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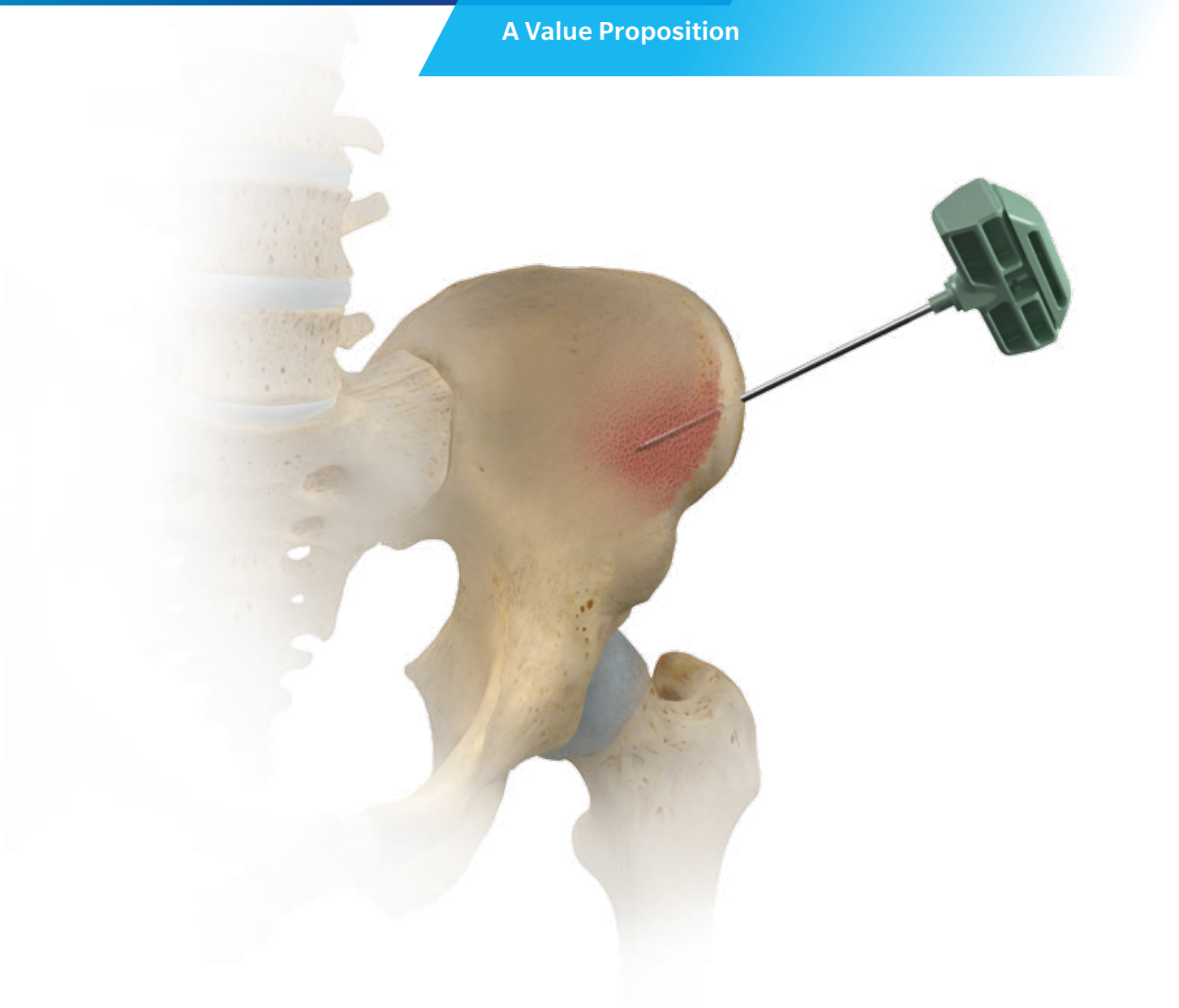
The Use of Bone Marrow Aspirate in Bone Grafting

A Value Proposition



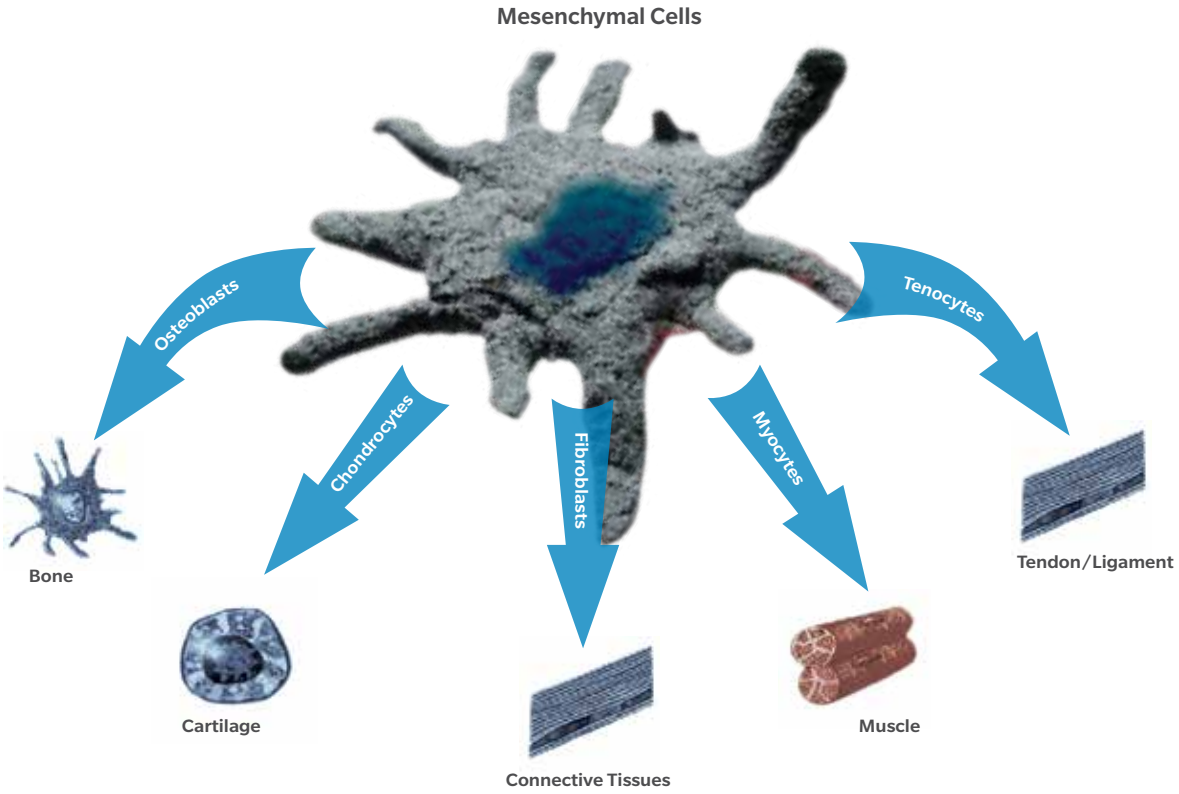


Figure 1

MSCs differentiate into osteoprogenitor cells, and osteoprogenitors differentiate into osteoblasts.

Rationale

Bone marrow is often aspirated to utilize the stem cells for tissue repair applications such as bone regeneration. The specific type of stem cells of interest are adult mesenchymal stem cells (MSCs), which differentiate into osteoprogenitor cells, which then further differentiate into mature bone-forming cells, called osteoblasts (Figure 1). Bone marrow aspirate (BMA) is a rich source of MSCs and osteoprogenitor cells in the body.[1, 2]

Several studies show BMA alone or BMA used in conjunction with autograft or allograft/DBM or synthetic materials can influence new bone formation.[1,3-6] When BMA is combined with graft material, bone regeneration is enhanced and is shown, in some cases, to be equivalent to results obtained from using autograft alone.[1,7,8] This graft combination provides the surgical site with the scaffold, cells and signals necessary for successful bone healing without the graft site morbidity[9,10] and time-consuming steps associated with harvesting iliac crest autograft. Furthermore, bone quality and availability concerns can hamper the surgeon's ability to use autograft in many cases.

Clinical Evidence (BMA only)

- Studies show bone marrow aspirate is an effective method for the treatment of tibial nonunions.[6,11,12]
- Bone marrow mononuclear cells can reduce joint pain and increase joint function in osteonecrosis.[13]

Clinical Evidence (BMA used in combination with graft materials)

- Bone marrow-derived cell-enriched allograft is shown to be comparable to autograft when used in bone grafting and spinal fusion procedures.*[14,15]
- Bone marrow aspirate with allograft may be appropriate as a substitute for autogenous bone graft in single-level revision posterolateral lumbar fusion (PLF) and may be a more cost-effective option than rhBMP-2.[8]
- "Autologous BMA can increase the regenerative potential of corticocancellous allogeneic bone grafts."[16]
- A meta-analysis of 62 articles on treatment of unicameral bone cysts found healing rates for bone marrow with demineralized bone matrix injection are high (98.7 %).[17]

* Animal data not necessarily indicative of clinical results.

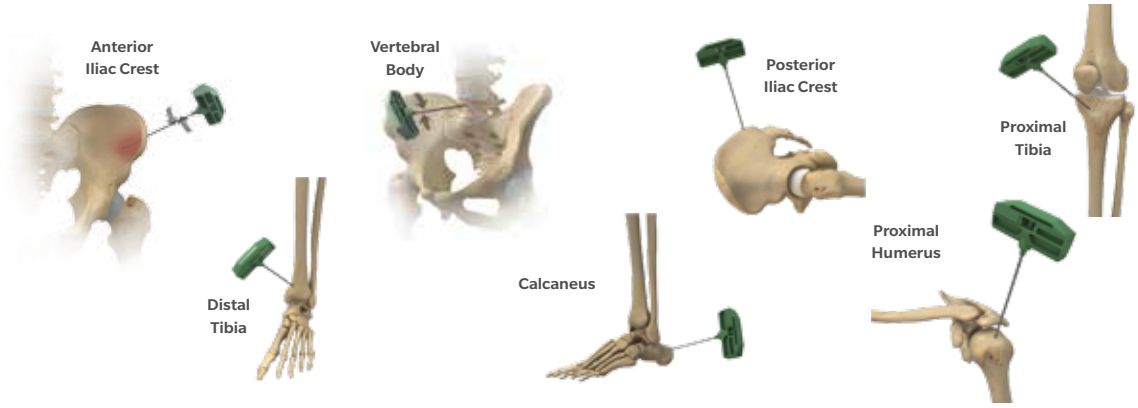


Figure 2

BMA may be aspirated from various anatomic locations.

Figure 3

Aspiration needle with multiple distal holes.

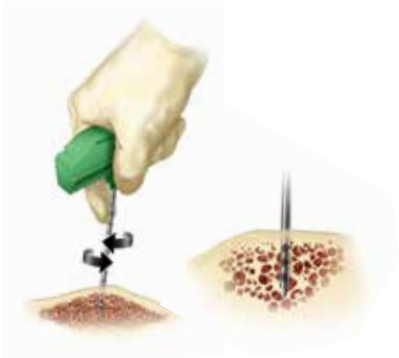


Figure 4

Advance needle in an alternating clockwise/counter clockwise motion and ensure all distal holes are well beyond cortical wall.

Anatomic Locations for Bone Marrow Aspiration

- Bone marrow may be aspirated from a variety of anatomic locations: iliac crest, vertebral body, calcaneus, proximal/distal tibia, distal femur and proximal humerus (see Figure 2). However, the number of MSCs can vary significantly between locations.
- Concentration of osteogenic progenitor cells were shown to be 71% higher on average in vertebral aspirates compared to iliac crest samples.[2]
- Arthroscopic technique for bone marrow aspiration from the proximal humerus and distal femur yielded reliable numbers of MSCs.[18]
- BMA from the iliac crest demonstrated higher yields of MSCs compared to distal tibia or calcaneus.[19]

Bone Marrow Aspiration Technique Highlights

- Bone marrow aspiration volumes from one site can significantly affect the number of MSCs obtained. It is recommended not to aspirate more than 2cc of bone marrow from one site, since larger volumes result in excessive dilution of the bone marrow with peripheral blood.[20] "Site" is defined here as a specific location within the cancellous bone adjacent to a hole in the cannula.
- Using a bone marrow aspiration needle with multiple distal holes (Figure 3) enables the surgeon to aspirate small volumes from different sites simultaneously, resulting in time-efficiency in the OR. Note there are many types of BMA needles/cannulas on the market. In this document, the Biomet BMA Needle is used for illustration purposes.
- To minimize aspirating air into the syringe, ensure all distal holes are located beyond the cortical wall and well within cancellous bone, as shown in Figure 4.

Morbidity of Autograft Harvesting versus BMA Aspiration

Hernigou et al10 retrospectively studied approximately 1000 patients who had either autograft harvested or bone marrow aspirated to treat fractures that needed grafting for delayed union or nonunion. The study reported that the following adverse events were significantly lower with the BMA group compared to the autograft group:

- Anemia - 16 cases in BMA group versus 87 for autograft group
- Early pain - 6 BMA versus 152 autograft
- Persistent pain - 2 BMA versus 21 autograft
- Neuralgia - 3 BMA versus 11 autograft
- Minor complications - 10 BMA versus 56 autograft
- Major complications - 3 BMA versus 22 autograft

Cost Considerations

- Although autograft is currently the gold standard for bone grafting applications, the high complication rate and morbidity associated with its use can result in increased time and costs to the hospital,[21, 22] both within the OR and during the recovery period.
- Abidi et al showed that incremental costs associated with iliac crest autograft begins at $1,601CAD (approx. $1,465 USD26), and can often be higher.[22]
- Allograft cancellous chips combined with a BMA kit costs significantly less with average pricing for allograft cancellous chips at $242 for 15 cc23 and a BMA kit at $175.[24]
- Average selling price for 10 cc of growth factor product (such as, Infuse Bone Graft) is $5,000,25 DBM putty is $1,531, bone graft substitutes are $1,994, and allogeneic cell-based matrices is $4,223.[23]

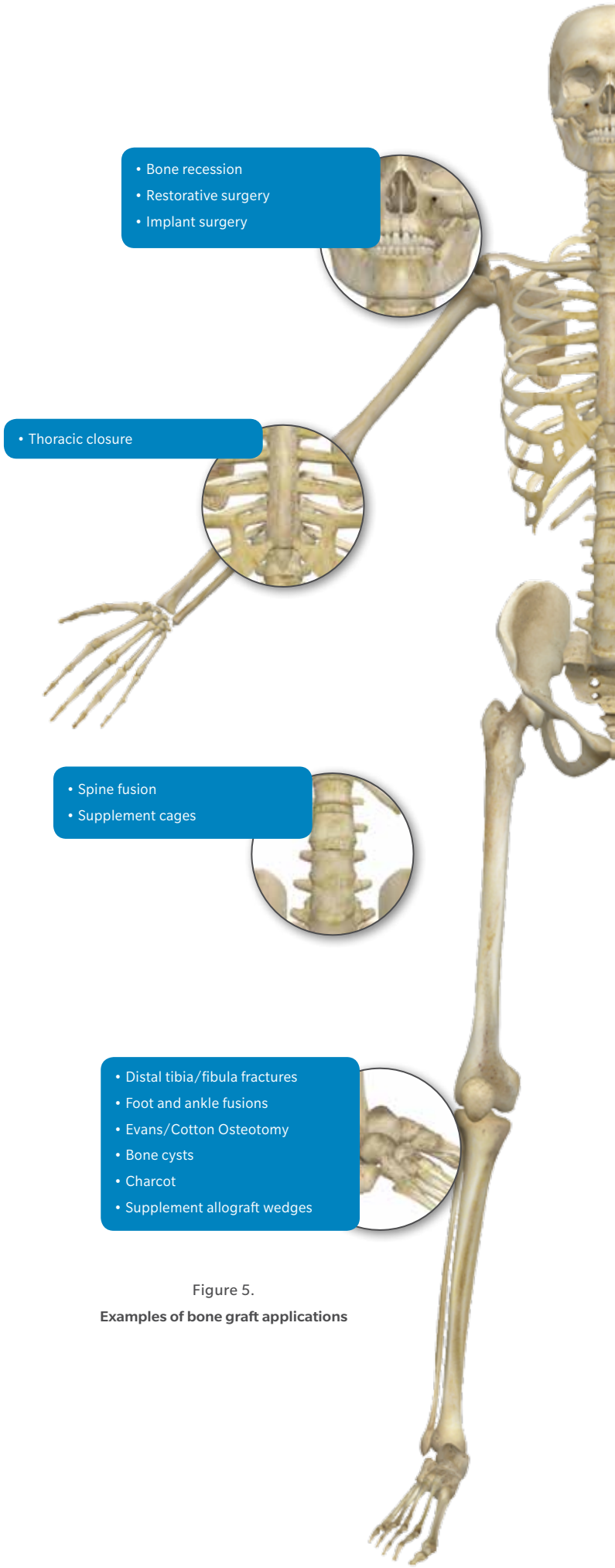
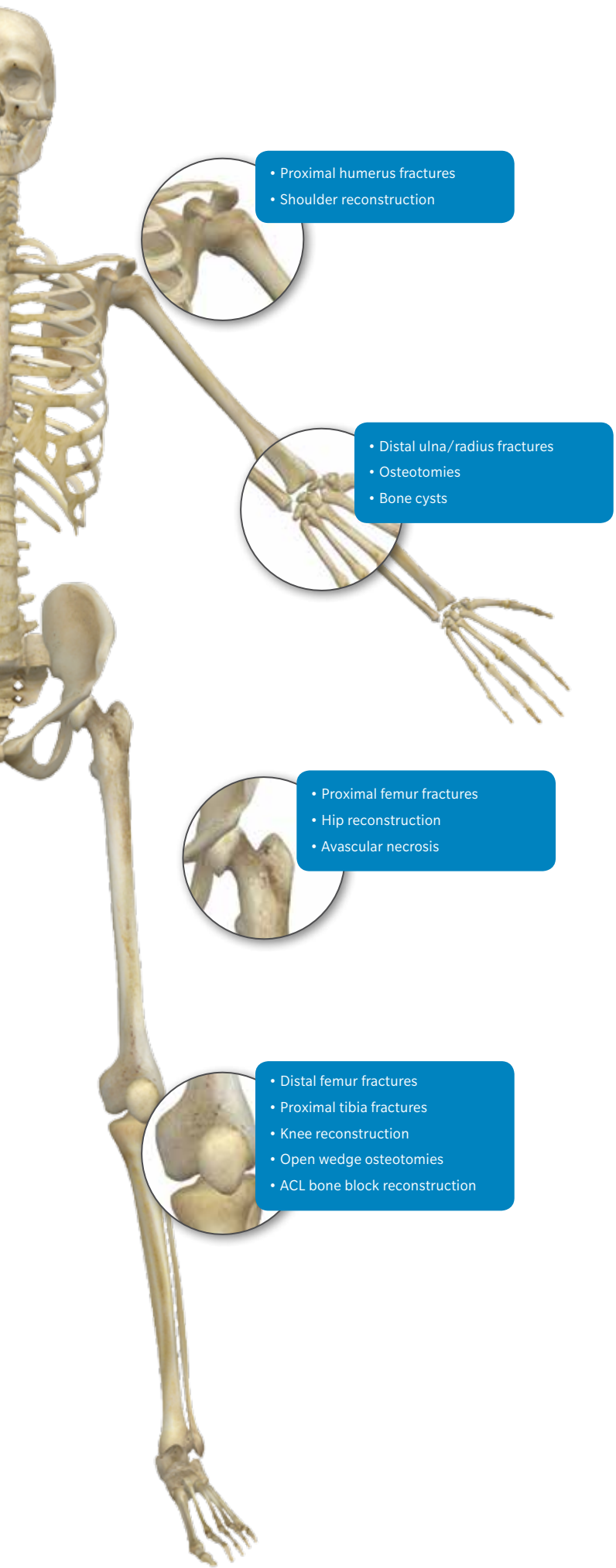


Figure 5.
Examples of bone graft applications



Average Pricing for Bone Grafting Products [22-25]	
Autograft	$1, 465
Growth Factor (such as Infuse Bone Graft), 10cc	$5,000
DBM Putty, 10cc	$1,531
Bone Graft Substitutes, 10cc	$1,994
Allogeneic Cell Matrices, 10cc	$4,223
BMA Kit with Cancellous Chips, 15cc ($175 + $242)	$417

Table 1. Comparison of average pricing for commonly used bone grafting products.

Clinical Applications

BMA combined with graft materials, such as autograft or allograft/DBM or synthetic bone substitutes, may be used in a variety of orthopedic bone grafting applications. Figure 5 illustrates examples of clinical applications for the use of BMA in bone grafting.

Conclusion

Like autograft, BMA is a rich autologous osteogenic cell source. Increased graft site morbidity, OR time and quality/availability concerns present significant challenges with the use of autograft. BMA combined with appropriate graft materials is an excellent, cost-effective choice for bone grafting.

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