Patellofemoral Osteoarthritis: Treatment with Autologous Bone Marrow Mononuclear Cells and Arthroscopic Surgery, a Prospective Study

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Citation: Guimaraes MV, Rios PAGM, Ruiz MA, et al. Patellofemoral Osteoarthritis: Treatment with Autologous Bone Marrow Mononuclear Cells and Arthroscopic Surgery, a Prospective Study. J Stem Cell Res. 2018; 2(1): 1-6.

ABSTRACT

Objective: The aim of this study was to evaluate the treatment using BMMCs and arthroscopy in PF OA through functional questionnaires and MRI evaluations in a two year follow up. The use of mononuclear cells derived from bone marrow (BMMCs) is under investigation, and in vitro and pre-clinic studies showed promisor results. In comparison to the mesenchymal stem cells (MSC), the effectiveness is lower, however the costs for manipulation and laboratory handling make it difficult to use in clinical practice.

Design: This was a pilot, longitudinal and prospective trial and 8 patients with patellofemoral osteoarthritis who met the study criteria were included. All of the patients underwent arthroscopic debridement and received an injection of autologous BMMCs. Clinical outcomes were evaluated using SF-36 and the TLKSS questionnaire at baseline, one and two years after the procedure.

Results: In this study, an improvement in all of the evaluated parameters of the questionnaire was verified even after two years following the applications. The functional score of TKLSS showed a significant improvement in one and two years in comparison to the baseline (p<0.001). A significant improvement in SF-36 for all of the domains (p<0.001) was also verified. In addition, an improvement in the MRI images of the patients was noticed, which indicates patellar cartilage recovery.

Conclusion: The procedure of the arthroscopy and the application of BMMCs has proved promising results to reduce the signs of PF OA and ensure the patient satisfaction with a safe return to social life and sports practice. The completed questionnaire confirmed a clear improvement and a strong impact on the quality of life of the patients with the regeneration of their articular cartilage and restored subchondral bone. These results offer a wide perspective for future studies with the use of BMMC to treat articular diseases.
Mononuclear cells (BMMCs). The therapy with BMMCs led to a weaker, albeit significant therapeutic effect, when compared with the bone marrow mesenchymal stem cells (BMSCs). The efficacy of BMMCs is related to the HSC population, with the secretion of a variety of cytokines and growth factors and may act through paracrine signaling to enhance the survival and proliferation of BMSCs [10]. In 2014, Song et al., published one pre-clinical study with promising results, suggesting that even with a lower proportion of MSCs, BMMCs exert a reasonable regeneration effect on cartilage and the non-MSC component may play an important role in this process. In this context, we believe that a combined treatment including arthroscopic debridement, lavage and local administration of the autologous fraction of the BMMCs can improve the articular function and the quality of life of the patients through a simple and secure procedure with a low morbidity rate. The aim of this study was to evaluate the treatment using BMMCs and arthroscopy in PF OA through questionnaires and MRI evaluations in a two year follow up.

Material and Methods

Research Design
This was a pilot, longitudinal and prospective study. After a review and approval by the institutional ethics committee, the volunteers underwent cell collection and received treatment from the interventionist. Clinical and radiological evaluations were made before the procedure and then two years later. Questionnaires such as Short Form 36 (SF-36) and the Tegner-Lysholm Knee Scoring Scale (TLKSS) were used for quality of life and functional condition of the knee, respectively. These evaluations were made at baseline, one year and two years after the procedure. The grade of osteoarthritis was verified through the Outerbridge classification.

Patients
The study was conducted in the Nucleus of Orthopedics and Traumatology, in Belo Horizonte, MG, Brazil from June 2012 to January 2016. Eight patients were enrolled in our study. All eight patients were evaluated and deemed eligible for participation in this study. These patients were operated on between June 2012 and January 2014. The study was approved by the Orthopedics and Traumatology Center Ethics Committee of Belo Horizonte (authorization number: 01/2012) and all participants signed an informed consent form. Patients with a positive diagnostic for arthritis, obtained via magnetic resonance imaging (MRI) and corresponding radiological evidence of the affected knee were selected for the treatment. The inclusion criteria for the study were: 30-80 years of age; non-reactive and negative results for rheumatic disease (dependent on medication); positive or reactive tests for syphilis; Chagas disease; B, C, or HIV1+2 and HTLV1+2 hepatitis serological markers [12]. Patients were screened for clinical and demographic characteristics.
and baseline assessment. Patients were followed for two years and they were submitted to one more follow-up evaluation two years after the procedure, where they completed SF-36 and TLKSS questionnaires and did clinical, functional, and radiological evaluation. The SF-36 and TLKSS evaluations were regularly performed in one and two years after the procedure. Radiology was performed two years after the application.

**Cells preparation**
The procedure was conducted at a clinical setting. Patients were not allowed to use NSAIDs and corticosteroids for three months after the treatment.

For sample removal, the patient was placed in a prone position on the Criovida® operating table. After the proper asepsis of the pelvis, the posterior superior iliac crest was anesthetized with 20 ml of lidocaine 1%. Four 20 ml syringes were each filled with 1ml of heparin (5000 UI). Puncture aspiration of the area anesthetized was performed with an Osgood-type myelogram needle. After being filled, the syringes were properly capped and homogenized. An average of 52 ml (30-87) of bone marrow material was collected from each patient. Due to the pain and anxiety, the fifth and the eighth patient did not consent to have a larger amount collected. The samples were kept in cold storage and prepared between 12-18 hours after the collection. BMMCs were sorted and isolated using a Ficoll® method (Ficoll-Paque PREMIUM 1.073 GE) and a Sepax® separator CS-900.2 - Biosafe – Switzerland. Ficoll was used to isolate lower-density human mononuclear cells (e.g., mesenchymal stromal cells or monocytes). After the separation of cells, the mononuclear cells were washed two times using a solution of saline and 20% of autologous albumin. This mixture was centrifuged at 400 x g for 10 minutes in order to remove the Ficoll. After the second wash, the cells were resuspended in the same solution of saline and autologous albumin and then transferred into a sterile syringe. The average surgical time was 12 minutes. One aliquot of the cells was used to quantify the cell content through a hematological counter (KX21 Roche).

**Intervention procedure**
The knee was washed with an Arthrex® pump filled with saline solution and the pressure used was 40 mmHg. 20 ml of BMMCs were handled via arthroscopic superolateral parapatellar articular puncture after the arthroscopic debridement of the PF using an Arthrex® shaver, for all the patients. Arthroscopy was performed in all patients. Anesthesia was performed by epidural block with Marcaine. The patients were placed in a dorsal decubitus position. The lower limb marked for operation was fixed in a legholder and a pneumatic cuff was maintained at the root of the limb. Vascular emptying was performed by compression with a search strip and the tourniquet pump was operated with a pressure of 300mmHg for an average time of 15 minutes. The arthroscopic access was performed by the medial and lateral para-patellar portals. An inventory of the knee was performed to rule out femorotibial arthritis and meniscal injury. An area of patellofemoral control larynx was debrided with a shaver (mechanical debridement) in order to expose the subchondral bone. The joint was washed with 0.9% saline solution. An intra-articular needle was placed via lateral access and direct vision with the arthroscope. The arthroscope was removed, the accesses sutured and a bandage was applied. BMMC injection was performed by the aforementioned needle.

**Results**

**Patients**

Eight patients were included in the study: four men and four women. The average age was 52.5 years (37-76 years of age). Seven patients had a compromised right knee; one patient had a compromised left knee. All the patients presented grade 4 in the Outerbridge classification (complete erosion of the cartilage with bone exposure). In regards to racial classification, two patients were identified as Caucasian while six other patients were identified as brown. Regarding comorbidities, one patient presented type 2 diabetes mellitus, controlled with medication. Due to complaints about the knee, none of the patients practiced physical activities. The characteristics of the patients are described in the table 1.

| Patients | 8 |
|----------|---|
| Gender (M:F) | 4:4 |
| Mean age | 52.5 years |
| Ethnicity | 75% Brown | 25% Caucasian |
| Outerbridge grade | 4 (100%) |
| Comorbidities | 12.5% type 2 Diabetes mellitus |

**Table 1:** Patients casuistic.

All the patients had previously undergone a one-year conservative treatment with the administration of non-hormonal anti-inflammatory drugs and physiotherapy treatment. All patients discontinued the use of anti-inflammatories before the treatment. Regarding treatment alternatives while taking into consideration the clinical condition of patients, none of them agreed to have a total knee replacement (arthroplasty).

**Cell content**

As described in table 2, different volumes of bone marrow from the posterior iliac crest were collected, varying from 30 mL to 87 mL. The final volume injected was the same for all patients (20 mL). However, the concentration of BMMCs was different between 0.4 – 3.1 x 10^8 cells/µL, due to the variation of volume collected.

| Patients | Volume of Bone Marrow Collected (mL) | Final volume administered (mL) | BMMC (cells/µL) |
|----------|--------------------------------------|-------------------------------|-----------------|
| 1 | 68 | 20 | 1.4 x 10^6 |
| 2 | 58 | 20 | 1.3 x 10^6 |
| 3 | 87 | 20 | 3.1 x 10^6 |
| 4 | 81 | 20 | 2.4 x 10^6 |
| 5 | 44 | 20 | 0.8 x 10^6 |
| 6 | 73 | 20 | 1.04 x 10^6 |
| 7 | 56 | 20 | 1.4 x 10^6 |
| 8 | 30 | 20 | 0.4 x 10^6 |

**Table 2:** Characteristics of the BMMC samples as description of the
The results obtained with the use of the TLKSS are shown in table 3. The average score before the treatment (basal) reached 48.3 points. One year after the treatment it reached 97.3 and then at the two-year mark it reached 96.7. The increase in score after the treatment represents an improvement in the functional condition of the knee. This increase was significant in comparison with basal and one year after treatment (p<0.001) and no significant differences between one and two years after treatment were observed (p>0.1). There was no loss of follow-up during this study among the patients included.

### Table 3: Results of patients evaluation under the Lynsholm Scale in basal, one and two years after treatment.

| Scoring by topic | Basal | 1 year | 2 years |
|------------------|-------|--------|---------|
| Limp             |       |        |         |
| Never = 5        | 8     | 8      | 8       |
| Light / periodic = 3 | 4  | 0      | 0       |
| Intense and continuous = 0 | 4 | 0     | 0       |
| Cane / Crutch = 2 | 0     | 0      | 0       |
| Impossible = 0   | 0     | 0      | 0       |
| None = 15        | 0     | 8      | 8       |
| Feels like, not real = 10 | 0 | 0     | 0       |
| Occasional = 6   | 4     | 0      | 0       |
| Frequent = 2     | 4     | 0      | 0       |
| Joint locking during examination = 0 | 0 | 0     | 0       |
| Never =25        | 8     | 8      | 8       |
| Rarely, while practicing sports =20 | 0 | 0      | 0       |
| Frequently, while practicing sports =15 | 0 | 0      | 0       |
| Occasionally, during daily activities =5 | 0 | 0      | 0       |
| In every step = 0 | 0     | 0      | 0       |
| None = 25        | 0     | 7      | 6       |
| Inconsistent or during heavy exercise = 20 | 0 | 1      | 1       |
| Continuous during heavy exercise = 15 | 0 | 0      | 1       |
| Continuous during or after walking more than 2 km = 10 | 0 | 0      | 0       |
| Continuous during or after walking less than 2 km = 5 | 1 | 0      | 0       |
| Continuous = 0   | 7     | 0      | 0       |
| None = 10        | 0     | 8      | 8       |
| With heavy exercise = 6 | 0 | 0      | 0       |
| With regular exercise = 2 | 6 | 0      | 0       |
| Impossible = 0   | 2     | 0      | 0       |
| No difficulty = 10 | 0 | 7      | 6       |
| Slight difficulty = 6 | 0 | 1      | 2       |
| One step at time = 2 | 6 | 0      | 0       |
| Impossible = 0   | 2     | 0      | 0       |
| No difficulty = 5 | 0     | 4      | 5       |
| Slightly difficulty = 4 | 0 | 4      | 3       |
| Not beyond 90 degrees = 2 | 8 | 0      | 0       |

There were no adverse reactions, like local infections or complaints about the intra-articular administration of BMMC.

Regarding clinical conditions, during the physical evaluation before treatment, all patients reported severe patellar pain and gross cracking under patellar compression. One year later, two patients reported a much lighter cracking while this same observation was absent in the other six patients. Four patients informed recurrent pain at the lower end of the patella in the treated knee until two years, which ceased after stretching sessions, cold compress and muscle strengthening.

The review of MRI revealed osteophytes as well as reduction or lack of cartilage in the patellofemoral compartment. Six of the patients who had an increased patellar sign in T2 also displayed a significant improvement of the patellofemoral chondral cap without any increase of patellar sign (Figure 1).

**Figure 1:** Female patient, 76 years old, axial MRI of the knee image
Discussion

In this study, only 8 patients were included but, despite the small sample size, promising results were still obtained, which were applicable to post-treatment evaluation, even for patients that received less quantity of BMMCs.

Relative to the clinical evaluation, the TLKSS, a significant improvement in the functionality of the knee was verified in the first year which lasted until the two-year mark. Also, during the evaluation of the eight domains of the SF-36 before treatment, a low score was observed under the pain domain along with a great impact on the functional capacity and limitation of the patients’ physical, social and emotional conditions. The patient evaluation completed after one and two years of treatment showed a significant improvement of the pain domain with a clear improvement of the conditions mentioned above, particularly the positive evolution of the emotional skills reflected in their social reintegration and sports practice. Four patients informed recurrent pain at the lower end of the patella in the treated knee until two years, which ceased after stretching sessions, cold compress and muscle strengthening. This improvement was also verified in the MRI of some patients.

In the literature, the BMMC potential to regenerate the articular cartilage is described in pre-clinical studies [13,14] and few clinical trials with a reduced number of patients or even case reports using the bone marrow components to treat orthopedic conditions [15,16].

Centeno et al., studied nucleated cells of the bone marrow in the regeneration of severely degenerated human hip [17]. For this investigation, a bone marrow sample was collected and centrifuged in order to concentrate nucleated cells. Two harvested bone marrow were administered in a one month interval. A significant change in 15 degrees of the hip extension was verified. According to a self-reported functional index, changes in function were observed. After 12 weeks, the questionnaire showed an improvement of one level in travel, recreation, and standing tolerance. An improvement of two levels in walking distance and sitting tolerance was also verified. MRI images described apparent positive results obtained via the use of fresh mesenchymal stem cells, evidenced in the MRI. These results can be attributed to the decrease of the pro-inflammatory proteins like as TNF-α and prostaglandin E2. Also, cell therapy promotes collective improvement in histological and macroscopic evaluation verified in animal studies [12].

The limitations of this study were attributed to the use of subjective evaluation, such as questionnaires and the concentration of the administered BMMCs which was different in all the patients.

Conclusion

The arthroscopy procedure and application of BMMCs have proven to be quite promising in reducing the signs of PF OA, ensuring patient satisfaction in regards to a safe recommencement of sports practice and social life. The completed questionnaire confirmed a clear improvement and a strong impact on the quality of life of patients with the regeneration of their articular cartilage and subchondral bone restoration. These results offer a wide perspective for future studies with the use of BMMC to treat articular diseases.

List of Abbreviations

BMMCs = Bone Marrow Mononuclear Cells, PF = Patellofemoral, OA = Osteoarthritis, MSC = Mesenchymal Stem Cells, SF-36 = Short Form 36, TLKSS = Tegner-Lysholm Knee Scoring Scale, MRI = Magnetic Ressonance Imaging, HSC = Hematopoietic Stem
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