Bone Marrow Aspirate Processing Systems: A Comparison Study

Arthrex Research

PURPOSE

This study aimed to compare the cellular content produced by 3 commercially available bone marrow aspirate (BMA) processing systems—the Angel® system (Arthrex), the SmartPrep 2 Bone Marrow Aspirate Concentrate (BMAC) system (Harvest), and the Magellan MAR0Max system (Arteriocyte)—using marrow from the same donor. In addition to other cellular components, BMA contains progenitor cells such as hematopoietic progenitor cells (HPCs) and mesenchymal stem cells (MSCs), which have the potential to repair damaged tissues. However, BMA processing systems differ in their methods of concentration, leading to significant differences in cellular output. The Angel system features a technological advantage with its 3-sensor technology, which enables customization of the final product by adjusting the hematocrit (HCT) setting and the output volume. In this study, a 15% HCT setting was used.

MATERIALS AND METHODS

Human BMA was obtained from the ilium of 5 donors (Lonza), yielding a total of approximately 100 mL. The BMA was split between the systems and processed using each company's standard operating procedures. A sample of unprocessed BMA was aliquoted for control purposes. After processing, the BMA concentrates from the Angel, SmartPrep 2 BMAC, and Magellan MAR0Max systems were analyzed for specific cell concentrations using the Sysmex XE-5000 automated hematology system. The cell types measured included red blood cells (RBCs), white blood cells (WBCs), neutrophils (NEs), platelets (PLTs), total nucleated cells (TNCs), and HPCs. For all 4 mL samples of concentrated BMA from each system, colony-forming units (CFUs) were cultured over 96 hours, and connective tissue progenitor cells (CTPs) were counted after 48 hours. Statistical analysis was performed using one-way ANOVA with a significance level of $\alpha = .05$. Pairwise multiple comparisons were conducted using Holm-Sidak testing.

RESULTS

Table 1 presents the cellular concentrations measured in unprocessed BMA and in the concentrated outputs from the 3 BMA processing systems. Table 2 and Figure 1 illustrate the cellular ratios, or fold changes, of the BMA output from each system compared to baseline values in unprocessed BMA. Table 3 summarizes the statistical differences in cellular concentrations among the systems. The Angel system produced an average of 2.0 ± 0.3 mL concentrated platelet-rich plasma (cPRP) from BMA ("Angel System 2 mL") compared to 4 mL outputs from both the Magellan MAR0Max and SmartPrep 2 BMAC systems. For equal-volume comparisons, the Angel cPRP from BMA was expanded to 4 mL using platelet-poor plasma (PPP) from the output bag by pulling back on the syringe postprocessing ("Angel System 4 mL"). Figure 2 shows the 96-hour culture results of BMA from 2 donors processed using the Angel, Magellan MAR0Max, and SmartPrep 2 BMAC systems.

DISCUSSION

The Angel system 2 mL sample produced significantly higher TNC and HPC concentrations compared to both the Magellan MAR0Max and SmartPrep 2 BMAC systems. When comparing the 4 mL samples, the Angel system also demonstrated a trend toward higher concentrations of CTPs after 48 hours in culture. After adjusting for volume, the SmartPrep 2 BMAC system yielded a significantly higher concentration of RBCs than both the Angel and Magellan MAR0Max 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 and an increased production of proinflammatory cytokines.[1] Although it may not be possible to eliminate RBCs from cPRP from BMA due to the density gradient associated with regenerative cells after centrifugation, minimizing RBC content may be beneficial.

No correlation was observed between TNC and HPC concentrations. For example, although the SmartPrep 2 BMAC system produced a higher TNC concentration than the Angel system 4 mL sample, the Angel system sample contained higher levels of both HPCs and CTPs. The Angel system 4 mL sample also had higher concentrations of TNCs, HPCs, and CTPs than the Magellan MAR0Max 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 unprocessed BMA and BMA concentrates from the Angel®, SmartPrep 2 BMAC, and Magellan MAR0Max systems.

	Volume (mL)	RBC (M/μL)	WBC (×10³/μL)	NE (×10³/μL)	PLT (×10³/μL)	TNC (×10³/μL)	HPC (×10³/μL)	CTP (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 BMAC System	4	3.2 ± 1.1	116.6 ± 23.3	52.3 ± 22	409.8 ± 119.3	130.3 ± 28.3	0.043 ± 0.028	479 ± 341
Magellan MAR0Max System	4	1.1 ± 0.3	86.1 ± 21	24.5 ± 5.5	464.3 ± 94.3	106 ± 27.1	0.023 ± 0.011	584 ± 264
Angel System 4 mL	4	1.4 ± 0.3	101.4 ± 26.3	47.1 ± 13.4	479.3 ± 177.4	113.2 ± 27.5	0.06 ± 0.018	843 ± 169
Angel System 2 mL	2 ± 0.3	2.7 ± 0.4	205.2 ± 58.3	96.3 ± 30.9	898.8 ± 285.7	229.3 ± 68	0.122 ± 0.034	N/A

Table 2. Cellular ratios following BMA processing with the Angel, SmartPrep 2 BMAC, and Magellan MAR0Max systems compared to unprocessed BMA.

	RBC Ratio	WBC Ratio	NE Ratio	PLT Ratio	TNC Ratio	HPC Ratio
SmartPrep 2 BMAC System	0.8 ± 0.2	5.2 ± 0.7	5.2 ± 1.9	4.6 ± 1.7	5.6 ± 0.8	9.6 ± 2.4
Magellan 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 ± 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 ± 9.4

Figure 1. Cellular ratios following BMA processing with the Angel, SmartPrep 2 BMAC, and Magellan MAR0Max systems compared to unprocessed BMA.

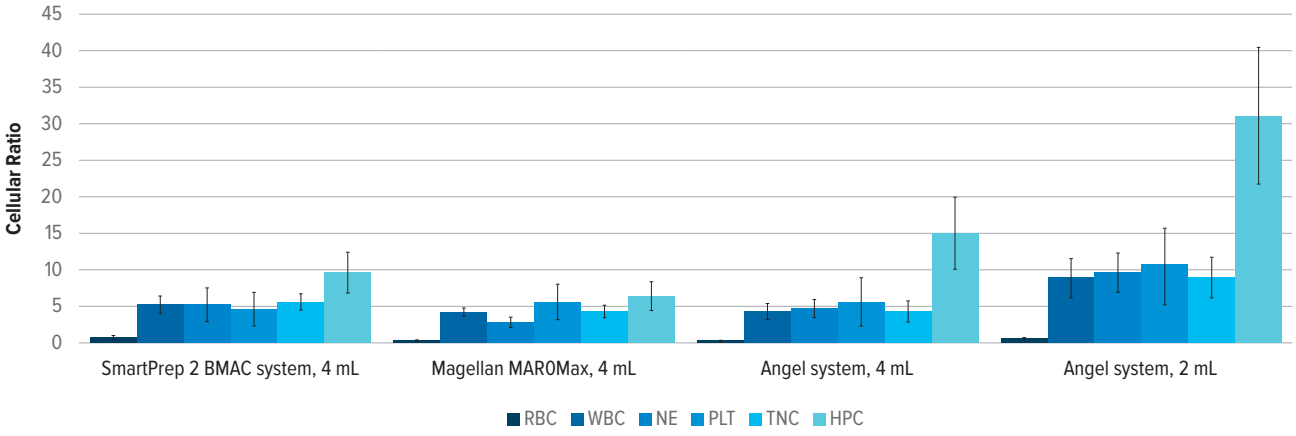
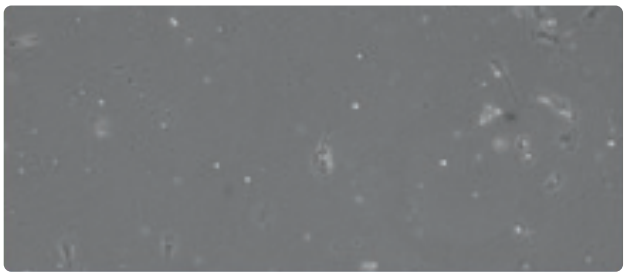


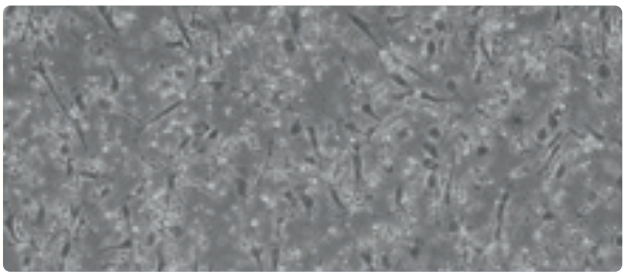
Table 3. Statistical comparisons of cellular components between the Angel, SmartPrep 2 BMAC, and Magellan MAR0Max systems.

System Comparison	RBC (M/μL)	WBC (×10³/μL)	NE (×10³/μL)	PLT (×10³/μL)	TNC (×10³/μL)	HPC (×10³/μL)	CTP (cm³)
Angel system 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 system 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 system 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 system 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 system 4 mL	No, $P = 1.000$	No, $P = .068$	No, $P = .408$	No, $P = 1.008$	No, $P = 1.000$	No, $P = .259$	No, $P = .066$

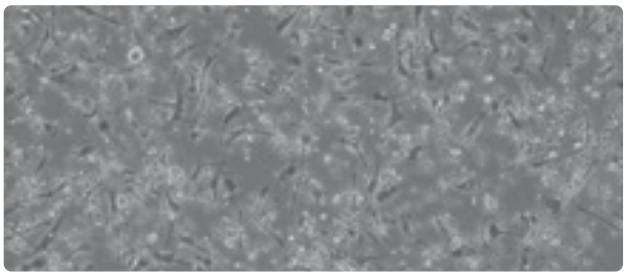
Figure 2. 96-hour cultures of BMA from Donor 1, processed using the Angel®, SmartPrep 2 BMAC, and Magellan MAR0Max systems.



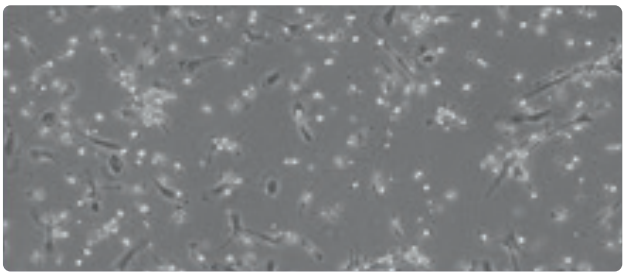
Unprocessed BMA



Angel system

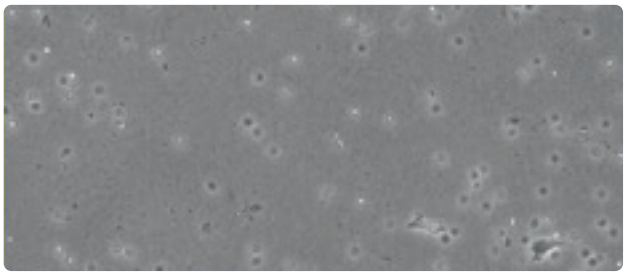


SmartPrep 2 BMAC system

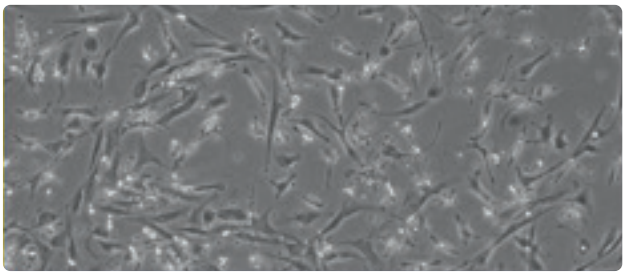


Magellan MAR0Max system

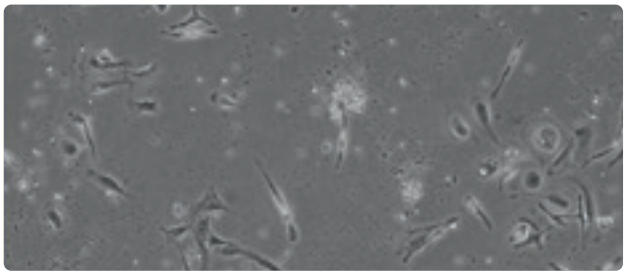
Figure 3. 96-hour cultures of BMA from Donor 2, processed using the Angel, SmartPrep 2 BMAC, and Magellan MAR0Max systems.



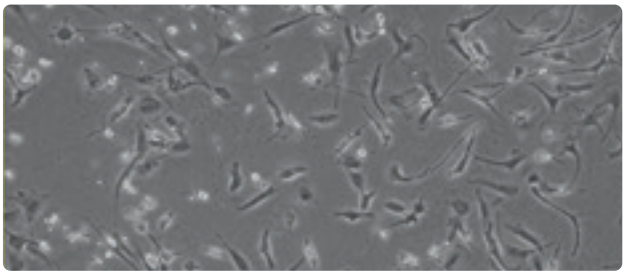
Unprocessed BMA



Angel system



SmartPrep 2 BMAC system



Magellan MAR0Max system

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