Bone Marrow Aspiration: Technique, Grafts, and Reports

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There are 4 main elements necessary for successful bone grafts of the mandible and maxilla: soluble regulators, a resorbable matrix, stabilization of the matrix during healing, and cells. Soluble regulators are acquired from the blood. An abundance of resorbable matrices are available to the surgeon. Stabilization of the matrix can be achieved with guided resorbable membranes, titanium mesh, bone tacks, and screws. However, cells are the most critical component of a successful bone graft. More specifically, osteoblasts must populate the matrix in sufficient quantity to form bone.¹

Cells are the answer. Without osteoblasts or precursor cells, bone will not form.² The “gold standard” for bone grafts suggests that harvested autogenous bone will provide osteoblasts.³,⁴ A recent article by Soltan et al.⁵ presents the rationale and method of obtaining adult stem cells from bone marrow aspirate that differentiates to osteoblasts.

Bone is encircled by periosteum of dense connective tissue that contributes to the generation of osteoblast. It has 2 layers: an outer fibrous layer with typical fibroblasts; and an inner cellular layer, which contains osteoprogenitor cells that are capable of contributing to osteoblasts.⁶,⁷ In addition, a layer of cells called the endosteum (endosteal cells) lines the marrow surface of compact bone. Like the periosteal cells, these endosteal cells are also osteoprogenitor cells capable of becoming osteoblasts.⁸

This article describes a technique for obtaining adult stem cells from bone marrow aspirate. Case reports show how this procedure might replace the gold standard for bone grafts with the platinum standard of obtaining stem cells. The bone marrow aspirate and transplantation of adult stem cells within the resorbable matrix and under the influence of soluble regulators have the potential for introducing the platinum standard for bone grafts. There are several advantages to using bone marrow aspirate. The technique is simple, a second surgical site is not needed, there is minimal postoperative morbidity, and adult stem cells populate the graft site with osteoblasts. (Implant Dent 2006; 15:229–235)

Key Words: adult stem cells, aspirant, bone graft, surgery, autogenous bone

Osteoblasts and/or adult stem cells or primitive mesenchymal cells may also be present in the cancellous compartment of the recipient site. Osteoblasts are also found in adjacent decorticated bone, harvested autogenous bone, circulating blood, or bone marrow aspirate. If osteoblasts are not present at the recipient site, they must be harvested as a graft material.¹⁰ The absence of osteoblasts will cause graft failure.

Stem Cells

By definition, stem cells are capable of both self-renewal and differentiation into a mature cell type. Stem cells divide to form one daughter cell that goes on to differentiate and one daughter cell that retains its stem cell properties. Differentiation of stem cells is based on their species of origin, tissue of origin, or differentiation capability of ≥1 specific type of the mature cells.¹¹ Some stem cells are more pluripotent than others. For example, all cells within the early embryo are totipotent up until the 16-cell stage or so and are thought to be the only single cells capable of differentiating into any cell type.¹²,¹³ Adult stem cells are pluripotent but have more limited differentiation ability and, thus, are considered multipotent. Multipotent stem cells are only committed to differentiate to a limited number of types of cells that have a specific function (e.g., cells that contribute to all the cells of the blood [hematopoietic stem cells] and other committed stem cells, such as mesenchymal stem cells). Mesenchymal stem cells are multipotent, reside in the bone marrow of adult human beings, and have differentiated into bone, fat, muscle, cartilage, and neurons.¹⁴ These cells have been used to repair successfully a large cranial defect in a human patient.¹⁵ Where do we find mesenchymal stem cells, osteoblasts, and the precursor for osteoblasts?

Bone Marrow

Bone marrow is found in the center of large flat bones and can be transplanted. Bone marrow contains abundant adult stem cells. Recent studies have shown that adult stem cells are more plastic than previously thought.¹⁶ The term plasticity refers to the ability of adult stem cells to cross lineage barriers, and adopt the expression and function of other cell type.¹⁷,¹⁸ It might be that adult stem cells hold the same clinical potential of embryonic stem cells, thus allowing researchers to bypass the ethical and practical issues related to the
preparation and use of embryonic stem cells.19

Bone marrow-derived stem cells include hematopoietic stem cells,20,21
marrow stromal cells (mesenchymal stem cells),22,23 and multipotent adult
progenitor cells.24,25 Bone marrow represents the main source of mesenchymal
stem cells.26 The hematopoietic cells are irreversibly committed toward a blood
lineage, but other stromal cells can differentiate to form adipocytes, chondro-
cytes, osteoblasts, and other connective tissue cells.27,28 Therefore, transplanta-
tion of marrow cells contributes to hematopoietic and osteogenic cells. A
central issue concerning bone formation regards the developmental lineages of
osteoblasts and osteoclasts. Osteoblasts derived from mesenchymal cells present
in the skeletal environment: bone.29 Osteoclasts are derived from blood-borne
monocyte/macrophage cells.30,31

Living cells, particularly bone marrow cells, make cellular contributions to
bone formation. Marrow cells promote osteogenesis.32-34 Bone marrow contains
osteoblast precursors that can differentiate into the mature osteoblasts that are
needed to promote osteogenesis.35 Developing a method and technique to har-
vest bone marrow and its osteoblastic precursor cells, and subsequently, im-
plant them into sites of impaired bone healing or bone-graft matrix might lead
to a new approach, a “platinum standard” for bone regeneration.

Bone Marrow Aspiration Technique

The delivery of pluripotent mesenchymal stem cells within a resorbable
matrix to induce osteogenesis has been successful.36 The evidence that bone
marrow fosters successful grafts is compelling and indicates that significant
bone formation occurs when marrow is implanted in osseous defects.37,38 Bone
marrow can be extracted from the sternum, posterior ilium, or anterior ilium.
The technique of autogenous bone marrow aspiration and grafting is virtually
free of complications. Bone marrow aspiration and injection can be per-
formed as outpatient procedures with the patient under oral sedated and lo-
cal anesthesia, intravenous sedation, or general anesthesia.

Anterior Iliac Crest Bone Marrow Aspiration

The patient is lying in a prone po-
sition, and garments are removed to ex-
pose the anterior wing of the ilium. The
border of the anterior wing is palpated.
Palpation of the medial and lateral wall
of the anterior ilium orients the site of
needle puncture. The skin is stretched
between 2 fingers over the bone crest
identifying the thickness of the bone
crest (Fig. 1). The anterior position of
the iliac crest and site of needle puncture
can be outlined. The site is prepared
with Betadine (Purdue Pharma L.P., Stamford, CT) solution, and an adhesive drape is placed over the aspiration site. Xylocaine (AstraZeneca Pharmaceuticals LP, Wilmington, DE) local anesthesia is placed under the skin. A longer needle is used to identify the midpoint of the iliac crest and deposit 3–4 mL 2% Xylocaine under the periosteum (Fig. 2).

A “J” needle (Jamshidi Bone Marrow Biopsy and Aspiration Tray; Cardinal Health, McGaw Park, IL) is inserted by hand through the skin into the anterior/posterior iliac wing (Fig. 3). The needle is rotated gently into 1 cm of the marrow cavity. The stylet is removed from the needle and a 5-cc syringe attached. Bone marrow is aspirated by retraction of the plunger of the syringe (Fig. 4). After 2–3 mL of marrow is collected, the needle can be repositioned if more marrow can be obtained, if needed. The marrow is aspirated with a glass syringe in 3–5-cc aliquots with repositioning of the needle after each aspiration. This procedure is performed to ensure that marrow is aspirated rather than venous blood. The syringe is removed from the needle, and the needle is removed from the marrow space with an upward twisting motion. Pressure is placed over the aspiration site for 5 minutes, and a bandage is placed.

**Case No. 1.** The bone marrow aspirate is mixed with resorbable matrix in a glass syringe (Fig. 5). After sinus-lift surgery to create the graft recipient site, the graft is deposited with loose compaction to reconstitute the buccal wall of the maxilla (Fig. 6).

### Posterior Iliac Crest Bone Marrow Aspiration

The patient is lying flat and turned onto the hip. The bottom leg is extended straight, and the upper leg is bent at the knee. The patient is prepared and draped as usual for this procedure. The juncture of the sacroiliac region is palpated, and the finger is moved up away from the space over the broad crest of the posterior iliac wing. Following injection of local anesthesia, the biopsy needle is placed through the skin, over the iliac crest, and rotated 1 cm into the marrow space. The stylet is removed, syringe is attached, and bone marrow aspirate is taken (Fig. 7).

**Case No. 2.** This 42-year-old female patient presents with partially edentulous maxilla. There is insufficient bone height of the right posterior maxilla for placement of implants. In addition, there is severe atrophy of the anterior maxilla. The treatment plan is sinus-lift subantral bone graft augmentation of the posterior maxilla. Bone graft of the anterior maxilla will add sufficient bone for implants to support fixed crown and bridge restorations.

The atrophic recipient site was prepared and decorticated. There were 2 cortico-cancellous allograft bone blocks contoured to fit the anterior recipient site. Care was taken not to over contour the bone blocks at the expense of the cancellous bone. Transosseous lag screws stabilized the bone blocks for contouring and decortication, with small fissure burs, of its cortical surface. The bone blocks were removed and placed in an occluded syringe. The bone marrow aspirate was placed in the syringe covering the bone block. The plunger was placed, the syringe inverted to expel air, and the needle port again occluded. Pulling back on the plunger created a vacuum and saturated the bone blocks with marrow aspirate (Fig. 8). Particulate resorbable matrix saturated with the
marrow aspirate was mortised over the bone blocks (Fig. 9). The mucoperiosteal flap was closed and sutured without tension on the incision.

**Sternum Bone Marrow Aspiration**

In this awake patient, the area of the sternum below the suprasternal notch is shaved and prepared in the usual manner (Fig. 10). Subcutaneous local anesthesia is given (Fig. 11). Approximately one inch below the notch, the needle finds the cortical plate of the sternum, and anesthesia is deposited under the periosteum (Fig. 12). It is important that the length of needle passing from skin to making contact with bone is noted and recorded. The needle guard of the syringe is locked to expose the length of needle as noted when giving local anesthesia (Fig. 13). This procedure is important so that the aspiration needle passes through only the outer cortex into the marrow space and not through the inner cortex into the aorta (Fig. 14). The syringe is connected to the needle after the stylet is removed and bone marrow drawn into the syringe. The needle is twisted as it is removed from the bone, leaving a small puncture (Fig. 15) that is covered with a Band-Aid (Johnson & Johnson, Somerville, NJ).

**Case No. 3.** A 52-year-old male presented with partially edentulous mandible and failing right canine, first bicuspid, and molar teeth. The indicated teeth were extracted, and the sockets debrided irrigated and decontaminated of the dental lamina. The porous resorbable matrix was saturated with bone marrow aspirate and placed in the sockets. The mucoperiosteal flap was reposited and sutured without tension (Fig. 16).

**Conclusions**

Using autogenous bone marrow grafts to promote osteogenesis in resorbable matrix has the following advantages:

1. Aspirated autogenous bone marrow used in conjunction with a resorbable allograft or xenograft matrix has ideal properties for stimulating bone osteoinduction and osteoconduction.
2. The aspiration technique is relatively simple and can be performed on an outpatient basis.
3. The need for an open surgical site to harvest autogenous bone is eliminated, along with any attendant complications.

**Disclosure**

Dr. Dennis Smiler claims to have a financial interest in Dentisply. CeraMed, as a consultant, whose products are shown in this article. Dr. Mona Soltan claims to have no interest in any company whose products are mentioned in this article.

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Abstract Translations

**GERMAN / DEUTSCH**

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**Aspiration des Knochenmarks:** Technik, Berichte, Transplantate


**SCHLÜSSELWÖRTER:** ausgereifte Stammzellen, Aspirat, Knochentransplantat, chirurgischer Eingriff, autogenes Knochengewebe

**SPANISH / ESPAÑOL**

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**La aspiración de la médula ósea:** Técnica, Informes, Injertos

**ABSTRACTO:** Este artículo describe una técnica para obtener células madre adultas de la aspiración de la médula ósea. Los informes del caso muestran cómo este procedimiento podría reemplazar al procedimiento conocido para los injertos de hueso como la norma de plato para obtener células madre. La aspiración de la médula ósea y el trasplante de células madre adultas dentro de la matriz que se reabsorbe y bajo la influencia de reguladores solubles tienen el potencial de introducir la norma de plato en los injertos de hueso. Hay varias ventajas en el uso de la aspiración de la médula ósea. La técnica es simple, no se requiere un segundo sitio quirúrgico, existe una morbo- sidad postoperatoria mínima y las células madre adultas pueblan el sitio del injerto con osteoblastos.
RESUMO: Este artigo descreve uma técnica para obter células-tronco adultas a partir de aspirado de medula óssea. Os relatos de caso mostram como esse procedimento poderia substituir o padrão de ouro de enxertos ósseos com o padrão de platina de obtenção de células-tronco. O aspirado de medula óssea e o transplante de células-tronco adultas dentro da matriz reabsorvível e sob a influência de reguladores solúveis têm o potencial de introduzir o padrão de platina para enxertos ósseos. Há várias vantagens em usar aspirado de medula óssea. A técnica é simples, um segundo local cirúrgico é necessário, há morbidade pós-operatória mínima e as células-tronco adultas povoam o local do enxerto com osteoblastos.

PALAVRAS-CHAVE: células-tronco adultas, enxerto ósseo, cirurgia, osso autólogo
骨髓穿刺：技巧、报告、移植

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摘要：本文描述從骨髓抽出液取得成人幹細胞的技巧。案例報告顯示此程序可能以鉑金標準的幹細胞取代黃金標準的骨移植。在可吸收基質內與在可溶解調節器的影響下，成人幹細胞骨髓抽出液與移植有引進骨移植鉑金標準的潛在可能。利用骨髓抽出液有多項優點，其技巧很簡便，不需要別外科部位，僅有最低的術後發病率，而且成人幹細胞能以成骨細胞在移植部位繁殖。

關鍵字：成人幹細胞、抽出液、骨移植、外科手術、自體骨

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