are more complicated to discuss because of the small number of cases. They are rare in traumatic cases, and are usually found in valgus pes planus. We found that the collapse of the medial arch and the posterior tibial tendon dysfunction were difficult to manage with anything but triple arthrodesis.

Nine ankles (43%) in our series underwent revision surgery, including six (29%) for additional correction. These early revisions included 40% of ankles presenting with a varus deformity, both congruent and incongruent. These procedures were performed in 2/3 cases (4/6) to correct edge-loading on residual varus due to a ligament

![Figure 6](image-url) a. Kaplan-Meier survival curve with arthrodeses and late implant replacements considered as failures. b. Kaplan-Meier survival curve with all revisions considered as failures.
imbalance and in 1/3 cases to correct residual congruent varus malalignment of the hindfoot. The three failures in
the series occurred in incongruent ankles (2 varus, 1 val-
gus) in whom the initial procedure did not provide optimal talar tilt. These observations support those by Henricson and
Agren [21] who report a rate of revision that is twice as high
in case of residual varus than in case of valgus in an aligned
ankle. These secondary procedures are fairly common. Spirit
and Assal [8], in a series of 306 Agility® replacements, iden-
tified 168 secondary procedures in 28% of patients including
40 to correct malalignment [9]. These early revisions did not
compromise prognosis of the implant.

Two tibial bone cysts were identified on AES® implants,
which did not cause implant failure. This has already been
described with AES®, [22,23] as well as with other implants
[19]. The pathophysiology of bone cysts is not well under-
stood, but is probably multifactorial, both biological and
biomechanical. Management of this entity is in the process
of being clarified [19].

Results for survival are not as good as in the literature
with estimated survival rates of between 67–89% at 5 year
and 62–95% at 10 years [4,8,19,24–31]. These previous
series did not specifically study coronal plane deformities
as in our study. On the contrary, authors who studied the
management of these ankles specifically evaluated the risk
of failure. Thus Wood and Deakin [3] reported edge-loading
in 18% (7/39) of patients in case of deformities of more than
15° with a rate of failure and revisions correlated to the
extent of the deformity. Haskell and Mann [1] also found
edge-loading in 23% (8/35) in case of deformities of more
than 10°. For Doets and Brand [12], implant survival in defor-
mities greater than 10° was less than 50% at 8 years, while
it was nearly 90% if the deformity was less than 10°.

Because of these poor results, TAR is contraindicated
in cases of coronal plane deformities of more than 15° [3,11],
or even 10° [1,12] and arthrodesis is considered the method
of choice in these difficult cases [32]. In most cases, the fail-
ures in this series were associated with ligament instability
and residual joint incongruence which caused edge-loading
[1–3,7] for which few additional procedures were per-
formed. For Haskell and Mann [1], although incongruent
ankles have a 10-fold higher risk of developing edge-loading,
coronal plane malalignment and joint incongruence are not
contraindications to TAR, as long as the necessary proce-
dures are performed on osteoarticular or ligament defects
to obtain a stable, aligned ankle. Doets and Van der Plaat [9]
obtained 13 good results in a series of 15 ankles with more
than 15° of coronal plane deformity without recurrence
more than 2 years after surgical correction. The results of
Kim and Choi [5] were similar and indicated that the clinical
survival of ankle replacements in ankles with more than 10°
of varus was comparable to implants on aligned ankles as
long as associated deformities were corrected at the same
time. Simultaneous correction of deformities should make it
possible to improve implant survival and extend the indica-
tions for these arthroplasties [5–11,33].

Conclusion

Analysis of our results and of the literature show
that improvement in clinical and radiological scores is
maintained whatever the group, in ankles which are prop-
erly corrected. Correction of ligament imbalance and the
position of implants are essential during surgery to avoid
the development of edge-loading which could compromise
implant survival. Correction of architectural deformities
of the foot is also essential [9]. Any instability or resid-
ual deformity must be managed and requires additional
early surgery to obtain perfect correction. Intermediate
term radiographic and clinical results of these implants for
these rare indications are encouraging in ankles that are
adequately corrected, however more detailed longer-term
follow-up is necessary.

Disclosure of interest

The authors declare that they have no conflicts of interest
concerning this article.

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