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Kinematic and kinetic modifications in walking pattern of hip osteoarthritis patients induced by intra-articular injections of hyaluronic acid

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ABSTRACT

Background: A growing body of evidence points to the efficacy of intra-articular injections of hyaluronic acid, in dealing with pain and function in hip osteoarthritis. To date, however, no data exist as to this treatment's effect on walking pattern.
Methods: We performed a prospective, open study in order to verify, in a group of 20 hip osteoarthritis patients (12 men, 8 women, mean age 60.5, range 47–73), the clinical effects of 3 intra-articular injections of 2 ml of hyaluronic acid in the hip (1/week) in terms of pain and function at 1 (T1), 3 (T2) and 6-month (T3) follow-ups, as well as changes in the kinematics and kinetics of gait at 6-month follow-up.
Findings: Pain as measured with visual analog scale significantly dropped after this procedure ($P<0.0001$). A significant improvement was noted regarding stiffness ($P=0.005$) and disability ($P=0.04$), as measured by the Western Ontario and McMaster Universities osteoarthritis index. As regards gait analysis, patients at T3 walked with higher cadence ($P=0.004$) and stride length ($P=0.02$) compared to T0. Moreover, a significant increase for the pelvic tilt at heel contact ($P=0.0004$) and for hip flexion–extension moment at loading response sub-phases of gait cycle ($P=0.02$) was noted at T3.
Interpretation: In line with current literature, our patients display clinical improvement 6 months after intra-articular injections of hyaluronic acid, accompanied by changes in walking pattern, as measured by instrumental gait analysis. The kinematic and kinetic changes observed may be the consequence of the therapeutic effect of intra-articular injections of hyaluronic acid.

1. Introduction

Hip osteoarthritis (OA) is a disease characterized mainly by cartilage degradation, which is clinically reflected by a gradual development of pain and impairment of joint function. Current treatment strategies with both non-pharmacologic and pharmacologic therapies aim to reduce pain and physical disability and, when possible, to limit structural deterioration in the affected joints. In the last decade the use of intra-articular (IA) injections of hyaluronic acid (HA) has become more and more popular, and a number of paper have addressed the efficacy of this intervention on pain and function in hip OA (Migliore et al., 2006, 2008, 2009). HA is a high-molecular-weight glycosaminoglycan composed of continuously repeating molecular sequences of glucuronic acid and N-acetyl-glucosamine (Brockmeier and Shaffer, 2006). In the arthritic joint, the concentration and molecular weight of HA are decreased by 33% to 50%, limiting its role in maintaining normal joint biomechanics (Berg and Olsson, 2004; Brockmeier and Shaffer, 2006) The purpose of IA injections is to replace the lost HA and potentially stimulate the production of endogenous HA within the joint (Bagga et al., 2006). To date, the effect of IA injections of HA on hip OA has been evaluated only from a clinical perspective. Although pain relief represents the primary goal in treating patients affected by hip OA, another issue to be addressed by research in this field should be the role of any proposed intervention on joint biomechanics. As a result of the last decade's dramatic advances in the technology supporting the three-dimensional (3D) analysis of human gait, quantitative gait analysis is now proposed as a clinically useful tool in musculoskeletal diseases (Laroche et al., 2006). To date, there exist no data concerning the effect of IA injections of HA on the walking pattern of patients suffering from hip OA.

Therefore, the purpose of the present study is to determine if this therapy offers effective treatment for hip OA patients, not only from a clinical, but also from a biomechanical point of view. For this reason, we scheduled a prospective open study with 6-month follow-up.

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2. Methods

2.1. Patients

Consenting patients of both sexes older than 45 years attending our out-patient clinic between January 2008 and January 2009 were enrolled in the present study according to the following inclusion criteria:

- diagnosis of primary hip OA according to American College of Rheumatology criteria (Altman et al., 1991) >12 months;
- a score II, III or IV on the Kellgren and Lawrence (Kellgren and Lawrence, 1957) grading scale (KLS);
- pain score moderate to severe during walking, as evaluated on a 10 cm visual analogue scale (VAS) (≥5) and persisting for more than 30 days;
- ability to walk at least 10 m without an assistive device.

Patients were excluded if one of the following occurred:

- bilateral symptomatic hip OA;
- evidence of rapidly destructive hip OA, major dysplasia or congenital abnormality of the target hip;
- rheumatoid arthritis, chondrocalcinosis, metabolic bone disease, psoriasis, gout, active infection;
- history of previous IA injections of HA;
- hypersensitivities to avian protein;
- oral or IA administration of corticosteroids within the last month;
- planned surgery during the study period;
- psychiatric diseases;
- neurological or orthopedic conditions known to affect walking abilities;
- anticoagulant therapy.

2.2. Procedure

All patients were orally informed of the potential risks of treatment. Written informed consent was obtained from all subjects, and the procedures followed were approved by our institution's Committee on Human Experimentation.

Prior to the commencement of treatment, each participant underwent (T0) a clinical and gait analysis evaluation. Patients were treated with 3 ultrasound-guided IA injections of 2 ml of high molecular weight (>1500 kDa) HA (Hyalubrix®, Fidia Farmaceutici SpA, Italy) over 3 consecutive weeks, according to the manufacturer's treatment recommendations, which is considered to be a safe and effective dosage for this specific product (Foti et al., 2011). Clinical evaluation was performed at 1 month (T1), 3 months (T2) and 6 months (T3) after treatment ended. At T3 a gait analysis evaluation was also performed.

2.3. Clinical evaluation

A 10-cm VAS with 0 labeled “no pain” and 10 labeled “the worst pain I have ever had” was used to assess pain. The patient answered the question “with respect to the worst pain you have experienced in your life, what was the actual level of your hip pain while walking?” by placing a mark somewhere along the line. At T3, the percentage of pain reduction for each patient was calculated in relation to the baseline. Patients were classified as responders (VAS_R) if pain was reduced by ≥30%, and as non-responders (VAS_{NR}) if pain was reduced by <30%. The Italian version of the Western Ontario and McMaster Universities (WOMAC) OA index (Salaffi et al., 2003), a self-assessment multi-dimensional instrument that evaluates 17 functional activities, 5 pain-related activities, and 2 joint stiffness categories in three different sub-scales, was used to measure dysfunction and pain.

2.4. Gait analysis evaluation

Gait analysis was performed using the ELITE system (BTS, Milano, Italy), with 8 infrared video cameras (TVC, BTS, Milano, Italy) for the acquisition of the kinematic variables. Two Kistler platforms (Kistler Instruments, Winterthur, Switzerland) were used to acquire the ground reaction forces (GRF). Kinematic and kinetic data were collected and digitalized with a sampling rate of 100 Hz. Anthropometric data were collected for each subject and retroreflective spherical markers were placed over prominent bone landmarks to determine the joint centers and segment axis (Davis et al., 1991). Subjects were then instructed to walk at a self-selected speed along a level surface approximately 10 m in length; three valid trials were acquired for each subject and the mean value was considered for time/distance, kinematic and kinetic data throughout the analysis. A valid trial was defined as one in which subjects struck the force platforms without adjusting their stride length. Mean velocity (m/s), stride length (m), step width (m) and cadence (step/min) were collected as spatial–temporal parameters. Three-dimensional marker trajectories during walking were obtained by means of a frame-by-frame tracking system (Tracklab, BTS, Milan, Italy) and joint angular excursion, defined as a rotation of the distal segment relative to the proximal segment in our biomechanical model (Vaughan et al., 1999), was calculated; joint excursion data were normalized to the stride duration and reduced to 100 samples over the gait cycle. Because hip OA determines, even at early stages of disease, modification of both hip and pelvis motion (Watelain et al., 2001), we decided to focus attention on kinematics of these segments. The following parameters were considered for the kinematic evaluation: the angle of hip and pelvis flexion at heel contact, in order to describe joint position in the first moment of the stance phase; hip flexion–extension range of movement (RoM) during the whole gait cycle, to understand if, after therapy, the hip was able to gain motion on sagittal plane; and pelvis flexion–extension RoM during the whole gait cycle, which represents the compensative action of pelvis to the decrease motion of the hip (Watelain et al., 2001). Angle–angle hip flexion–extension and pelvic tilt diagrams were also plotted to allow qualitative inspection of inter-joint coordination in the sagittal plane.

Net internal joint moments were calculated by means of an inverse dynamics approach. Joint moments were normalized to the subject's body weight. Joint moment curves were used to calculate the angular impulse, i.e., the area under the joint moment curve within a specific time interval (Don et al., 2007). We considered the following parameters for the kinetic analysis: hip flexion–extension angular impulse during the whole stance phase, as well as during stance sub-phases.

Furthermore, a sub-group analysis of spatial–temporal, kinematic and kinetic data was conducted in the groups of VAS_R and VAS_{NR} patients.

2.5. Injection technique

The injection of HA into the hip joint under sonographic guidance was performed in all patients by the same experienced physician by means of a 7.5-MHz linear or 3.5-MHz convex transducer (GE Healthcare, Logiq P5 pro, Japan). While the patient lay supine with the hip in an internal rotation of 15–20°, the hip region was scanned to localize the femoral neurovascular bundle, femoral neck, hip joint capsule, and anterior synovial recess. The transducer was aligned with the long axis of the femoral neck, including the acetabulum and the femoral head. By a freehand technique, a 20-gauge (9 cm) spinal needle was then advanced under direct sonographic guidance into the anterior synovial recess at the junction of the femoral head and neck. Once the needle touched the femoral head it was retracted by 1 mm and a pre-injection arthrocentesis was performed in order to remove any effusion that may be present, decreasing the concentration of *in situ*