Bone Marrow Aspirate Processing Systems: A Comparison Study

Arthrex Research and Development

Purpose

This study compared 3 commercially available bone marrow aspirate (BMA) processing systems: Arthrex Angel®, Harvest® SmartPrep® 2 Bone Marrow Aspirate Concentrate (BMAC®), and Arteriocyte Magellan® MAR0Max™ systems. In addition to other cellular components, BMA contains progenitor cells such as hematopoietic progenitor cells (HPCs) and mesenchymal stem cells (MSCs) that have the potential to repair damaged tissues. BMA processing systems differ in the way they create their concentrates and there can be great variability in their cellular output. The technological advantage of the Arthrex Angel® system centers on the 3-sensor technology (3ST) that allows for customization of cellular output by changing the hematocrit setting (15% HCT was used in the current study) and the output volume. The purpose of this study was to compare the cellular content achieved from 3 BMA processing systems using marrow from the same donor.

Materials and Methods

Human BMA from the ilium (Lonza) was harvested from 5 donors, for a total of approximately 100 mL BMA. The BMA was split between the systems and was processed using each company's standard operating procedures. Before processing, a sample of BMA was also aliquoted for control purposes. After processing, the Angel platelet-rich plasma (PRP) concentrate from BMA ($cPRP_{BMA}$), SmartPrep 2 BMAC, and Magellan MAR0max were analyzed for specific cell concentrations (Sysmex XE-5000™ Automated Hematology System): red blood cells (RBCs), white blood cells (WBCs), neutrophils (NEs), platelets (PLTs), total nucleated cells (TNCs), and HPCs. For all 4 mL $cPRP_{BMA}$, BMAC, or MAR0Max samples, colony-forming units (CFUs) were cultured over 96 hours and connective tissue progenitor cells (CTPs) were counted after 48 hours. Statistics were performed using a 1-way ANOVA, α=.05, with pairwise multiple comparisons via Holm-Sidak testing.

Results

Table 1 illustrates the cellular concentrations in BMA versus the outputs from the different BMA processing systems. **Table 2** and **Figure 1** depict the cellular ratios or fold changes of the $cPRP_{BMA}$, BMAC, or MAR0Max systems' outputs when compared to BMA. **Table 3** shows statistical differences between the cellular concentrations within each system. The Angel system averaged 2.0 ± 0.3 mL ("Angel System 2 mL") of $cPRP_{BMA}$ output vs 4 mL for the Magellan and Harvest systems. For equal volume comparison, the Angel $cPRP_{BMA}$ was expanded with platelet-poor plasma (PPP) from the output bag by pulling back on the syringe post-processing ("Angel System 4 mL"). **Figure 2** illustrates the 96-hour culture results (from 2 separate donors) of BMA processed through the Arthrex, Harvest, and Magellan systems.

Discussion

The Angel system 2 mL $cPRP_{BMA}$ had significantly higher TNC and HPC concentrations than the Magellan and Harvest systems. Comparing the 4 mL specimens, the Angel system trended higher in the amount of CTPs after 48 hours in culture. Once controlled for volume, the Harvest system had a significantly higher concentration of RBCs than the Angel and Magellan systems. In vitro studies have shown that exposure to increased levels of RBCs in PRP leads to a higher rate of cell death of human synoviocytes, as well as increased production of pro-inflammatory cytokines. Although it may not be possible to eliminate RBCs from PRP concentrated from BMA due to the density gradient associated with regenerative cells after centrifugation, it may be advantageous to limit their presence to the degree possible.

There was no correlation between TNC concentration and HPC concentration. For example, the Harvest system had a higher concentration of TNCs when compared to the Angel system 4 mL sample, but the Angel system 4 mL sample had a higher concentration of HPCs and CTPs. The Angel sample 4 mL sample also had higher concentrations of TNCs, HPCs, and CTPs than the Magellan system. While the majority of MSCs and HPCs are stratified within the TNC layer, TNC concentrations are not a direct indicator of the presence of any specific progenitor cell. Specimens should be cultured in vitro for adequate quantification.

***Table 1*: Cellular Concentrations in BMA and BMA Processed Through Arthrex Angel, Harvest SmartPrep 2, and Magellan MAR0Max Systems**

	Volume (mL)	RBC (M/µL)	WBC (x10³/µL)	NE (x10³/µL)	PLT (x10³/µL)	TNC (x10³/µL)	HPC (x10³/µL)	CPT (cm³)
BMA		4.2 ± 0.4	21.9 ± 2.9	9.6 ± 2.5	88.9 ± 23.3	24.5 ± 3.2	0.004 ± 0.002	28 ± 54
SmartPrep 2 System	4.0	3.2 ± 1.1	116.6 ± 23.3	52.3 ± 22.0	409.8 ± 119.3	130.3 ± 28.3	0.043 ± 0.028	479 ± 341
MAR0Max System	4.0	1.1 ± 0.3	86.1 ± 21.0	24.5 ± 5.5	464.3 ± 94.3	106.0 ± 27.1	0.023 ± 0.011	584 ± 264
Angel System 4 mL	4.0	1.4 ± 0.3	101.4 ± 26.3	47.1 ± 13.4	479.3 ± 177.4	113.2 ± 27.5	0.060 ± 0.018	843 ± 169
Angel System 2 mL	2.0 ± 0.3	2.7 ± 0.4	205.2 ± 58.3	96.3 ± 30.9	898.8 ± 285.7	229.3 ± 68.0	0.122 ± 0.034	N/A

***Table 2*: Cellular Ratios of BMA Processed Through Arthrex Angel®, Harvest SmartPrep 2, and Magellan MAR0Max Systems When Compared to BMA Concentrations**

	RBC Ratio	WBC Ratio	NE Ratio	PLT Ratio	TNC Ratio	HPC Ratio
SmartPrep 2 System	0.8 ± 0.2	5.2 ± 0.7	5.2 ± 1.9	4.6 ± 1.7	5.2 ± 0.8	9.6 ± 2.4
MAR0Max System	0.3 ± 0.1	4.2 ± 0.6	2.8 ± 0.5	5.6 ± 2.1	4.3 ± 0.8	6.3 ± 1.8
Angel System 4 mL	0.3 ± 0.1	4.3 ± 1.2	4.7 ± 1.3	5.6 ± 3.1	4.3 ± 1.2	15.0 ± 4.8
Angel System 2 mL	0.6 ± 0.1	8.9 ± 2.5	9.6 ± 2.6	10.7 ± 5.2	8.9 ± 2.5	31.0 ± 9.4

***Figure 1*: Cellular Ratios of BMA Processed Through Arthrex Angel, Harvest SmartPrep 2, and Magellan MAR0Max Systems When Compared to BMA Concentrations**

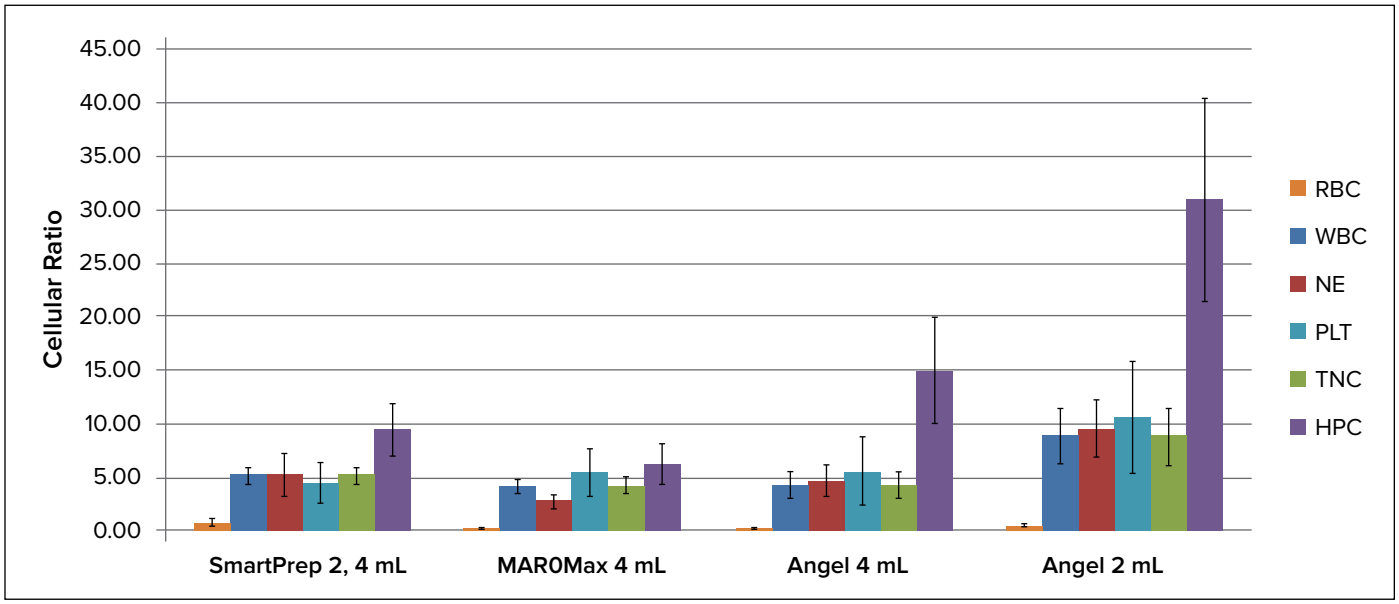
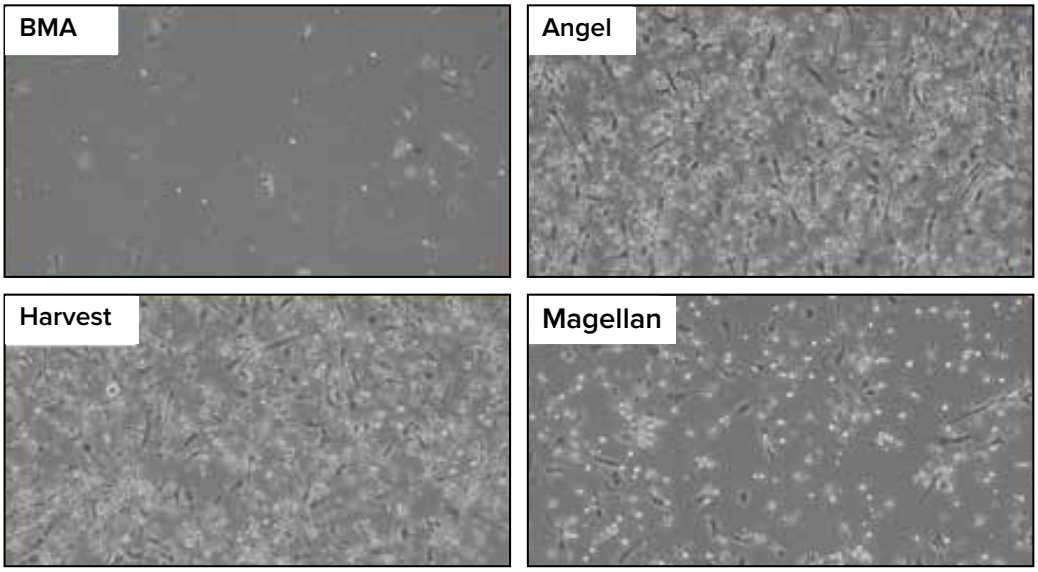


***Table 3*: Statistical Analysis of BMA Processed Through Arthrex Angel, Harvest SmartPrep 2, and Magellan MAR0Max Systems**

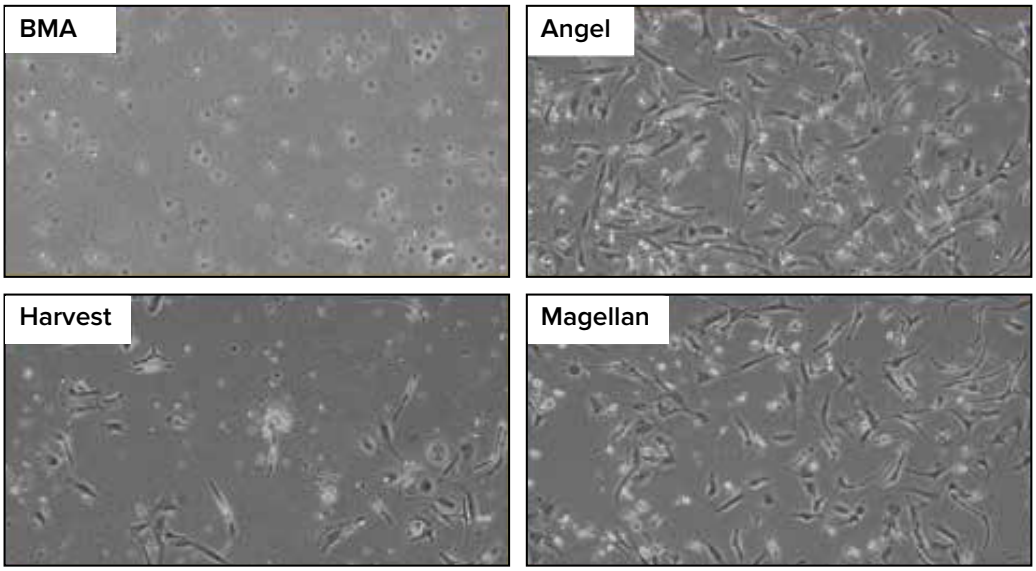
System Comparison	RBC (M/µL)	WBC (x10³/µL)	NE (x10³/µL)	PLT (x10³/µL)	TNC (x10³/µL)	HPC (x10³/µL)	CPT (CM³)
Angel 2 mL vs SmartPrep 2	No, *P*=.058	Yes, *P*=.004	Yes, *P*=.020	No, *P*=.060	Yes, *P*=.005	Yes, *P*<.001	N/A
Angel 2 mL vs MAR0Max	Yes, *P*<.007	Yes, *P*<.001	Yes, *P*<.001	No, *P*=.104	Yes, *P*<.001	Yes, *P*<.001	N/A
Angel 2 mL vs Angel 4 mL	Yes, *P*=.010	Yes, *P*<.001	Yes, *P*=.007	No, *P*=.128	Yes, *P*=.001	Yes, *P*=.001	N/A
SmartPrep 2 vs MAR0Max	Yes, *P*<.001	No, *P*=.650	No, *P*=.237	No, *P*=.953	No, *P*=.585	No, *P*=.356	No, *P*=.350
SmartPrep 2 vs Angel 4 mL	Yes, *P*<.001	No, *P*=.570	No, *P*=.569	No, *P*=.870	No, *P*=.733	No, *P*=.068	Yes, *P*=.012
MAR0Max vs Angel 4 mL	No, *P*=1.000	No, *P*=.068	No, *P*=.408	No, *P*=1.008	No, *P*=1.000	No, *P*=.259	No, *P*=.066

***Figure 2*:**

Donor 1 – 96-Hour Cultures of BMA Processed Through Angel, Harvest, and Magellan Systems



Donor 2 – 96-Hour Cultures of BMA Processed Through Angel, Harvest, and Magellan Systems



Scientific Support

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