**Supplementary material**

This supplement contains a detailed surgical technique description, the results of univariate of multiple parameters and multivariate analysis including those that were statistically significant on univariate analysis.

It also includes the complete Hazard Ratios of progression and conversion to total hip arthroplasty when comparing only two cohorts at a time in all combinations.

Surgical technique:

Bone marrow harvest: In the supine position, bone marrow aspirate was obtained utilizing the Harvest Technologies bone marrow aspirate concentrate (BMAC) system (https://www.harvesttech.com/clinician, Terumo BCT, Lakewood, Colorado). The aspirate was obtained from the ipsilateral anterior and middle iliac crest, using multiple aspirations with an 8 gauge marrow heparin coated aspiration trocar with specialized side ports for harvesting. After 5 ml was obtained, the trocar was either rotated 90 degrees or inserted another 1-2 cm in order to sample a wide area within the marrow. In total, 60 ml of bone marrow aspirate was obtained.

Cellular graft preparation: Two ml aliquots of harvested marrow, before and after concentration, were sent for quality control testing using cell counts, viability and CFU-GM (colony forming units – granulocyte/monocyte) culturing. Despite differences in osteoblastic and hematopoietic cell lineages the CFU-GM was used marker to verify actual progenitor cells were grafted. The remaining aspirate was spun a proprietary container separating cellular and blood components for 4 minutes at 2500 revolutions per minute (RPM) followed by 10 minutes at 2300 RPM yielding 10 ml of concentrated, nucleated cellular extract.

Core decompression: Following the bone marrow harvest, during graft processing, a 2.8 mm guidewire (6.5mm cannulated screw set, Synthes, Warsaw, IN, USA) was placed into the femoral head under fluoroscopic guidance. The superior and lateral portion of the lesion, being at greatest risk for fracture, was targeted. Femoral head perforation was avoided. The lateral half of the tract enlarged by drilling (cannulated 5.0 mm drill) in preparation for a 4 gauge (5.2 mm), 25 cm cannulated trocar (Ranfac Corp, Avon, MA, USA) which was placed over the guidewire and manually advanced, with a mallet as necessary, into the lesion to ensure a tight fit of the trocar against the tract’s bony sidewall, thus minimizing potential leakage of the graft alongside the cannula and sidewalls of the core tract. Curettage of the lesion was not performed to both maintain structural integrity of the femoral head, thereby reducing fracture risk, and providing a scaffold for engraftment of the concentrated mesenchymal progenitor cells.

Cellular graft insertion: The BMAC graft (8 ml) was slowly injected into the lesion. When necessary, the cannula was withdrawn and/or rotated slightly if it abutted sclerotic bone in order to facilitate graft insertion. The stylet was placed into the trocar to advance the remaining graft volume within the cannula into the lesion. After trocar removal, digital pressure was immediately maintained on the femoral cortex insertion site for several minutes to minimize any graft leakage. Weight bearing as tolerated was allowed post-operatively, however, patients refrained from impact loading activities for 1 month.

**Table 1: Univariate model results: PMMA, BMAC vs. CD only**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| PMMA | -0.27891 | 0.4929 | 0.4826 | 0.757 | 0.347-1.648 |
| BMAC | -0.77179 | 4.3159 | 0.0378 | 0.462 | 0.223-0.957 |

**Table 2: Univariate model results: Age**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| age | 0.00541 | 0.1552 | 0.6936 | 1.005 | 0.979-1.033 |

**Table 3: Univariate model results: Gender**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| Male | -0.45877 | 2.1057 | 0.1468 | 0.632 | 0.340-1.175 |

**Table 4: Univariate model results: BMI continuous**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| BMI\_cont | 0.04536 | 5.0788 | 0.0242 | 1.046 | 1.006-1.089 |

**Table 5: Univariate model results: BMI (<30, >30)**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| BMI\_>30 | 0.92457 | 8.4898 | 0.0036 | 2.521 | 1.353-4.695 |

**Table 6: Univariate model results: ARCO stage 1 and 2 vs. 3 and 4**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| ARCO\_1&2 | -0.21126 | 0.1942 | 0.6594 | 0.810 | 0.316-2.072 |

**Table 7: Univariate model results: Etiology vs. Steroid use**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| Etio\_other | -0.57208 | 0.8901 | 0.3454 | 0.564 | 0.172-1.852 |
| Etio\_Etoh | 0.00360 | 0.0001 | 0.9941 | 1.004 | 0.389-2.591 |

**Table 8: Univariate model results: Location as Medial, Central, Missing vs. Lateral**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| Central | -2.01586 | 3.9447 | 0.0470 | 0.133 | 0.018-0.974 |
| Medial | -14.32917 | 0.0002 | 0.9893 | 0.000 | 0.000- |
| Missing | 0.85625 | 3.7116 | 0.0540 | 2.354 | 0.985-5.626 |

**Table 9: Univariate model results: Percent Involvement**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| % Involved | 0.93590 | 10.3712 | 0.0013 | 2.550 | 1.442-4.506 |

**Table 10: Univariate model results: Necrotic Arc Index**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| Necrotic arc index | 0.01983 | 18.5975 | <.0001 | 1.020 | 1.011-1.029 |

**Table 11: Univariate model results: Modified Necrotic Arc Index**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| Modified Necrotic arc index | 0.01786 | 20.8848 | <.0001 | 1.018 | 1.010-1.026 |

**Table 12: Multivariate Model with Covariates that are statistically significant: obesity and necrotic arc index**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| Parameter | Parameter Estimate | Chi-square | P-value | Hazard Ratio | 95% CI |
| PMMA | -0.08026 | 0.0326 | 0.8567 | 0.923 | 0.386-2.206 |
| BMAC | -0.41682 | 1.0686 | 0.3013 | 0.659 | 0.299-1.453 |
| BMI\_>30 | 1.16528 | 10.9296 | 0.0009 | 3.207 | 1.607-6.399 |
| Necrotic arc index | 0.02251 | 14.8873 | 0.0001 | 1.023 | 1.011-1.035 |