Modular Ankle Arthroplasty

M. Núñez-Samper
Trauma and Orthopedic Surgery Service, Virgen del Mar Clinic, Madrid. Spain.

Artroplastia modular de tobillo

La implantación de prótesis total de tobillo es hoy por hoy una indicación limitada a casos muy concretos, casos que dispongan de integridad osteoligamentaria suficiente para facilitar la estabilidad y movilidad del tobillo y no ser la prótesis la única responsable de la función articular. El conocimiento de los riesgos y la minuciosa planificación preoperatoria deben ser factores conocidos para lograr resultados satisfactorios. La mayoría de las actuales artroplastias totales de tobillo que se implantan han sido desarrolladas con tres componentes y diseñadas para ser colocadas con una mínima resección ósea, actuando fundamentalmente como prótesis de resuperficialización.

Estas condiciones las reúnen las prótesis con componente intermedio móvil, cuyas versiones no cementadas, y cementada, permiten valorar en el mismo acto quirúrgico la calidad del hueso. Su implantación se realiza por vía anterior y la instrumentación es sencilla. Sin embargo, es recomendable hacer antes de su colocación algún tipo de implantación experimental. Los resultados que hemos obtenido en una primera serie del modelo Ramses® nos hacen ser optimistas en cuanto se refiere al futuro. No obstante, pensamos que estos modelos todavía deben ser mejorados tanto en su implantación primaria como para la revisión de aquellos casos que fracasen.

Palabras clave: *tobillo, prótesis de tobillo, artroplastia total de tobillo.*

Total ankle replacement (TAR) is currently a procedure used in a limited number of concrete cases. These cases must have sufficient bone and ligament integrity to allow ankle stability and mobility so that joint function is not solely dependent on the prosthesis. To obtain satisfactory results careful preoperative planning and risk assessment are necessary. Most current TARs have 3 components and have been designed to be placed with a minimum amount of bone resection: their main function is to act as a resurfacing prosthesis.

These conditions are met by a prosthesis with a mobile intermediate component, which has cemented and non-cemented versions that allow for bone quality to be assessed during surgery. They are implanted using an anterior approach and instrumentation is simple. However, before performing this surgical procedure it is advisable to carry out some experimental implants.

The results we obtained in our first series using the Ramses® model gave us reason to be optimistic about the future of this procedure. However, we believe that this model should be improved, both for use in primary TAR and in revisions of failed TAR.

Key words: *ankle, ankle prosthesis, total ankle replacement (TAR), ankle arthroplasty.*

Placement of internal ankle prostheses has undergone marked development over the last years, mainly due to the new designs and materials available, which have increased the indication for this procedure, the main objective of which is, undoubtedly, the recovery of the tibio-fibular-talar joint thus avoiding arthrodesis. Procedures that failed initially now have favorable outcomes, and this has made it possible to increase investigation of designs and materials, resulting in an improvement of implantation techniques and final results. These advances will undoubtedly mean that within a few years ankle arthroplasty will be as widespread as prosthetic replacement of other joints, such as hip and knee[1].

Classically, severe degeneration of the tibiotarsal joint has been treated by arthrodesis, with excellent results as to joint stabilization and pain suppression, but poor results from the functional point of view. However, this procedure

Corresponding author:
M. Núñez-Samper
C/ Honduras 14.
28016 Madrid.
Email: m.nusamp@terra.es

Received: April 2006.
Accepted: April 2006.

also has certain complications, such as Infection, non-union, lack of fusion, and subtalar joint pain, all of which determine whether further surgery will be performed. In spite of the risks, many studies of procedures of ankle arthrodesis show good outcomes; this may, in some degree, have limited the development of ankle joint arthroplasties.

At the beginning of the '70s, and with the aim of providing an alternative to arthrodesis, Buchholz et al[2] and Lord and Marotte[3] designed and implemented the first ankle prosthesis. The first internal prostheses were cylindrical, mimicking the anatomy of the tibiotarsal joint and were placed by transmaleolar route. Buchholz demonstrated his faith in these prostheses by placing one in his own ankle. Unfortunately it had to be removed after a certain period of time. Lord and Marotte, using a more functional approach, in cases of severe ankle arthritis, removed the talus and placed a stem ending in a metallic ball in the distal part of the tibia. This ball fitted into a concave plastic device fixed to the calcaneus.

Years later different two-component models were developed (Mayo Clinic, FCLH, Smith, Kirkup, Wildham, etc.) [3-11], but they had high rates of poor results, and this line of research was dropped. As to shape, some were cylindrical, others, to better neutralize shearing and improve the mechanics of the subtalar joint, were round, due to the fact that a prosthesis was necessary because the ankle had usually become ankylosed. In Spain, this procedure did not become widespread due to the failures reported in foreign publications. A. Viladot placed a first series of Smith and Wildham (1975-1992) prostheses with not very satisfactory results; 30% of all cases ended up as arthrodesis[1].

Due to these outcomes it was decided that ankle arthroplasty required further technical advances. Subsequently, with the aim of improving mechanics and design, prostheses with an intermediate mobile component–a type of meniscus–were developed, to absorb the shearing forces affecting existent prostheses, since the first models had two constrained components that had to deal with all mechanical aggression, a fact that may have been the reason for their failure.

From 1995-2000, several series were published on the use of three-component non-constrained models; the outcomes were more satisfactory and the rates of revision/arthrodesis due to failure were in the longer term. Prostheses placement techniques had changed substantially, there was minimal bone resection and the prosthesis models had 3 components, with a mobile intermediate one, and 2 options: cemented and non-cemented. In some cases previous syndesmosis fusion was necessary[5,11-16].

GENERAL INDICATIONS

Currently indications are strict and limited. Ankle arthrodesis is still an alternative to be considered. Patients must be carefully chosen based on bone and ligament anatomical integrity, central and lateral stability and bone in good condition[10,11,17] . Indications are summarized in Table 1.

Table 1. Main indications for ankle prosthesis placement

Primary osteoarthritis
Posttraumatic osteoarthritis (secondary to tibial plafond bimalleolar or talar fractures)
Rheumatoid arthritis
Degenerative inflammatory osteoarthritis
Talar avascular necrosis (limited to less than 20-30% of the body of the talus)
Exceptional cases (such as tibio-talar ankylosis rescue)

Table 2. Basic anatomical requirements

Adequate bone quality and quantity
Structural integrity of the tibio-fibular mortise
A sufficient amount of passive stabilizing elements (lateral ligaments and syndesmosis)
Altered articular surface
Severely affected joint function
Slight ankle deviation (10° maximum varus or valgus)

BIOMECHANICAL AND ANATOMICAL REQUIREMENTS

Although current prostheses preserve a considerable part of the tibial plafond, malleoli and talus, they also require an adequate ligament size and quality so that passive structures, as well as the prosthesis, contribute to stabilization. Basic requirements are summarized in Table 2.

CONTRAINDICATIONS

Relative contraindications are injuries with loss of joint surface due to an open fracture or septic arthritis in the recent past. Also cases that have undergone long-term treatment with steroids or suffered talar avascular necrosis that has affected more than 30-40% of the talar surface, or marked osteoporosis, especially insulin-dependent diabetics.

Absolute contraindications: all patients with Charcot-Marie-Tooth type neuropathic arthropathy, severe sequelae of pyogenic, tubercular or specific arthritis with persistent active or closed fistulae, severe conditions of the skin, soft tissues or fracture mal-unions with more than 15º varus or valgus. It must be kept in mind that these ankle prostheses do not correct large angulations, since their main function

is to achieve a new ankle joint surface. Acquired immunodeficiency of any degree is also an absolute contraindication.

ARTHROPLASTY MODELS

Currently there are different models with published series documenting good results in the medium and long term. There are some prostheses such as the 2 component Agility®, placed exclusively under authorization by the USA Food and Drug Administration (FDA), with very homogeneous results, as it is only used by a certain number of surgeons[15]. In Europe prostheses with an intermediate mobile component are more popular (Ramses®, Hintegra®, Star®), also with a large number of series, with comparable favorable results in different publications[8,11,18].

The Hintegra®, Star® and Buechel-Pappas® models (with and without hydroxyapatite) implanted without cement are preferred by some authors such as Hintermann[14], Myerson and Mroczeck[19], Couglin[6] and Buechel et al[5], who have shown very favorable outcomes in their series. Hintermann et al[20] obtained, after 18.9 months' follow-up, in a series of 122 Hintegra®, prostheses placed in 116 patients with posttraumatic (75%), primary (13%) and degenerative (12%) osteoarthritis, satisfactory results in 84% of cases and excellent clinical results in 82% of cases of which 68% were patients completely pain-free and with a mean joint mobility of 15 to 55°.

The "Talus" group working with Mendolia[17] also published a series of excellent results using the Ramses® prosthesis, cemented and not cemented according to bone quality (an undoubtedly reasonable indication). In a first series of 38 cases with a minimum of 2 years' follow-up, 73% of satisfactory outcomes were seen in pain-free patients with excellent joint stability during normal work and daily living activities.

However, 8 patients continued to suffer pain and had a dorsal flexion of 10°. In 5 cases the patients suffered permanent pain, therefore their prostheses had to be removed and they underwent ankle arthrodesis. In this article we are going to review the Ramses® model, with which we have a certain amount of experience.

RAMSES® PROSTHESIS DESIGN AND CHARACTERISTICS

This type of prosthesis must be considered a "resurfacing prosthesis", since for its placement only a slight amount of bone is resected, passive ligament structures are preserved (lateral ligaments and syndesmosis), and only the affected joint surfaces are eliminated. This prosthesis has three components, described below.

Tibial Component

Due to its design the lateral and medial sides adapt in such a way that there are no lateral displacements and there is transverse stabilization without alterations of the mechanics of the 2 malleoli. The upper anchorages ensure appropriate stability[17,21]. The anterior trimming does not involve a great part of the anterior cortex, making it easier to fit the prosthesis in the box-like space in such a way as to prevent bone stress on the anterior tibial edge during dorsiflexion. It has a furrow so that the mobile component can move backwards and forwards 1).

Talar Component

The straight section of the talar bone allows implant of a component similar to the talar dome, with a coronal plane curvature that allows for a certain varus-valgus, without loss of joint congruence due to the intermediate component. The anteroposterior curvature allows dorsiflexion of 40 to 60°.

Mobile Intermediate Component or Plate

With a flat tibial surface and doubly concave lower surface, this component acts as a joint with the talus, sliding along the furrows 5 millimeters backwards and forwards, its anteroposterior curvature allows rotation of the anatomical dorsiflexion rotation center so that dorsiflexion increases in 10°. Other prostheses that do not possess this mobile component do not possess this capability.

IMPLANTATION TECHNIQUE

Instruments

For surgical implants, general instruments for use with bones are necessary, two curved Hohmann retractors or similar instruments, 1 and 2 cm gouges or osteotomes, a vibrating cutting saw of sufficient depth (9 × 2 cm) is indispensable, as also an oscillating saw of 1 cm in width. The

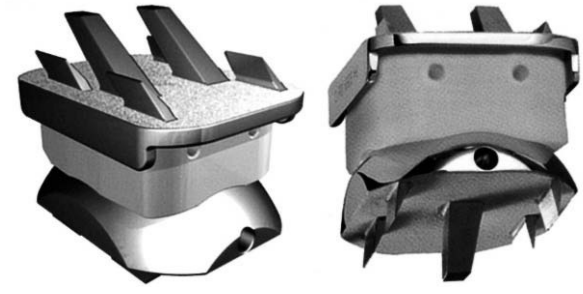


Figure 1. *Ramses II 3-component modular total ankle replacement prosthesis. The tibial component has a furrow to allow displacement of the intermediate component.*

implant kit contains the necessary instruments and three test components. An image enhancer is useful so as to check the surgical steps intraoperatively.

Prosthesis

There are 3 sizes of prostheses: small, medium and large, and their composition is chrome-cobalt. The intermediate mobile component is made of high-density polyethylene and there are 4 different thicknesses from 10 to 16 mm for the small size, from 11 to 17 mm for the medium size and from 12 to 18 mm for the large size. The non-cemented version has a porous coating with 6 oblique anchorages for the tibial component and 4 for the talar component. The cemented version only has two central anchorages.

Surgical Technique

The patient is placed in a supine position. This operation must be performed with controlled ischemia, and access of the image intensifier both laterally and anteroposteriorly. A roller placed beneath the ankle makes it easier to perform surgical maneuvers.

Approach

An initial 10-12 cm anterior longitudinal incision midway between the malleoli is made. The musculocutaneous nerve is moved aside and a longitudinal incision is made in the subcutaneous tissue and the anterior aponeurosis between the anterior tibial tendon and the extensor digitorum communis. The foot nerves and vessels are protected and moved out of the way. The joint capsule must be opened and completely removed until the anterior tibial facet and the dome and neck of the talus are exposed to allow resection of all osteophytes and a full view of the joint.

First tibial section

The tibial section guide is fixed with 2 nails to the bone surface at a distance of 10 mm from the joint line; its height and thickness are different according to the size of the prosthesis to be used and are proportional to the thickness of the fixed components and the mobile component. The nails are fixed in two holes marked with an "O", and the guide must be correctly centered. This surgical step is the key to obtain an exact placement. There are 3 section guides: small, medium and large, for the corresponding tibial implants (Figure 2).

The section guide must be placed perpendicular to the tibial axis. There are another 2 holes that are marked "+4" if the size has to be increased due to the need for a larger box-like space. An image enhancer must be used to confirm the correct placement of the guide. To carry out the box-like section of the tibia a vibratory saw is used both in the upper and lateral areas, until a half section is achieved.

Talar section

Subsequently the talar section guide is put in place with the same nails anchored in the tibia that are placed in the holes marked with "O". The foot is now placed at a 90º angle so that the talar neck is in contact with the talar section guide and two nails are placed in the talar body, parallel to those in the tibia, but through the inferior and lateral box-like structure of the section guide. The image enhancer must be used to check this surgical step. Each talar section guide must be of the same size as the corresponding tibial section guide. Subsequently, both section guides are removed and the image enhancer is used to determine their correct placement; the talar section is now performed, the two lower nails act as guiding "rails". The sectioned talar bone fragment is removed (Fig. 3) and the section is checked to determine if it was correct.

Second tibial section

The tibial section is completed and the bone fragment removed, the box-like space is trimmed with a specific

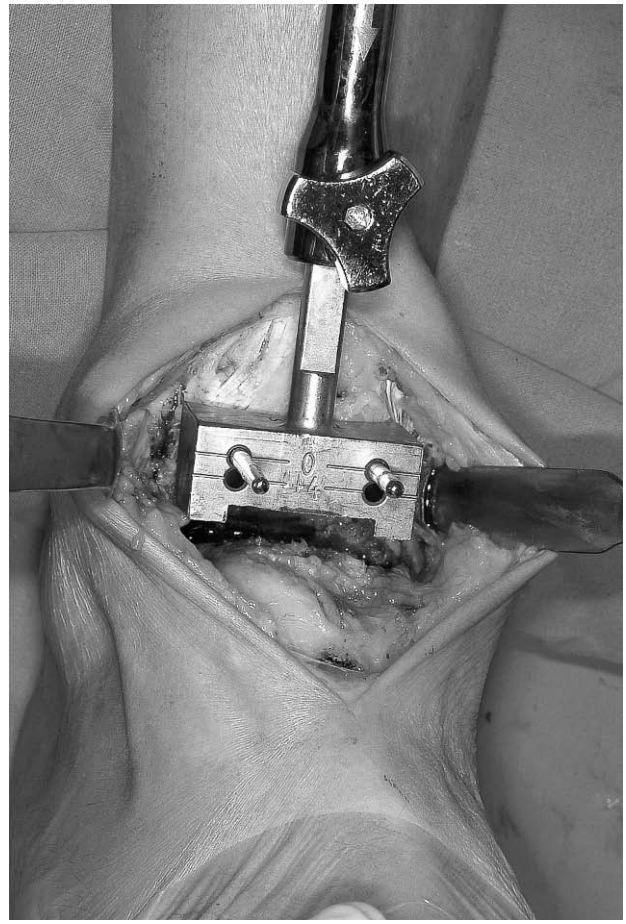


Figure 2. *Tibial section carried out with the guide so as to obtain the correct box-like space for the placement of the corresponding component.*

gouge that adapts to the tibial section guide. During this surgical step it is possible to injure the Achilles tendon or the flexor hallucis longus tendon. Once the bone fragment is removed and the box-like space has been created, a gouge is used to resect the malleolus bone surfaces next to the talus. Complete mobility of the prosthesis will depend on leaving 3 to 4 mm of free space between the talus and the malleoli on both sides.

Checking the space or bed for the prosthesis and preparing the anchorages

There are 3 spacers, one for each prostheses size, these ensure the minimum space necessary for a prosthesis placement. At the same time, this will allow, using special bits, the perforation of the talus and the tibia through one upper hole and two lower holes, to fix the prosthesis anchorages. The spacer must fit the box-like space perfectly when the foot is at a 90º angle. Otherwise resection is not sufficient and on forcing the prosthesis into the existing space the medial or lateral malleoli could suffer avulsion fractures. If further resection is necessary it must be decided whether it should be in the tibia or the talar bones. It is rarely necessary to perform further resection of both bones. For this purpose the tibial and talar section guides have holes marked "+4", the guide holes must be placed on the tibial nails, when performing further bone resection to allow adjustment of the spacer.

Test Components

Each model also has a test prosthesis that must be placed in position before the permanent one is used. This test component will make it possible to check the height of the intermediate mobile component, its sliding movement and the positions of the other two components. A minimum dorsal flexion of 10º must be achieved. If this is not achieved, it is necessary to lengthen the Achilles tendon.

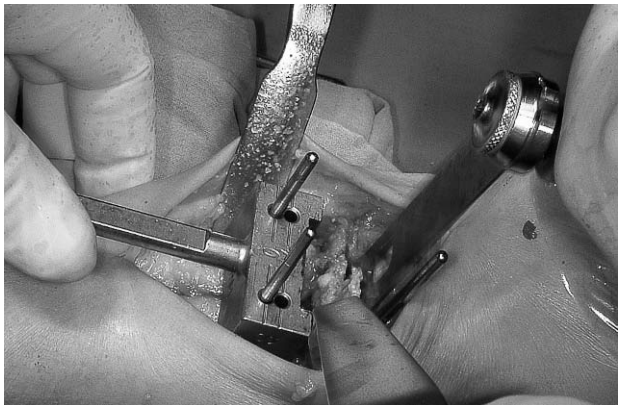


Figure 3. *Talar section. The saw slides along the two guiding nails placed in the body of the talus. The section must be flat to appropriately adapt to the surface of the talar component.*

Final Placement of the Prosthesis

If it is a cemented prosthesis, the cement is prepared and the components are implanted. If it is not cemented, the prosthesis is placed using the specific impactors designed for this procedure. First the tibial component is inserted, it must fit exactly and adapt to the tibial surface. Then the talar component is inserted, using progressive hammering with the impactor until it is exactly in place. Finally the chosen intermediate mobile component is put in place (Figure 4). Normal sliding movement along the furrows of the tibial component and joint mobility must be checked (Figure 5).

Closing the surgical wound

Suture is performed, with the usual techniques, and ischemia is removed before closing the skin incision. A Redon type aspiration drainage is left in place.

Postoperative Period

The stitches are removed 10 to 12 days postoperatively, and if the Achilles tendon was lengthened an orthopedic

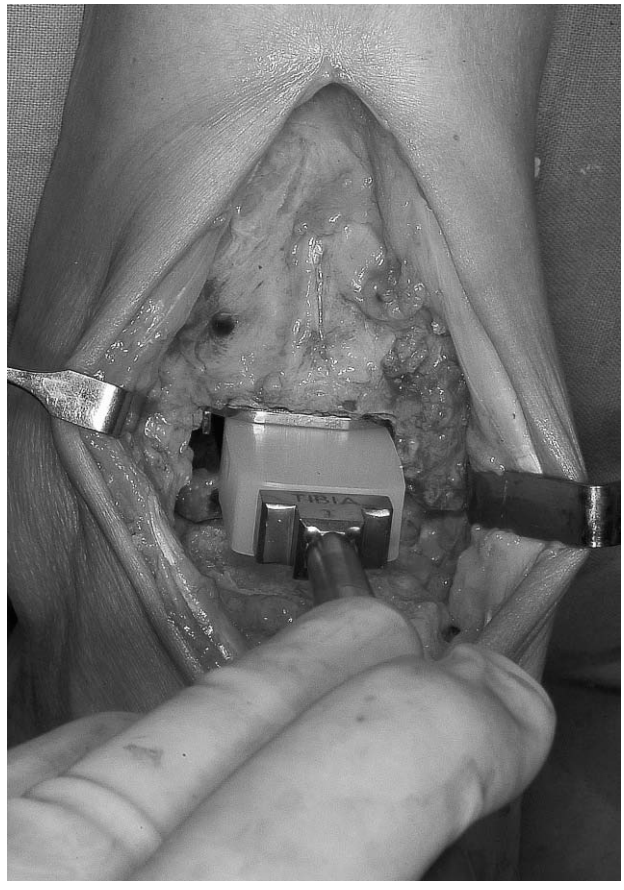
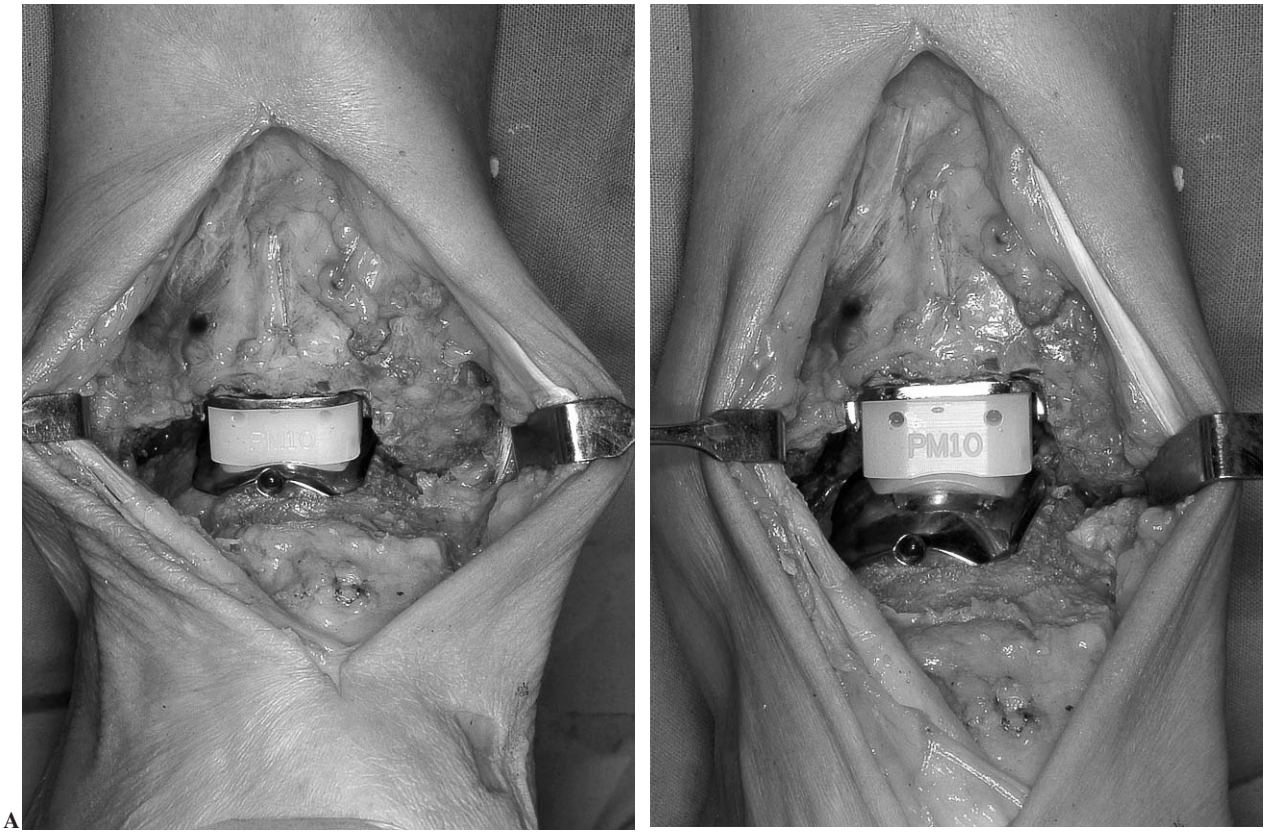


Figure 4. *Introduction of the mobile intermediate component. The tibial and talar components have already been implanted.*



A B

Figure 5. *Total prosthesis in place. (A) Dorsal flexion. (B) Plantar flexion. It is possible to see the sliding movement of the intermediate component.*

spica cast must be used for 6 weeks. If the Achilles tendon was not lengthened, specifically directed rehabilitation can be started 2 weeks postoperatively. Rehabilitation will be progressive from the 2nd to the 4th week, and will become total from the 6th week on; even if the patient uses some sort of cane, especially if the Achilles tendon was lengthened (Figure 6 and 7).

FAILURES AND COMPLICATIONS

Large series[14,15,17,20,22] show unfavorable results that must be kept in mind so as to offer patients therapeutic alternatives if these are possible. We must not forget that currently there are no standardized revision prosthesis to replace first time implants. On the other hand, a large loss of bone reserve, if a primary implant fails, makes it difficult to solve the problem with another implant, and, therefore, fusion is indicated[19,23] using a bone bank graft and stabilizing by means of osteosynthesis, with an AO plate or a retrograde pin.

However, the percentage of failures according to the different series analyzed is from 5 to 8%. The main ones can be seen in Table 3. These complications, that could be considered "minor" are resolved changing the corresponding component or both components or performing an arthrolysis and capsulectomy or lengthening the Achilles tendon if dorsal flexion is limited in such a way that normal walking is impossible.

CONCLUSIONS

The development of modular ankle prosthesis over the last few years has achieved a high level of quality both in design and material, this has made it possible to carry out implants with greater confidence and the knowledge that the percentage of successes will outweigh that of failures. The technique is not complex, although it requires a degree of knowledge and experience with ankle and foot surgery, as also previous experience with arthrodesis and familiarity with joint prosthesis of this type.

Surgery is practically performed by one person alone, therefore assistance is not as relevant as in the case of knee or hip replacement. All surgical steps must be exact and programmed sequentially, it is not possible to improvise, and it is necessary to consider there may be a fracture of the tibial plafond or the medial malleolus when

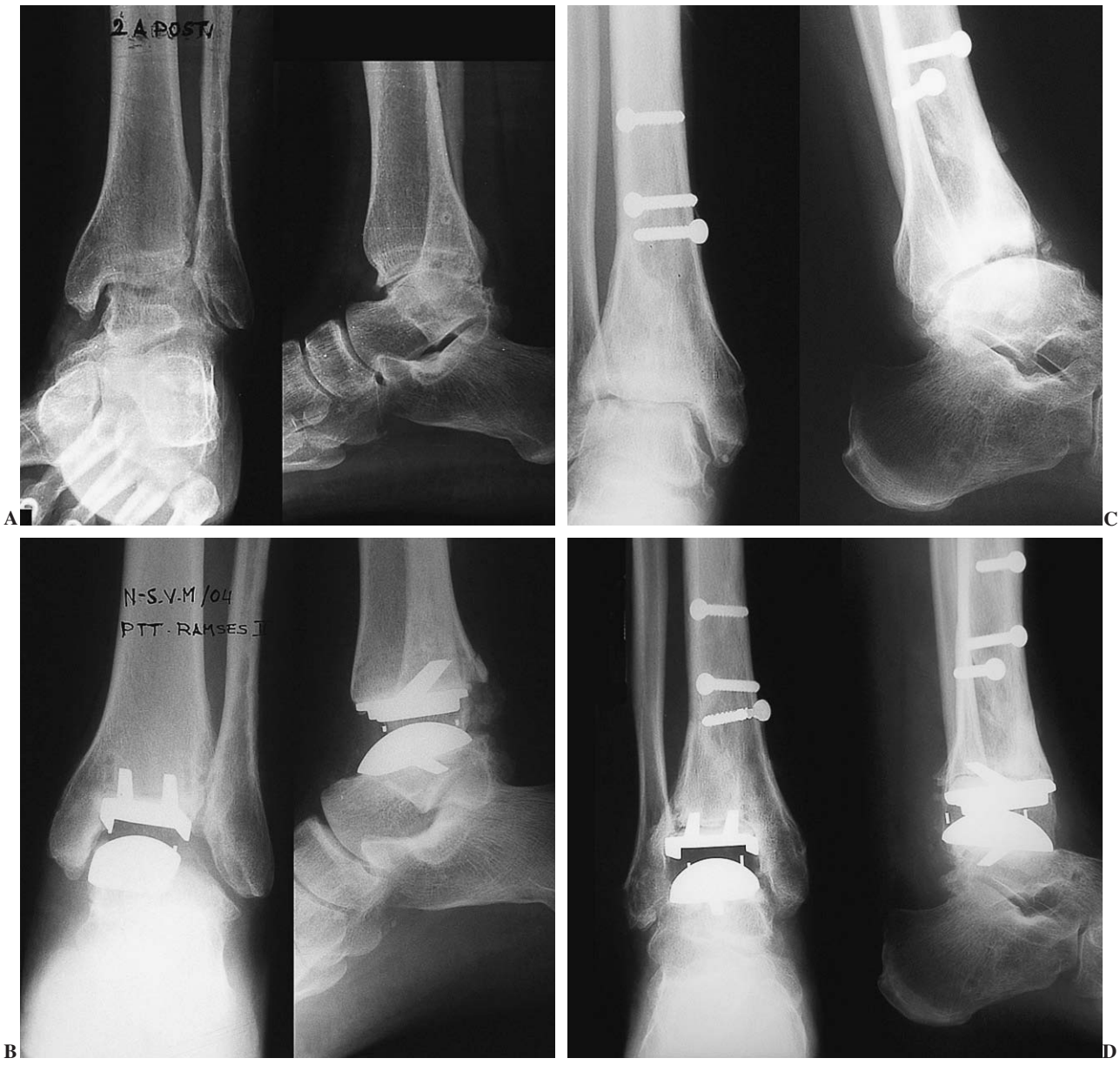


Figure 6. *(Left) Patient with primary ankle osteoarthritis. (A) AP and lateral X-ray. (B) AP and lateral check X-ray of implants. (Right) Sequelae of a fracture of the tibial plafond. (C) Preoperative image. (D) check X-ray of implant.*

Table 3. Reasons for ankle prosthesis failures

Anterior or lateral dislocations
Movement of the tibial component
Movement of the talar component
Submalleolar blocks
Pain of unknown cause
Limitation of dorsal flexion

creating the box-like space in the tibia. Indications for this procedure are limited and the patient must be provided with all the necessary information on the procedure.

We started implanting the Ramses® model prosthesis because it is a simpler procedure. Up to the moment we have performed about a dozen implants, mostly in ankle fracture sequelae and rheumatoid arthritis, cases in which we consider this procedure is absolutely indicated, especially in bilateral cases.

In this first series, the results are very favorable. Patients have retained ankle movement of 40-50º, and pain has decreased in a high percentage of cases, almost 80%.

We have recently operated on an exceptional case, which undoubtedly will open up the way to increasing the indications for this procedure. A rescue of an ankle ankylo-

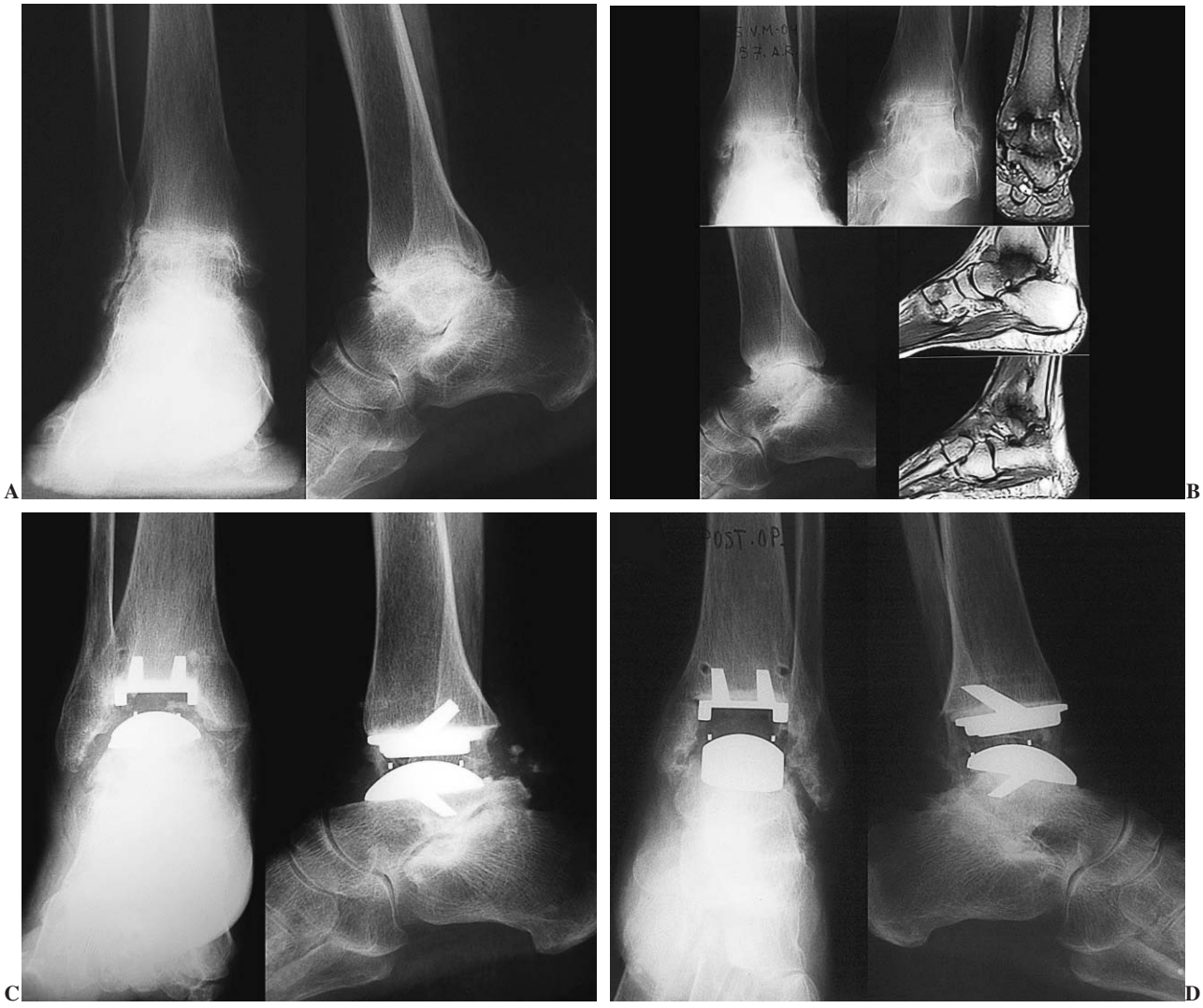


Figure 7. *Patient with rheumatoid arthritis. Bilateral lesion. AP and lateral images (A) and (B). AP and lateral check X-ray of implants. Right ankle (C) and left ankle (D).*

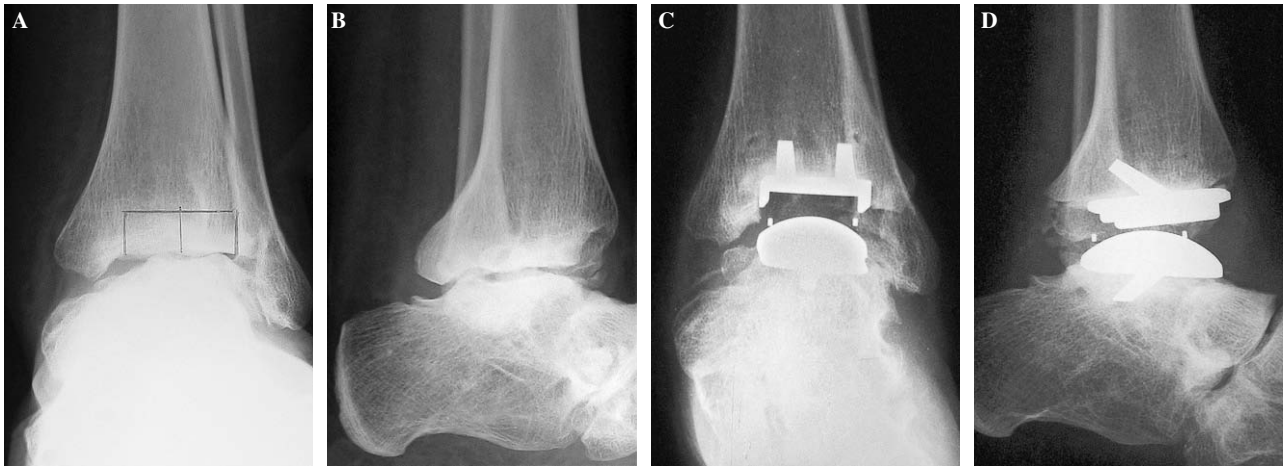


Figure 8. *Exceptional indication. Patient of 41 years of age with sequelae in a congenital clubfoot. Failed ankle arthrodesis. Painful ankylosis. Degree of movement: 10°. Preoperative X-rays: AP (A) and lateral (B). Postoperative Control: Anteroposterior (C) and lateral (D) X-rays. Arc of movement of 40°, non-painful joint.*

sis due to arthrodesis failure in a 41 year old female patient with sequelae of congenital clubfoot that had undergone several surgical procedures (Figure 8).

The functional and clinical improvements we have seen lead us to consider the future of this procedure with optimism. Implants need to be improved, especially revision prosthesis which have not yet been completely developed. However, in our opinion, we must be prudent when indicating this surgical procedure and plan even the smallest details to avoid failure.

REFERENCES

1. Viladot A. Prótesis de tobillo y pie en: Núñez-Samper M, Llanos Alcázar LF, editores. Biomecánica, medicina y cirugía del pie. C. 61. Barcelona: Masson; 1997. p. 552-5.
2. Buchholz H, Engellbrecht E, Siegel M. Complete ankle joint endoprothesis type «St. Georg». Chirurg. 1973;44(5):241-4.
3. Lord G, Marotte JH. Prosthese totale de cheville. Rev Chir Orthop. 1973;59:139.
4. Buechel F, Pappas M, Iorio JL. New Jersey Iow contact stress total ankle replacement: biomechanical rationale and review of 23 cementless cases. Foot Ankle. 1988;8(6):279-90.
5. Buechel F, Pappas M. Eighteen-year evaluations of cementless meniscal bearing. Total ankle replacement. Instr Course Lect. 2002;51:143-52.
6. Couglin MJ. The Scandinavian total ankle replacement. Instr Course Lect. 2002;51:135-42.
7. Dini A, Bassett FH. Evaluation of the result of Smith total ankle replacement. Clin Orthop. 1980;146:228.
8. Kirkup J, Regan MW. The bath and wessex ankle arthroplasty. J Bone Joint Surg. 1987;69B:153.
9. Smith TW, Elson RA, Hay SM. Long term follow-up of total ankle arthroplasty: the Sheffield experience. J Bone Joint Surg. 1993;75B:297.
10. Takakura Y, Tanaka Y, Sugimoto K, Tamai S, Masuhara K. Ankle arthroplasty. Clin Ortop. 1990;252:209.
11. Valderrábano V, Hintermann B. Prótesis de tobillo Hintegra. Foot Ankle. 2004;2:97-109.
12. Burge P, Evans M. Effedct of surface replacement arthroplasty on stability of the ankle. Foot Ankle. 1986;7:1.
13. Giannini S, Leardini A, O'ConnorJJ. Total ankle replacement: review of the desing and of the current status. Foot Ankle Surg. 2000;6:77-88.
14. Hintermann B, Valderrabano V. Total ankle arthroplasty. Foot Ankle Clin. 2003;8:375-405.
15. 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;80A:1410-20.
16. Stengel D, Bauwens K, Ekkerndamp A, Cramer J. Efficacy of total ankle replacement with meniscal-bearin devices: a sistematic review and meta-analysis. Arch Orthop Trauma Surg. 2005;125(2):109-19.
17. Mendolia G. The Ramses ankle replacement. Maitrise Orthopedique. 2002; cap. 21: 100-5.
18. Rippstein PF. Clinical experiences with three different designs of ankle prostheses. Foot Ankle Clin. 2002;7:817-31.
19. Myerson MS, Mroczeck K. Perioperative complications of totals ankle arthroplasty. Foot Ankle Int. 2003;24:17-21.
20. Hinterman B, Valderrabano V, Dereymaeker G. The Hintegra ankle: Rationale and short-term. Results of 122 consecutives ankles. Clin Orthop Rel Rese. 2004;424:57-68.
21. Núñez-Samper M, Kubba MN. Prótesis total de tobillo Ramsés: Indicaciones y técnica de implantación. Rev Pie y Tobillo. 2005;T XIX:51-8.
22. Hinterman B. Short and mid term results with the Star total ankle prosthesis. Orthopaede. 1999;28:792-803.
23. Sanders RW. Failed total ankle arthroplasty Advanced reconstruction. 201-4. Foot Ankle Ed AOFAS/AAOOS. Rosemont. Illinois (2004).

Conflict of interests: We, the authors, have not received any economic support to carry out this study. Nor have we signed any agreement with any commercial firm to receive benefits or fees. On the other hand, no commercial firm has provided nor will provide economic support to non-profit foundations, educational institutions or any of the other non-profit organizations that we are members of.