Gait & Posture 38 (2013) 945–950

Contents lists available at SciVerse ScienceDirect

Gait & Posture

journal homepage: www.elsevier.com/locate/gaitpost

Functional evaluation of patients treated with osteochondral allograft transplantation for post-traumatic ankle arthritis: One year follow-up

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ARTICLE INFO

Article history:
Received 9 January 2013
Received in revised form 15 March 2013
Accepted 27 April 2013

Keywords:
Gait analysis
Functional evaluation
Ankle arthritis
Allograft transplantation
EMG

ABSTRACT

Severe post-traumatic ankle arthritis poses a reconstructive challenge in active patients. Whereas traditional surgical treatments, i.e. arthrodesis and arthroplasty, provide good pain relief, arthrodesis is associated to functional and psychological limitations, and arthroplasty is prone to failure in the active patient. More recently the use of bipolar fresh osteochondral allografts transplantation has been proposed as a promising alternative to the traditional treatments. Preliminary short- and long-term clinical outcomes for this procedure have been reported, but no functional evaluations have been performed to date.

The clinical and functional outcomes of a series of 10 patients who underwent allograft transplantation at a mean follow-up of 14 months are reported. Clinical evaluation was performed with the AOFAS score, functional assessment by state-of-the-art gait analysis.

The clinical score significantly improved from a median of 54 (range 12–65) pre-op to 76.5 (range 61–86) post-op ($p = 0.002$). No significant changes were observed for the spatial–temporal parameters, but motion at the hip and knee joints during early stance, and the range of motion of the ankle joint in the frontal plane (control: $13.8^\circ \pm 2.9^\circ$; pre-op: $10.4^\circ \pm 3.1^\circ$, post-op: $12.9^\circ \pm 4.2^\circ$; $p = 0.02$) showed significant improvements. EMG signals revealed a good recovery in activation of the biceps femoris.

This study showed that osteochondral allograft transplantation improves gait patterns. Although re-evaluation at longer follow-ups is required, this technique may represent the right choice for patients who want to delay the need for more invasive joint reconstruction procedures.

1. Introduction

Severe post-traumatic ankle arthritis poses a reconstructive challenge in the active patient. Current treatments for arthritic ankles include three main options: arthrodesis, arthroplasty, and transplantation allograft [1]. The treatment of choice is still arthrodesis, which is indicated for patients with no arthritis at the mid-tarsal joints and with satisfactory movement of the other joints of the foot, therefore with a well-compensated ankle rigidity. This treatment provides significant pain relief [2,3], but the combined loss of ankle joint mobility can be psychologically challenging [4,5]. Functional evaluation with gait analysis has also revealed that compensatory motion is necessary at the knee and foot joints [6,7]. In addition, alteration of gait parameters [8], stiffness and loss of motion in the subtalar joint [9] have been observed. A more physiologic range of motion has been claimed in patients who underwent total ankle replacement [10], but implant wear and loosening still remain important limitations of this option. Furthermore, gait analysis at 5-year follow-up (Giannini et al. [11] revealed a decrease in speed, cadence and stride length, and a reduction in plantarflexion in terminal stance with a deficit in push-off. Similar deterioration of the spatial–temporal parameters and abnormal muscular activation have also been noted more recently [12]. Despite the improved AOFAS scores and function, only 6 months after surgery [13,14], and some restoration of the main gait parameters [15,16], current total ankle arthroplasty does not seem able to re-establish normal joint function fully.

The use of frozen allografts, alone or in combination with internal fixation devices, has long been employed as a modular, versatile, and durable substitution for a resected malignant bone tumor [17–19]. Following the modern development of bone banks in the last decade, alternative biological reconstruction techniques have been sought. In particular, bipolar fresh osteochondral

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http://dx.doi.org/10.1016/j.gaitpost.2013.04.020

allografts (BFOA) can now provide a viable alternative in special cases of human joint replacement. The term "bipolar" relates to the replacement of both sides of the affected joint which, in the ankle, are the distal portion of the tibia and the proximal aspect of the talus. It has been established that an appropriate layer of cartilage from a donor can survive transplantation when supported by intact subchondral bony structure, and is progressively replaced by the host bone after surgery [18]. Although preliminary studies have reported contrasting outcomes, with about 50% of cases requiring revision following failure [20,21], more recent clinical reports have indicated that BFOA is a promising option in the treatment of post-traumatic arthritic ankles and represents a practicable alternative for younger and more active patients, where arthrodesis is not accepted and prosthetic replacement is not desired [2,22]. BFOA of the ankle is also conservative and not irreversible, thus multiple options are still available to the surgeon in case of failure [21]. In fact it is becoming a promising alternative in case of failure of the other two options [23,24].

Whereas gait analysis has already been employed for the functional assessments of patients following arthroplasty [11,12,14] and arthrodesis [6,8], no such objective instrumental investigation has been performed on BFOA. Therefore the aim of this study was to assess traditional clinical outcomes in ten BFOA patients with modern gait analysis, by providing an objective measure of the function of the main lower limb joints. The analyses were performed pre-operatively and at 1-year follow-up to identify patient-specific improvements.

2. Methods

Ten patients (two women and eight men, age 38 ± 9 years, BMI 24.0 ± 2.7) affected by Grade III post-traumatic ankle arthritis who underwent BFOA were enrolled in this study. Patients were assessed pre-operatively and at a mean follow-up of 14 ± 3.7 months. Inclusion criteria were age lower than 55 years, and the presence of painful unilateral ankle arthritis (Grade III) unresponsive to a minimum of 6 months of medical and physical therapies, including limiting the activities of daily living. Exclusion criteria were the following: ankle anatomy disruption, osteopenia, rheumatoid arthritis, infections, and vascular and neurological diseases. Informed consent was obtained from all patients after extensive discussion about the various risks, benefits, and alternatives to fresh osteochondral allografting. The study was approved by the Ethics Committee of the authors' Institution.

The proper size allograft for each patient was identified through a standard bone bank program. The details of the surgical technique have already been reported in a previous study [2]. In brief, a jig was employed to prepare the bone grafts by cutting a semi-lunate tibial surface and a talar surface, using a lateral approach after the distal fibula was everted. The same jig was employed to resect the corresponding arthritic surfaces from the patient's ankle. The allograft was then fixed with 14–18 mm twist-off screws and the full ankle range of motion was assessed. A plaster cast was applied after surgery for 15 days to allow wound healing. Continuous passive motion was advised following removal of the cast. The range and speed of motion was gradually increased during this phase according to the level of pain. Progression to complete weight-bearing was advised six months after surgery.

Pre- and post-operative clinical evaluation of the patients was performed by the American Orthopedic Foot and Ankle Society (AOFAS) score, and functional assessment was performed with gait analysis. A validated protocol was employed to measure rotations of the joints in the relevant lower limb of each patient pre- and post-surgery [25,26]. An eight camera motion system (Vicon 612, Vicon Motion Capture, Oxford, UK) was used to track 12 reflective markers attached to the pelvis, thighs, shanks and feet at a sampling rate of 100 Hz during barefoot level walking at self-selected normal speed. Each patient performed a minimum of three full gait cycles along a 15-m long walkway. Local anatomical reference frames at the body segments were determined according to the location of the markers and hip, knee and ankle joint rotations in the three anatomical planes were determined using the joint coordinate system convention [27]. In particular, at the latter, we reported dorsi/plantarflexion, inversion/eversion and ab/adduction, respectively in the sagittal, frontal, and transverse planes.

Simultaneously, two dynamometric platforms (Kistler Instruments, Einterthur, Switzerland) measured the ground reaction forces at a frequency of 2000 Hz, and a wireless electromyographic system (Zerowire, Aurion, Milan, Italy) recorded the activity of the rectus femoris, long head of biceps femoris, medial head of gastrocnemius and tibialis anterior muscles at a frequency of 2000 Hz. Internal joint moments during the stance phase were calculated as the vector product of the ground-reaction force and position vector of the joint center. Surface dynamic EMG data were manually processed by the same operator, with extensive experience with EMG signals of the main lower limb muscles during gait, in order to obtain on-off patterns of activity over the gait cycle. This was obtained for each muscle in each trial by determining the onsets and offsets of muscular activity from visual inspection of the raw EMG data. Finally, a global temporal profile of activation was obtained for each muscle by calculating the percentage of muscular activity across all trials and all patients at each time frame of normalized gait cycle. The recorded kinematics, kinetics, and spatial–temporal data were used to calculate a set of parameters according to a previously described procedure [28].

The Wilcoxon non-parametric test, evaluated by exact method for small samples, was used to compare pre-operative and post-operative AOFAS scores. The Kolmogorov–Smirnov test was performed to assess normality of gait analysis data. Pre- and post-operative gait data were compared using the Generalized Linear Model (GLM), with the patient as a random effect. Clinical and functional data were also compared to those of a control group [14] consisting of 20 healthy subjects (11 men and 9 women; mean age 27.9 years, range 23–36; mean BMI 21.9, range (18.5–25.0) using the Mann–Whitney test, for not normally distributed or not homoscedastic data, or the one-way ANOVA test otherwise. p-Values <0.05 were considered significant.

3. Results

The AOFAS score significantly improved, from a median of 54 (range 12–65) pre-op to 76.5 (range 61–86) post-op ($p = 0.002$). In particular, the pain relief sub-score improved from 20 (range 0–30) to 30 (range 20–30) ($p = 0.016$), function from 25.5 (range 7–35) to 41 (range 31–46) ($p = 0.002$). Only the alignment did not improve significantly, from 5 pre- (range 0–10) to 10 post-op (range 5–10) ($p = 0.078$).

No statistical significance was found between pre- and post-operative measurements in any spatial–temporal parameter (Table 1). As far as the kinematic parameters, no significant modifications between pre- and post-op were found for the pelvis kinematics. Conversely, hip joint flexion at foot contact (control: $30.9^\circ \pm 5.7^\circ$; pre-op: $26.0^\circ \pm 4.4^\circ$, post-op: $29.3^\circ \pm 6.7^\circ$; pre-op vs. post-op $p = 0.0034$) and its range of internal/external rotation (control: $10.5^\circ \pm 4.4^\circ$; pre-op: $14.6^\circ \pm 7.8^\circ$, post-op: $11.5^\circ \pm 4.4^\circ$; pre-op vs. post-op $p = 0.044$) had significantly improved at the follow-up. The motion of the knee joint also appeared to become more physiological after surgery. A significant increase in maximum knee flexion at loading response (control: $16.0^\circ \pm 6.0^\circ$; pre-op: