

# Monograph



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# Preface

This document will provide the following:

- Introduction to epidermal grafting and the CELLUTOME<sup>™</sup> Epidermal Harvesting System
- Literature review of epidermal grafting
- Description of CELLUTOME<sup>™</sup> Epidermal Harvesting System
- Science supporting epidermal grafting
- Clinical case studies

# Introduction

Skin grafts have been used to achieve successful wound healing when primary wound closure is not a feasible repair option.

Traditional types of autografts include full-thickness and split-thickness skin grafts. Some disadvantages of autografts include the need for a surgical procedure with anesthesia, creation of a second wound at donor site, difficulty in obtaining uniform graft thickness, pain, and challenges with graft take and graft rejection. Allografts and xenografts address some of these disadvantages. However, chances of graft rejection are greater with allografts and xenografts than autografts. Typical grafting techniques include the use of biologics and skin substitutes, surgical techniques, and standard wound care (moist wound healing). Some of these treatment modalities are painful procedures, require long recovery times for the donor site, and may increase operating room costs and potential donor site complications, such as infection. The rates of donor site complications vary, depending on donor site location, comorbidities of the patient, and other risk factors, and can be as high as 28%.<sup>1,2</sup>

Epidermal skin grafts offer an alternative to traditional autografts and use only a minimal amount of autologous tissue from the donor site. Epidermal skin grafts differ from full-thickness and split-thickness skin grafts in that they only contain the epidermal layer of the skin (Figure 1), which is comprised of 5 layers and 4 cell types. The cell types of most relevance to epidermal grafting are keratinocytes and melanocytes, which play an important role in reepithelialization and repigmentation, respectively. Specifically, basal keratinocytes are the key epithelial cells responsible for wound closure. Reepithelialization is an important aspect to the proliferation phase of wound healing during which epithelial cells cover the wound surface. Good wound bed preparation (ie, adequate granulation tissue formation) is also necessary for reepithelialization to occur with the use of epidermal skin grafts.

Various methods of epidermal skin grafting have been developed and expanded throughout the years since Jacques-Louis Reverdin first used small, full-thickness skin

pieces as grafts for wound healing in 1869.<sup>3</sup> The Reverdin technique (ie, epidermic grafting) consisted of removing the epidermis with a needle point and transplanting it to a granulating wound bed to assist with epithelialization.<sup>4</sup> Pinch grafting involves the harvesting of small areas of skin that will be used over a wound, enabling epithelialization from the wound edge to the graft. Patch/postage stamp grafts allow for more uniform skin islands to be created and involve removing donor pieces of skin and placing them (dermis side up) on sheets of sticky paper. The paper is then cut into strips, placed on another piece of paper, and then cut horizontally into small squares. In 1958, C. Parker Meeks introduced the dermatome, which creates skin pieces from small donor skin areas. A thin, standard split-thickness skin graft is placed dermal side down on a cork carrier, which is then placed on the cutting block of the microdermatome. Both the carrier and graft are passed through the dermatome. The carrier is then moved 90 degrees and passed through again to create the micrografts.

Several studies have demonstrated successful use of epidermal skin grafting using suction blisters in pigmentation disorders, such as both nondermatomal and segmental vitiligo<sup>3, 5-8</sup> as well as for lesions of chronic discoid lupus erythemaosus.<sup>9</sup> When treating pigmentation disorders using epidermal skin grafting, the recipient site is dermabraded mechanically (eg, sand paper) or chemically (eg, lasers and liquid nitrogen) in order to remove the existing hypopigmented epidermis. This creates a superficial wound that is then covered with autologous transplanted epidermal skin grafts. The use of epidermal grafting has effectively transitioned into use in acute and chronic wounds, most notably in burns and in cases of leg and foot ulcers.<sup>10-18</sup> However, the value of epidermal skin grafting to close wounds has traditionally had limited use in clinical practice due to the lack of a reliable and automated methodology for harvesting patient epidermal skin. Additionally, the previous harvesting methods were often tedious and time consuming. This has led to the development of a suction blister harvesting system that simplifies the harvesting process: the CELLUTOME™ Epidermal Harvesting System.



#### Figure 1. Schematic of Skin Layers

The CELLUTOME<sup>™</sup> Epidermal Harvesting System (Figure 2) is a minimally invasive tool for harvesting epidermal micrografts and is designed for use in the office or outpatient setting. This system combines suction and warmth and produces consistentthin sections of epidermal skin. The technology of thedevice involves splitting the dermal-epidermal junction to formmicrodomes (ie, blisters), which are harvested into epidermal micrografts. These micrografts consist of undamaged epithelium with keratinocytes. The benefits of epidermal skin grafting using suction microdomes are listed in Table 1.<sup>15-17,19</sup>

The purpose of this document is to review the literature relating to epidermal grafting in wound healing, describe the CELLUTOME<sup>™</sup> Epidermal Harvesting System, provide scientificevidence supporting its use for harvesting epithelium, and provide examples of epidermal grafting applications, including donor site outcomes.

#### **Literature Review**

Epidermal grafting for dermatological use is well-documented in the literature, specifically in treating vitiligo<sup>3, 5-8</sup> and lesions of chronic discoid lupus erythemaosus.<sup>9</sup> **Table 2** summarizes the literature on epidermal grafting for the treatment of wounds.

Serena, et al.<sup>10</sup> (2015) reported their initial clinical experience

Figure 2. CELLUTOME<sup>™</sup> Epidermal Harvesting System



Table 1. Benefits of Epidermal Skin Grafting

#### Benefits

- Minimally invasive procedure
- Can be performed in the office/outpatient setting
- Does not require anesthesia at the donor site Minimal patient discomfort with procedure
- Minimal scarring at donor site
- Autologous grafts
- Keratinocytes are sufficient for graft acceptance
- Provides consistent microdome spacing and proper graft orientation
- Optimizes cosmesis of the donor site
- Patients willing to undergo multiple epidermal grafts
- Operation technique and postoperative care are simplified and convenient
- Less expensive/cost-effective alternative to skin substitutes

using the CELLUTOME<sup>™</sup> Epidermal Harvesting System for harvesting epidermal grafts when they treated 7 Haitian patients with chronic lower extremity wounds. In contrast to previous methods of raising microblisters that took from 1 to 4 hours, the average time for epidermal microdome formation with the CELLUTOME<sup>™</sup> Epidermal Harvesting System was 32.8 (range 25-35) minutes. Of the 7 wounds, 3 closed completely in 4 weeks and 3 showed marked improvements. According to the authors, inability to adequately secure the graft on the 7th patient's thigh may have contributed to the lack of improvement in this 2-year-old wound. All donor sites healed without any visible scarring. The harvesting of epidermal grafts using CELLUTOME<sup>™</sup> Epidermal Harvesting System was accomplished in an outpatient setting and did not require anesthesia or specialized surgical technique. Thus, epidermal grafting may provide a promising option for patients in resource-poor countries.<sup>10</sup>

Gabriel, et al.<sup>11</sup> (2014) provided a general overview of epidermal grafting and reported results of 4 patients treated with epidermal grafts harvested by the CELLUTOME<sup>™</sup> Epidermal Harvesting System from patients' thighs. Complete reepithelialization was achieved in 3 wounds: a heat burn to the right radiated breast, right scalp melanoma excision site, and wound created after removal of a sacral tattoo. The fourth wound was a diabetic foot ulcer of 8 years' duration that maintained 50% reepithelialization at the 2-month follow-up. All donor sites healed without scarring within 1-2 weeks. The authors concluded that epidermal skin grafting was found to be a viable reconstruction option for three out of the four wounds; additional studies evaluating efficacy of epidermal skin grafts and cost effectiveness of using this harvesting system are needed.<sup>11</sup>

Richmond, et al.<sup>12</sup> (2014) treated 5 patients with chronic recalcitrant lower extremity ulcers (pyoderma gangrenosum) with epidermal grafts harvested by the CELLUTOME™ Epidermal Harvesting System. The epidermal grafts were covered with absorbent foam dressings, and the patients' legs were wrapped in 4-layer compression bandages. All patients continued to receive medical care for pyoderma gangrenosum. Three of the 5 wounds achieved full reepithelialization at 5, 7, and 12 weeks, respectively. The remaining 2 wounds reduced in size by 64% and 99%, respectively, within 8 weeks. Minimal pain was associated with the procedure, and all donor sites healed within 1 week. There were no complications at donor and recipient sites. The authors noted that the epidermal grafts did not appear to "take" and that reepithelialization moved in from the wound edges.

Costanzo and Braathen<sup>13</sup> (2008) investigated the use of autologous suction blister grafting for chronic leg ulcers. Eighteen patients with 29 chronic leg ulcers were treated with epidermal grafts from the lower abdomen. The suction device was comprised of an oil rotary vacuum pump, manometer, and rubber tubes that connected to suction cups. The suction cups had 5-40 openings on one side and were fixed to the lower abdomen. Blisters were produced using -200 to -300mmHg negative pressure for 2-3 hours, excised using a spatula-like scalpel, and then transferred to the ulcer. The grafts were covered with non-adherent dressings and gauze bandages, followed by a compression bandage. Only those wound beds with at least 50% granulation tissue formation and no necrotic tissue received grafts. Results showed that 89% of the ulcers were completely healed 12 weeks after grafting. Most ulcers also demonstrated a stimulation of reepithelialization from the wound edge and increased healthy granulation tissue formation. The authors concluded that autologous epidermal grafting is a viable treatment for chronic leg ulcers.<sup>13</sup>

Ichiki and Kitajima<sup>14</sup> (2008) presented a case study of a patient with scleroderma and a refractory toe ulcer that was successfully treated with suction blister grafting. Comorbidities included sclerodactylia, arthralgia, and Raynaud's phenomina. Patient received intravenous antibiotics and underwent surgical therapy in which the necrotic bone was removed and ulcer debrided thoroughly. An artificial bilayer dermis was then used over the ulcer bed for 28 days. The suction blister graft was taken from

the inner thigh using syringes and a three-way stopcock. Blisters were completely formed after 2 hours and were removed by cutting around the periphery. The epidermal grafts were lifted with intertulle gauze, placed over the ulcer, and then wrapped in a pressure dressing. After 14 days, there was complete improvement of the graft.<sup>14</sup>

Burm, et al.<sup>15</sup> (2007) evaluated the use of superficial dermabrasion and suction blister epidermal grafting for the treatment of postburn dyspigmentation in 23 patients. Superficial dermabrasion was performed on the variable pigmented and irregular skin surfaces. Epidermal grafts were harvested from the thigh and abdomen to cover the hypopigmented lesions and from the buttock or sole of the foot for hyperpigmented lesions. Blisters were produced using a suction pump (250-300mmHg) and suction cups with a one-way check valve. Small vesicles were formed within 1.5 hours followed by a complete blister 3-4 hours later. The blisters were removed with iris scissors and placed over the dermabraded skin areas. Results showed that all grafts had taken completely within 4 or 5 days postoperatively and without any complications during the follow-up period.<sup>15</sup>

Hanafusa, et al.<sup>16</sup> (2007) presented a case study of a patient with chronic renal failure and arteriosclerosis obliterans who suffered a wound with exposed bone on the left great toe.

Patient had been receiving hemodialysis for 6 years. Necrotic tissue was debrided and exposed bone was shaved with a bone scraper until bleeding from bone marrow was observed. Occlusive dressings were used and further debridement

occurred until completion of healthy would bed preparation. Blisters from the abdomen were produced using syringes and a three-way stopcock that created enough negative pressure to cause a blister to form within 30 minutes.

Blisters were excised with scissors and then placed over the wound followed by 4 days of occlusive dressing therapy. Results showed that aggressive debridement and epidermal grafting was effective. The wound healed in 13 weeks.<sup>16</sup>

Yamaguchi, et al.<sup>17</sup> (2005) compared the use of an experimental therapy (n=7) of bone marrow exposure, occlusive dressings, and epidermal grafting to standard therapy (n=8) of local wound care, debridement, bed rest, and parenteral antibiotics in patients with rheumatic diseases who had wounds with exposed bones. Epidermal grafts were harvested under local anesthesia from the abdomen or anterior thigh. Blisters were produced using syringes and a three-way stopcock that created enough negative pressure to cause a blister to form within an hour. Blisters were excised using a scalpel and then placed over the wound. Results showed that the healing rates of both therapies were similar; however, the experimental therapy using epidermal grafting reduced the risk of amputation (p=0.020).<sup>17</sup>

Yamaguchi, et al.<sup>18</sup> (2004) compared epidermal sheets obtained from suction blisters and standard local wound care for treating intractable (ie, ulcers that did not respond to conservative treatments) diabetic foot ulcers (DFUs). A total of 38 patients were enrolled in this study and were compared as follows: 10 patients with DFUs without exposed bone who received epidermal grafts vs 8 patients who received standard therapy and 11 patients with DFUs with exposed bone who received an initial occlusion dressing followed by epidermal grafts vs 9 patients who received standard therapy. Epidermal graft sheets were obtained from suction blisters harvested under local anesthesia from the abdomen or the anterior thigh. Blisters were produced using syringes and a three-way stopcock that created enough negative pressure to cause a blister to form within an hour. Blisters were excised using a scalpel and then placed over the wound. Because of blister size (1.5cm), several grafts were sometimes used to cover the wound. Standard therapy was composed of local wound care (debridement, bed rest, special cast, and antibiotics, when necessary). Patients with DFUs without exposed bone who received epidermal grafts had significantly shorter healing times compared to patients who received standard therapy  $\pm$  0.6 weeks vs 11.6  $\pm$  3.4 weeks, respectively; p=0.042). Patients with DFUs with exposed bone who received epidermal grafts did not require any amputations (0/11) compared to 8/9 patients with standard therapy (p<0.0001).<sup>18</sup>

#### Table 2. Literature Review

Author	Study Type and Patients	Results/Conclusions
Serena, et al. <sup>10</sup> (2015)	Case series of 7 Haitian patients with chronic lower-extremity wounds that were treated with epidermal grafting	<ul> <li>The average epidermal blister formation time was 32.8 (range 25-35) minutes.</li> <li>For lower extremity wounds, 2-layer compression dressings were placed over epidermal grafts.</li> <li>Six of the 7 wounds improved or closed completely in 4 weeks.</li> <li>Three wounds had complete graft take, and 3 showed marked improvement in their wounds.</li> <li>The patient with the 2-year-old thigh wound did not improve (possibly due to inability to adequately secure the graft).</li> </ul>
Gabriel, et al. <sup>11</sup> (2014)	<ul> <li>Case series of 4 patients whose wounds were treated with epidermal grafts.</li> <li>Epidermal skin grafts were raised and harvested from patients' thighs using the CELLUTOME" Epidermal Harvesting System.</li> <li>In addition to the case reports, the authors included a general overview of epidermal grafting.</li> </ul>	<ul> <li>Complete reepithelialization was achieved in 3 of the 4 wounds (heat burn to the right radiated breast, right scalp melanoma excision site, and wound created after removal of a sacral tattoo).</li> <li>The fourth wound (a chronic diabetic foot wound of 8 years' duration) maintained 50% reepithelialization at 2-month follow-up.</li> <li>All donor sites healed without scarring within 1-2 weeks.</li> </ul>
Richmond, et al. <sup>12</sup> (2014)	<ul> <li>Case series of 5 patients with recalcitrant lower extremity ulcers diagnosed as pyoderma gangrenosum.</li> <li>CELLUTOME<sup>™</sup> Epidermal Harvesting System was used to harvest grafts from patients' thighs</li> <li>Absorbent foam dressings were placed over the epidermal grafts, and the patients' legs were wrapped in 4-layer compression bandages.</li> </ul>	<ul> <li>Full reepithelialization was achieved by 3 of the 5 wounds at 5, 7, and 12 weeks, respectively.</li> <li>The remaining 2 wounds had 64% and 99% reductions in ulcer size within 8 weeks.</li> <li>Minimal pain was associated with the harvesting, and all donor sites healed within 1 week.</li> <li>In this series the authors noted that reepithelialization moved in from the wound edges, and the epidermal grafts did not appear to "take" to the underlying tissue.</li> </ul>
Costanzo and Braathen <sup>13</sup> (2008)	<ul> <li>18 patients with 29 chronic, non-healing leg ulcers were treated with epidermal grafting using suction blisters from the lower abdomen.</li> <li>Blisters were formed using a suction device (oil rotary vacuum pump, manometer, and rubber tubes that connected to suction cups) and suction cups, which were fixed to the lower abdomen. Blisters were produced using -200 to -300mmHg negative pressure for 2-3 hours, excised using a spatula-like scalpel, and then transferred to the ulcer.</li> <li>The grafts were covered with non-adherent dressings and gauze bandages, followed by a compression bandage.</li> </ul>	<ul> <li>2-6 weeks post graft, 55% of the ulcers achieved complete healing.</li> <li>12 weeks post graft, the overall healing rate was 89%.</li> <li>Most ulcers demonstrated a stimulation of reepithelialization from the wound edge and increased healthy granulation tissue formation after application of the epidermal grafts.</li> <li>The authors concluded that autologous epidermal grafting is a viable treatment for chronic leg ulcers.</li> </ul>
Ichiki and Kitajima <sup>14</sup> (2007)	<ul> <li>Case study presentation of 53-year-old female with systemic sclerosis (SSc) who presented with a refractory toe ulcer.</li> <li>Patient received intravenous antibiotics and underwent surgical therapy in which the necrotic bone was removed and ulcer debrided thoroughly. This was followed by an artificial bilayer dermis over the ulcer bed for 28 days.</li> <li>The suction blister graft was taken from the inner thigh using syringes and a three-way stopcock. Blisters were completely formed after 2 hours. The epidermal grafts were lifted with intertulle gauze, placed over the ulcer, and then wrapped in a pressure dressing.</li> </ul>	<ul> <li>14 days post graft, there was complete improvement of graft.</li> <li>Authors concluded that suction blister graft is a viable therapy for refractory ulcers associated with SSc.</li> </ul>
Burm, et al. <sup>15</sup> (2007)	<ul> <li>Superficial dermabrasion and suction blister epidermal grafting was performed in 23 patients with postburn dyspigmentation.</li> <li>Epidermal grafts were harvested from the thigh and abdomen to cover the hypopigmented lesions and from the buttock or sole of the foot for hyperpigmented lesions.</li> <li>Blisters were produced using a suction pump (250-300mmHg) and suction cups with a one-way check valve for approximately 4-5 hours; blisters were removed with iris scissors and placed over the dermabraded skin areas.</li> </ul>	<ul> <li>Results showed that all grafts had taken completely within 4 or 5 days postoperatively, and without any complications, during the follow-up period.</li> </ul>
Hanafusa, et al. <sup>16</sup> (2007)	<ul> <li>Case study presentation of 78-year-old male with chronic renal failure and arteriosclerosis obliterans who suffered a wound with exposed bone on the left great toe.</li> <li>Necrotic tissue was debrided and exposed bone was shaved.</li> <li>An epidermal graft sheet harvested (using syringes and a three-way stopcock) from the abdomen was then placed over the wound and occlusive dressing therapy was continued for 4 days.</li> </ul>	<ul> <li>The wound healed in 13 weeks with no recurrence of osteomyelitis and erosion/ulceration.</li> <li>Authors stated that the treatment of bone marrow shaving and epidermal grafting should be recommended for intractable wounds in patients on hemodialysis.</li> </ul>
Yamaguchi, et. al <sup>17</sup> (2005)	<ul> <li>15 patients with rheumatoid arthritis or systemic sclerosis who had wounds with exposed bone were enrolled in this study.</li> <li>7 patients were treated with an experimental therapy (bone marrow exposure, occlusive dressings, and epidermal grafting).</li> <li>8 patients were treated with standard therapy (local wound care, debridement, bed rest, and parenteral antibiotics).</li> <li>Epidermal grafts were harvested under local anesthesia from the abdomen or anterior thigh. Blisters were produced using syringes and a three-way stopcock that created enough negative pressure to cause a blister to form within an hour.</li> </ul>	<ul> <li>Results showed that the healing rates of both therapies were similar.</li> <li>The experimental therapy using epidermal grafting reduced the risk of amputation (p=0.020).</li> </ul>
Yamaguchi, et al <sup>18</sup> (2004)	<ul> <li>38 patients with intractable diabetic foot ulcers (DFUs) were enrolled in the study comparing epidermal grafting versus standard therapy.</li> <li>Epidermal graft sheets were obtained from suction blisters harvested under local anesthesia from the abdomen or the anterior thigh. Blisters were produced using syringes and a three-way stopcock that created enough negative pressure to cause a blister to form within an hour.</li> <li>Standard therapy was composed of local wound care (debridement, bed rest, special cast, and antibiotics, when necessary).</li> <li>10 patients with DFUs without exposed bone received epidermal grafts were compared to 8 patients who received standard therapy.</li> <li>11 patients with DFUs without exposed bone received occlusion dressings and epidermal grafts were compared to 9 patients who received standard therapy.</li> </ul>	<ul> <li>Patients with DFUs without exposed bone who received epidermal grafts had significantly shorter healing times compared to patients who received standard therapy (4.3 ± 0.6 weeks vs 11.6 ± 3.4 weeks, respectively; p=0.042).</li> <li>Patients with DFUs with exposed bone who received epidermal grafts did not require any amputations (0/11) compared to 8/9 patients with standard therapy (p&lt;0.0001).</li> </ul>

# **CELLUTOME<sup>™</sup> Epidermal Harvesting System**

The CELLUTOME<sup>™</sup> Epidermal Harvesting System consists of a CELLUTOME<sup>™</sup> Control Unit, CELLUTOME<sup>™</sup> Vacuum Head, and a CELLUTOME<sup>™</sup> Harvester. The system produces autologous epidermal microdomes for use as skin grafts. An ADAPTIC TOUCH<sup>™</sup> Non-Adhering Silicone Dressing is currently used to transfer the microdomes onto the recipient site. **Table 3** describes the components of the CELLUTOME<sup>™</sup> Epidermal Harvesting System.

#### Table 3. CELLUTOME<sup>™</sup> Epidermal Harvesting System Components

Name/Description	Picture
<ul> <li>CELLUTOME<sup>™</sup> Control Unit</li> <li>Is a reusable component of the system.</li> <li>Creates and regulates the suction (negative pressure: -400 to -500mmHg) and warming (37°C to 41°C) required to raise the epidermal microdomes.</li> </ul>	Celuroge
<ul> <li>CELLUTOME<sup>™</sup> Vacuum Head</li> <li>Is a reusable component of the system.</li> <li>Delivers the negative pressure and warming from the CELLUTOME<sup>™</sup> Control Unit to the CELLUTOME<sup>™</sup> Harvester.</li> </ul>	
Harvester	
<ul> <li>Is a disposable component of the system.</li> <li>Provides the structure for formation of the microdomes.</li> <li>After insertion of the ADAPTIC TOUCH<sup>™</sup> Dressing, microdomes are harvested into micrografts.</li> <li>The ADAPTIC TOUCH<sup>®</sup> dressing is used both to capture the microdomes prior to cutting and transfer the micrografts to the recipient site. In addition, it aids in maintaining proper graft orientation. An ADAPTIC TOUCH<sup>™</sup> Dressing is also placed on the donor site after harvesting of micrografts.</li> </ul>	
Note: a 3M <sup>™</sup> TEGADERM <sup>™</sup> Film may also be used for transferring the microderms. <b>PERFORATION IS REQUIRED</b> .	

# Technology for the CELLUTOME<sup>™</sup> Epidermal Harvesting System

The development of the suction microdomes and the harvesting of the epidermal micrografts are automated, eliminating the need for physician handling of the grafts and resulting in proper graft orientation and simplified application. The film dressing is used to transfer the epidermal micrografts to the recipient site from the donor site (Figure 3). The microdomes form gradually over approximately 30-40 minutes. Visual observation is used to determine optimal harvesting time (Figure 4).

#### Figure 3. Harvesting Procedure



This step is only needed for some treatment procedures

#### Figure 4. Microdome Formation



Initial microdome formation



Partial microdome formation, low microdome height with opaque coloring.



Full microdome formation, optimal microdome height with clear fluid encapsulated in microdome, ready to harvest into micrografts.

# **Indications for Use**

The CELLUTOME<sup>™</sup> Epidermal Harvesting System is intended to reproducibly cut a thin skin graft for autologous skin grafting. There are no contraindications associated with this product. **Table 4** lists warnings and precautions for its use. It is important to read and follow all instructions for use and safety information prior to use.

Table 4. Warnings and Precautions

Warnings	Precautions
<ul> <li>Improper use of the CELLUTOME<sup>™</sup> Epidermal Harvesting System could cause patient injury, bleeding, scarring, inadequate micrografts, prolonged procedure time, incomplete or ineffective procedure, the need to perform harvesting at a second donor site, or patient discomfort.</li> <li>Harvest only from areas of healthy intact skin.</li> <li>Actuating the CELLUTOME<sup>™</sup> Harvester handle prior to complete microdome formation may result in patient pain and/or bleeding.</li> <li>The CELLUTOME<sup>™</sup> Harvester is intended for single use only. Reuse of disposable components may result in wound contamination, infection, and/or failure of the wound to heal.</li> <li>Inadequate cleaning may result in patient contamination. Wipe the CELLUTOME<sup>™</sup> Vacuum Head and the CELLUTOME<sup>™</sup> Control Unit with 70% isopropyl alcohol between each patient use.</li> <li>This system should only be used with the supplied components.</li> </ul>	<ul> <li>CELLUTOME<sup>™</sup> Epidermal Harvesting System should be inspected before use for signs of visible damage and should not be used if there are any indications of damage.</li> <li>All disposable items should be discarded in accordance with local medical waste disposal regulations.</li> <li>Actuating the CELLUTOME<sup>™</sup> Harvester handle prior to the insertion of the film dressing may result in an inability to secure the micrografts for application.</li> <li>The CELLUTOME<sup>™</sup> Vacuum Head should be handled with care. Do not suspend or hold the CELLUTOME<sup>™</sup> Vacuum Head by the tubing.</li> </ul>

# Science Supporting Epidermal Grafting

A post-market, non-comparative clinical trial was conducted to examine the viability, histology, proliferation, and presence of growth factors from microdomes obtained with the CELLUTOME<sup>™</sup> Epidermal Harvesting System.<sup>20,21</sup> Other assessments included characteristics of the donor site and subjective pain assessments.

Epidermal microdomes using the CELLUTOME<sup>™</sup> Epidermal Harvesting System were harvested from the thighs of 15bhealthy human Subjects; 12 of those subjects provided one donor site microdome array with approximately 30 microdomes for each *in vitro* assessment. Approximately 360 microdomes were assessed for viability, proliferation, and histology. The other three Subjects provided one donor site microdome array with approximately 60 microdomes (in one half of the array) for *in vitro* assessment; approximately 180 microdomes were assessed for secreted growth factors at different time points (24, 48, and 72 hours and 7 days).

The donor site (area of inner thigh skin where microdome harvesting occurred) was observed for healing during the study 28-day follow-up period. Additionally, pain assessments were obtained during microdome formation, after harvesting, and at Day 7 post harvest.

# Cell Viability

One quarter of each microdome array sample was assessed for uniform viability using fluorescent microscopy and stereoscopy. Another quarter was used to determine the number of live cells per individual microdome using flow cytometry cell counts.

#### Results

- Overall, a 99.5% viability of epidermal microdome samples from all 12 subjects was achieved (**Table 5**), and microdome arrays demonstrated uniform viability (**Figure 5A**).
- Figures 5B and 5C show staining of cells from a single microdome at different levels of magnification. The green staining is indicative of viable cells.
- Results from flow cytometry demonstrated live cells, confirming the viability of cells assessed visually

Table 5. Viability of Harvested Epidermal Microdome Arrays

Parameter		Statistic	Overall (N=12)	
Percentage Live		n	12	
Microdomes		Mean	99.5	
		Median	100.0	
		Standard Deviation	1.20	
		Standard Error	0.35	
		Minimum	96.6	
		Maximum	100	
Was Uniform	Yes	n	12	
Viability Achieved?		%	100.0	
	No	n	0	
		%	0.0	

Figure 5. Images of Cell Viability

A. Image of microdomes at 4.9x magnification used to assess the number and uniformity of microdomes in the sample.





**B.** Expanded image (82x magnification) of one microdome, showing cell viability (ie, green staining).





**C.** Further expanded image (100x magnification) of one microdome, showing cell viability (ie, green staining).

# Histology

One quarter of each microdome array sample was assessed for microdome formation at the dermal/epidermal (DE) junction using histological analysis. Microdome cross sections were stained with the cellular proliferation marker Ki67 (brown) and counterstained with hematoxylin (blue). Ki67 is a proliferation antigen found exclusively in basal layer skin cells.

#### Results

- Results showed that 100% of microdome arrays produced Ki67-positive microdomes, indicating that microdomes were formed at the DE junction (Figure 6).
- Data showed that epidermal micrografts contained proliferative cells with the potential to migrate and grow out to achieve reepithelialization.

Figure 6. Formation of Epidermal Microdomes at DE Junction



Left Illustration of layers of epidermis; Right Representative stained microdome cross section (100x magnification)

# Cellular Outgrowth

One quarter of each microdome array sample was assessed for cellular outgrowth, or proliferation, of keratinocytes and melanocytes from the DE junction using *in vitro* cell culture analyses on collagen matrices. Fluorescence staining of the plasma membrane, actin, and nucleus were used to highlight the structure of microdome outgrowing cells.

## Results

- All microdome grafts (100%) produced proliferative microdomes capable of cellular outgrowth, which is critical for reepithelialization and repigmentation (Figures 7 and 8).
- Keratinocyte outgrowth was observed from the graft edges for 100% of all samples, and bright field images of one representative sample are shown (Figure 7).
- A colony of keratinocytes (encircled, Figure 7A) emerged soon after harvest. Days after harvest, complete keratinocyte coverage between microdomes was observed (Figure 7B).
- The area between two microdome edges was imaged at a 40x magnification to demonstrate complete growth between microdomes (Figure 7C).
- Melanocyte outgrowth was observed for 100% of all samples; bright field images of one representative sample are shown in Figure 8.
- A colony of melanocytes and keratinocytes (encircled) emerged soon after harvest (Figure 8A). Days after harvest, complete coverage between microdomes by melanocyte/keratinocyte co-cultures was observed (Figure 8B).
- Upon observing cellular outgrowth, cells were stained to highlight the cytoskeleton (actin), cell boundaries (plasma membrane), and cell nucleus (Figure 9).

Figure 7. Keratinocyte Outgrowth



Figure 8. Melanocyte Outgrowth

![](_page_13_Figure_1.jpeg)

Figure 9. Cellular Outgrowth

![](_page_13_Picture_3.jpeg)

Cells were stained to highlight the cytoskeleton (actin), plasma membrane (cell boundaries), and cell nucleus.

# Growth Factors

Approximately one half of a microdome array was used to characterize and quantify the levels of various secreted factors [Granulocyte colony-stimulating factor (G-CSF), Vascular Endothelial Growth Factor (VEGF), Epidermal Growth Factor (EGF), Fibroblast Growth Factor 2 (FGF-2), Platelet-Derived Growth Factor AA (PDGF-AA), Platelet-Derived Growth Factor AB/BB (PDGF-AB/BB), Transforming Growth Factor alpha (TGF- ), and Hepatocyte Growth Factor (HGF)] from suction microdomes at various time points.

# Results

- Results showed that all microdome samples produced VEGF, TGF-, PDGF AA, PDGF AB/BB, HGF, and G-CSF at each time point tested (**Table 6**).
- Growth factor levels were observed to continue to increase over time, reaching a threshold at Day 3 and then remained constant until Day 7 (Figures 10A-10F).
- Each microdome array secreted growth factors important for reepithelialization including: VEGF, TGF-, PDGF AA, PDGF AB/BB, HGF, and G-CSF.
- Data showed that all epidermal microdomes contained proliferative cells capable of secreting critical growth factors important for modulating the wound healing response.

	Microdome (24 hr)	Microdome (48 hr)	Microdome (72 hr)	Microdome (7 day)	HEK Control (7 day)
*EGF	_	-	-	-	-
**FGF-2	_	-	-	-	-
TGF-	+	+	+	+	+
G-CSF	+	+	+	+	+
PDGF-AA	+	+	+	+	+
PDGF-AB/BB	+	+	+	+	+
HGF	+	+	+	+	-
VEGF	+	+	+	+	+

Table 6. Analysis of Secreted Growth Factors

\*The signal to noise ratio for EGF was greater than 1; therefore, results for EGF were not valid.

\*\*The signal for FGF-2 was not detectable in the positive control, HEK; therefore, the results for this analyte were not valid.

![](_page_15_Figure_1.jpeg)

![](_page_15_Figure_2.jpeg)

![](_page_15_Figure_3.jpeg)

\*Growth factor levels increased over time and remained constant until Day 7.

Average (n=3) Secreted TGF- (7 days) 500 -450 400 350 300 pg/ml 250 -15

В

D

F

![](_page_15_Figure_6.jpeg)

![](_page_15_Figure_8.jpeg)

![](_page_15_Figure_9.jpeg)

![](_page_15_Figure_10.jpeg)

![](_page_15_Figure_11.jpeg)

# Donor Site

The donor site of each Subject (n =15) was observed for healing. Pain was also assessed. Donor site healing after microblister harvesting was assessed using a Skin Appearance Scale and Dermal Response Score. After micrograft harvesting and through the follow-up visits, donor site skin appearance in comparison with its surrounding skin was summarized using percentages and digital photographs were collected. Pain during and after microblister harvesting was assessed using the Wong-Baker FACES Pain Rating Scale. The pain score was recorded as: 0 - No Hurt; 1 – Hurts a Little Bit; 2 – Hurts a Little More; 3- Hurts Even More; 4 – Hurts a Whole Lot; and 5 – Hurts Worst.

# Results

Skin assessment results showed that the donor sites appeared to heal with minimal irritation during the follow-up period and showed that 76-100% of donor sites were the same in appearance to the surrounding skin by 14 days after epidermal harvest (Figures 11A and 11B). The pain results showed minimal discomfort from Subjects during microblister formation and harvesting process, suggesting that no anesthesia is required at the donor site. The mean pain score was 1.3 (scale of 1-5) throughout the harvesting process (Figure 11C).

Figure 11A. Donor site images at harvest time and on Days 7, 14, and 28.

![](_page_16_Picture_5.jpeg)

Figure 11B. Dermal response scores post-harvest and at follow-up visits.

![](_page_17_Figure_1.jpeg)

Figure 11C. Average pain scale during and after micrograft harvest procedure. Mean pain score was 1.3.

![](_page_17_Figure_3.jpeg)

# **Clinical Case Studies**

As with any case study, the results and outcomes should not be interpreted as a guarantee or warranty of similar results. Individual results may vary, depending on the patient's circumstances and coandition.

# **Case Study 1: Crushed Left Foot Wound**

Patient was a 23-year-old female who presented with a crushed left foot following a rock climbing accident, resulting in ischemic damage to the tips of all her toes and amputation of the tips of toes 2-3 and total amputation of toes 4-5. There was also extensive tissue loss over the dorsal surface of the lateral foot and chronic refractory osteomyelitis. Prior medical history was unremarkable, and there were no pre-existing comorbidities. She was on no medications and had no surgeries prior to the injury.

After prepping donor site with isopropyl alcohol, epidermal micrografts were harvested from the patient's medial thigh area using the CELLUTOME<sup>™</sup> Epidermal Harvesting System. No anesthesia was necessary before or during the procedure. After approximately 30 minutes, the microdomes were raised and the epidermal grafts were successfully captured onto an adhesive dressing (Tegaderm<sup>™</sup> Film Dressing, 3M Company, Minneapolis, MN). The recipient site was debrided, and the epidermal grafts were immediately placed on the recipient site (Figure 12A). A foam dressing, plus Coban<sup>™</sup> (3M Company) layer, was used to secure the dressing with appropriate bolster.

Epidermal grafts were still visible at one week following removal of film dressing (Figure 12B). At 2 and 3-week follow-up visits, hypergranulation was observed (Figure 12C and 12D). The wound was progressing at 5-week follow-up (Figure 12E) and was completely healed by 6-week follow-up visit (Figure 12F). Patient reported minimal to no pain associated with the harvesting procedure (described as a "slapped skin" sensation), and the donor site healed rapidly and without scarring. The CELLUTOME<sup>™</sup> Epidermal Harvesting System allowed for epidermal skin grafts to be easily harvested as an outpatient procedure with no donor-site morbidity and without need for anesthesia. The goal to initiate epithelialization was achieved using the epidermal grafts.

# Figure 12. Wound on Left Foot

![](_page_18_Picture_7.jpeg)

A. Day of grafting

![](_page_18_Picture_9.jpeg)

E. Wound at 5-week follow-up

![](_page_18_Picture_11.jpeg)

B. Wound at 1-week follow-up, epithelial islands are visible

![](_page_18_Picture_13.jpeg)

F. Wound healed at 6-week follow-up

![](_page_18_Picture_15.jpeg)

C. Wound at 2-week follow-up, full skin bridges seen between hypergranulation buds

![](_page_18_Picture_17.jpeg)

D.Wound at 3-week follow-up

## **Case Study 2: Achilles Heel Wound**

A 52-year-old female patient presented with a postoperative wound on her right leg following repair of an Achilles tendon tear (Figure 13A). The patient had a 50 pack per year smoking history. The wound had been present for 9 months, with no response from previous treatments that included negative pressure wound therapy, enzymatic and sharp debridement, and topical silver alginate and ORC/Collagen dressings. Patient was treated with Trimethoprim Sulfa and a topical silver dressing to control bacterial burden prior to the procedure.

The CELLUTOME<sup>™</sup> Epidermal Harvesting System was used to harvest epidermal grafts from the patient's right inner thigh. Hair was removed from the donor site using clippers, and the skin was prepped with isopropyl alcohol. No anesthesia was required before or during the procedure. After the harvesting procedure, epidermal grafts were placed on a Tegaderm<sup>™</sup> Film Dressing (3M Company, Minneapolis, MN) and subsequently applied to the recipient site. A dressing using foam and a selfadherent wrap (Coban<sup>™</sup>, 3M Company) was used over the epidermal grafts as a bolster, and dressings were changed weekly. Patient was prescribed compression stockings.

One week following application of epidermal grafts, the film dressing was removed from the recipient site along with the dressings (Figure 13B). As demonstrated in the series of photos (Figures 13C-13F), the wound continued to heal steadily with only a single application of epidermal micrografts. No complications were reported, and the wound was completely closed approximately 8 weeks after initial application of epidermal graft. Patient reported minimal pain during the procedure, and donor site healed within 1 week with no visible scarring.

The patient's nonhealing wound had been present for 9 months with minimal response to previous treatments. The entire procedure, including harvesting the grafts, required 30 minutes. In this case, a single application of epidermal grafts and subsequent application of foam dressing and self adherent wrap healed this patient's wound. Patient experienced minimal to no discomfort, and wound improvement was visible at each follow up. The use of CELLUTOME<sup>™</sup> Epidermal Harvesting System allowed for epidermal skin grafts to be harvested easily in the outpatient setting with minimal discomfort.

# Figure 13. Wound on Right Foot

![](_page_19_Picture_6.jpeg)

A. Initial wound at presentation

![](_page_19_Picture_8.jpeg)

**B**. Dressing removal at 1 week post grafting

![](_page_19_Picture_10.jpeg)

C.2 weeks post grafting

![](_page_19_Picture_12.jpeg)

D.3 weeks post grafting

![](_page_19_Picture_14.jpeg)

E. 6 weeks post grafting

![](_page_19_Picture_16.jpeg)

F. 7 weeks post grafting

# **Case Study 3: Lymphatic Filariasis of Dorsum Right Foot**

The patient was a 20-year-old female with lymphatic filariasis involving the right leg who developed a wound on the dorsum of her right foot. Initial wound size was 8.5cm x 4.5cm x <0.5cm (Figure 14A). Compression wrapping controlled her lymphedema, but despite the fact that the wound was clean and granulating, it was not progressing towards closure. In this type of population, past experience shows that wounds associated with this disease can take months to years to heal.

Epidermal microdomes were obtained from the patient's thigh using the CELLUTOME<sup>T</sup> Epidermal Harvesting System. After 35 minutes, the microdomes were raised using the CELLUTOME<sup>T</sup> Vacuum Head, and an adhesive foam dressing was inserted into the CELLUTOME<sup>T</sup> Harvester. The foam served to secure the microdomes and permit transfer to the wound site. By actuating the CELLUTOME<sup>T</sup> Harvester handle, the microdomes were harvested from the thigh, captured onto the foam, and then transferred to the recipient site (Figure 14B). The dressing was held in place using a two-layer compression wrap,  $3M^{TT}$  Coban<sup>T</sup> 2 Layer Compression Therapy.

At one week, we observed nearly 100% take of the micrografts (Figure 14C). Over the next few weeks, the grafts continued to expand covering the wound area, as demonstrated in Figures 14D and 14E. In addition, the patient demonstrated repigmentation of the skin at the Day 30 follow up. Immediately after leaving the clinic at her one month follow-up visit, her right foot was run over by a motor bike. In the congested streets of Port-au-Prince, Haiti, this is not an uncommon occurrence. She returned to the clinic, and removal of the compression wrap revealed an intact graft (Figure 14F). Figure 14G shows the donor site (ie, thigh area) 30 days after harvesting with no visible signs of scarring.

Figure 14. Wound on the Dorsum of the Right Foot

![](_page_20_Picture_5.jpeg)

A. Initial presentation of wound

![](_page_20_Picture_7.jpeg)

E. 21 days post micrograft

![](_page_20_Picture_9.jpeg)

B. Placement of micrograft

![](_page_20_Picture_11.jpeg)

F. Intact micrograft after accident, 30 days post micrograft

![](_page_20_Picture_13.jpeg)

C.1 week post micrograft

![](_page_20_Picture_15.jpeg)

G.Donor site 30 days post micrograft

![](_page_20_Picture_17.jpeg)

D.14 days post micrograft

#### Case Study 4: Foot I&D Abscess

Patient was a 66-year-old female who presented with a wound on dorsum left foot 5 days following drainage of an abscess. Medical history included diabetes, obesity, hypertension and congestive heart failure. While hospitalized, she was treated for 3 days with parenteral piperacillin/tazobactam. She was given oral cephalexin upon discharge and directed to follow up in the outpatient wound care center. The wound was initially treated with silver-hydrofiber dressings, followed by 3% NaCl for one month. Initial wound size before application of an epidermal graft was 1.5cm x 2.3cm x 0.1cm (Figure 15A).

The CELLUTOME<sup>™</sup> Epidermal Harvesting System was used to harvest an epidermal graft from the patient's thigh after prepping the donor site with isopropyl alcohol. The recipient site was gently debrided of soft slough using a bone curette. No anesthesia was required before or during the harvesting procedure. The epidermal microdomes were secured to a Tegaderm<sup>™</sup> Film (3M Company, Minneapolis, MN), harvested, and then placed over the wound **(Figure 15B)**. A nonadherent dressing with gauze bolster was used over the micrografts for seven days. The film dressing was removed seven days following application of epidermal grafts. Subsequent dressings, which consisted of a nonadherent layer covered with dry gauze, were changed twice weekly.

By 3 weeks post epidermal grafting, there was a reduction in wound size to 0.6cm x 1.0cm x 0.0cm (Figure 15C). At 5 weeks, the wound was completely epithelialized (wound size: 0.2cm x 0.2cm x 0.0cm; Figure 15D). No scarring or loss of pigmentation was observed at the donor site, which healed completely after 7 days and required no further care. The procedure required 40-50 minutes, although total physician time in the room was approximately 15 minutes. Patient tolerance of the harvesting procedure was excellent. The CELLUTOME<sup>™</sup> Epidermal Harvesting System offered an opportunity to harvest epidermal micrografts for autologous skin grafts in the office/clinic environment without need for anesthesia.

Figure 15. Wound on the Dorsum of the Left Foot

![](_page_21_Picture_5.jpeg)

A. Initial presentation of wound

![](_page_21_Picture_7.jpeg)

B. Application of epidermal grafts

![](_page_21_Picture_9.jpeg)

C. Wound at 3 weeks post epidermal grafting

![](_page_21_Picture_11.jpeg)

D. Wound completely epithelialized at 5 weeks post epidermal grafting

#### Case Study 5: Foot Wound Due to Spider Bite

A 75-year-old female presented with a witnessed spider bite presumed to be a brown recluse spider due to the clinical progression of swelling, discoloration, necrosis, and subsequent wound formation (Figures 16A and 16B). Patient's medical history included hypertension, hyperlipidemia, coronary artery disease, congestive heart failure, and a cardiac arrest event.

When the necrotic area had demarcated, the eschar was thoroughly debrided (Figures 16B and 16C). V.A.C.<sup>®</sup> Therapy was used to promote the formation of granulation tissue (Figure 16D). After one month, the wound bed had filled with tissue adequate for grafting (Figure 16E). The patient's right thigh was prepped with isopropyl alcohol. Then epidermal micrografts were obtained using the CELLUTOME<sup>™</sup> Epidermal Harvesting System (KCI, San Antonio, TX). After approximately 45 minutes of negative pressure and heat, the resulting epidermal microdomes were successfully captured onto an adhesive film dressing (Tegaderm<sup>™</sup>, 3M Company, Minneapolis, MN) which was perforated to allow fluid drainage. The film with micrografts was placed on the wound bed and affixed with Steri Strips<sup>™</sup> (3M Company). Vaselinated gauze was used as a bolster. One week later, the dressing and film were removed. The wound was redressed with a layer of vaselinated gauze and Steri Strips<sup>™</sup>, and changed weekly. Visible islands of epithelial tissue were present two weeks after application. Patient reported minimal pain associated with the harvesting, and donor site healed without scarring (Figure 16F). Progressive healing was observed (Figure 16G), and complete epithelialization was achieved at six weeks. Over a month, further tissue thickening and remodeling was evident (Figure 16H).

The epithelial islands evident within the wound reflected the viability of the grafted tissue. This facilitated rapid epithelialization of the large, well-granulated wound. This unique wound with full-thickness dermal and subcutaneous tissue loss exhibited the value of micrografting onto traumatic-type wounds. The CELLUTOME<sup>™</sup> Epidermal Harvesting System allowed for rapid and efficient harvesting of epidermal micrografts. There was decreased donor-site morbidity compared to conventional split-thickness skin grafting. Since analgesia, sedation or anesthesia are not necessary, this procedure can be safely performed in the outpatient clinic setting.

#### Figure 16. Spider Bite Wound

![](_page_22_Picture_5.jpeg)

A. Wound at presentation

![](_page_22_Picture_7.jpeg)

E. Wound after 4 weeks of V.A.C.<sup>®</sup> Therapy and day of application of epidermal micrografts.

![](_page_22_Picture_9.jpeg)

B. Eschar on wound bed

![](_page_22_Picture_11.jpeg)

F. Donor site healed at 1 week follow- up

![](_page_22_Picture_13.jpeg)

C. Wound after debridement

![](_page_22_Picture_15.jpeg)

G. Wound at 3 week follow- up

![](_page_22_Picture_17.jpeg)

D. After one week of V.A.C.® Therapy

![](_page_22_Picture_19.jpeg)

H. Wound healed 2 months after micrograft application

![](_page_22_Picture_21.jpeg)

# **Case Study 6: Charcot Foot Deformity**

Patient was a 48-year-old female with diabetes and a Charcot foot deformity. Patient had a non-healing wound, which after post-operative debridement of 5th metatarsal for osteomyelitis, had been treated with hyperbaric oxygen therapy (40 treatments) as well as V.A.C.<sup>®</sup> Therapy with no significant improvements in closure (Figure 17A). Patient's past medical history included diabetes mellitus for 15 years (adequately controlled), fibromyalgia, hemorrhoids, pericarditis and endocarditis (resulting in heart valve replacement), sick sinus syndrome, Barrett's esophagitis, and gastroesophageal reflux disease. Patient had several existing comorbidities including polyps, fibroids, hyperlipidemia, high blood pressure and spinal stenosis. The right foot osteomyelitis had been present for 2 years prior to her 5th ray amputation, and her foot had a severe varus deformity in addition to the Charcot.

The patient's right medial thigh area was used as the donor site for the harvesting of autologous epidermal micrografts using the CELLUTOME<sup>™</sup> Epidermal Harvesting System. Donor site was prepped using isopropyl alcohol and the harvesting device was applied, without the use of anesthesia. After approximately 30 minutes of application of the device, the epidermal microdomes were raised, captured onto an adhesive dressing (Tegaderm<sup>™</sup> Film dressing, 3M Company, Minneapolis, MN), and subsequently placed onto the recipient site that had been debrided prior to epidermal micrograft application. A foam dressing (Mepilex<sup>®</sup>, Mölnlycke, Gothenburg, Sweden) was used as a bolster.

Seven days after application, the film dressing was removed (Figure 17B). At this point, the epidermal grafts were still visible over the wound bed. At 3-week follow up, we noticed that the patient had been ambulating on the foot. As a result, the dressing had been pushed off and rolled dorsally, and the distinct epidermal microdomes seen the week prior were no longer apparent (Figure 17C). However, the wound continued to show healing at week 4 (Figure 17D) and by 5-week follow up, the wound was fully healed after enforcing better offloading (Figure 17E).

The use of CELLUTOME<sup>™</sup> Epidermal Harvesting System in this case allowed for uniform epidermal microdomes to be harvested quickly and easily. The patient reported no pain associated with the procedure, and her donor site healed quickly. Although the epidermal grafts appeared to be accidentally wiped away by poor dressing maintenance, epithelialization had already been stimulated, and the wound was able to achieve full closure at a rate quicker than had been previously been demonstrated in this patient. As the patient refused another surgical procedure, STSG was not an option and epithelialization was achieved using the epidermal grafts in a clinic setting. Overall, the use of epidermal grafts showed to be a good alternative to using an STSG in this patient, with favorable results demonstrated by full healing without a second donor site wound.

#### Figure 17. Charcot Foot Deformity

![](_page_23_Picture_6.jpeg)

A. Wound pre-debridement and prior to application of graft

![](_page_23_Picture_8.jpeg)

B. Wound at 1-week follow up.

![](_page_23_Picture_10.jpeg)

C. Wound at 3-week follow up.

![](_page_23_Picture_12.jpeg)

D. Wound at 4-week follow up

![](_page_23_Picture_14.jpeg)

E. Wound healed at the 5-week follow up.

## **Case Study 7: Pressure Ulcer on Heel**

An 18-year-old female with a history of spina bifida presented with a pressure ulcer on her left heel (Figure 18A), which had failed to heal for 14 months. Previous treatments included offloading (heel protective boots and total contact casting), negative pressure wound therapy, topical growth factors, ORC/Collagen/Silver, Bioengineered skin (Apligraf<sup>®</sup>, Organogenesis, Inc., Canton, MA), and a dressing to control exudate (Drawtex<sup>®</sup>, Medline Inc., Mudelein, IL).

The CELLUTOME<sup>™</sup> Epidermal Harvesting System was used to harvest epidermal grafts from the patient's right inner thigh. Donorsite was prepped with isopropyl alcohol. No anesthesia was required before or during the procedure. After the harvestingprocedure, epidermal grafts were placed on a Tegaderm<sup>™</sup> Film (3M Company, Minneapolis, MN) and subsequently applied to the recipient site. Epidermal grafts were bolstered using Drawtex®, followed by reapplication of a total contact cast. At the time of the first dressing change (Day 3 post grafting, Figure 18B), the ulcer appeared clean with less depth. The Tegaderm<sup>™</sup> Transparent Film Dressing was removed 7 days after application of epidermal grafts (Figure 18C). The dressings were changed twice weekly with application of a non-adherent dressing (ADAPTIC TOUCH<sup>™</sup> Non-Adhering Silicone Dressing, KCI, San Antonio, TX) covered by a secondary antimicrobial absorbent dressing. The wound healed steadily over the next 11 weeks, as demonstrated by a reduction in wound depth and surface area (Figures 18C, 18E-18G). Complete closure was achieved in 12 weeks after a single application (Figure 18H). The treatment course was complicated by a superficial wound resulting from the total contact casting (Figure 18D), which healed within one week with application of a non-adherent dressing and additional cast padding. No other complications were observed. Donor site healed completely one week after harvesting with minimal scarring. The wound remained closed at follow-up one month later. The single application of epidermal grafts and subsequent use of a non adherent dressing in combination with a silver alginate dressing resulted in expeditious closure (12 weeks) of a difficult-to-heal pressure ulcer, which had been present for over a year. The patient experienced minimal to no discomfort. The use of CELLUTOME<sup>™</sup> Epidermal Harvesting System allowed for epidermal skin grafts to be harvested easily in the outpatient setting.

#### Figure 18. Wound on Left Heel

![](_page_24_Picture_4.jpeg)

A. Initial wound at presentation

![](_page_24_Picture_6.jpeg)

E. 7 weeks post grafting

![](_page_24_Picture_8.jpeg)

B. Wound at first dressing change

![](_page_24_Picture_10.jpeg)

F. 10 weeks post grafting

![](_page_24_Picture_12.jpeg)

C.1 week post grafting

![](_page_24_Picture_14.jpeg)

G.11 weeks post grafting

![](_page_24_Picture_16.jpeg)

D. Presentation of surrounding ulcer

![](_page_24_Picture_18.jpeg)

H.Wound closure 12 weeks post grafting

## **Case Study 8: Diabetic Foot Ulcer**

Patient was a 58-year-old male with a non-healing diabetic foot ulcer (DFU) of 5 months duration located on the plantar 5th metatarsal area of the right foot (Figure 19A). Patient previously received collagen dressings and was interested in receiving an autologous epidermal graft. Along with Type-2 diabetes of 23-years duration, the patient also had hypertension.

Epidermal grafts were obtained from the medial thigh area using the CELLUTOME<sup>™</sup> Epidermal Harvesting System (Figure 19B). No anesthesia was required before or during the procedure. The patient felt a little warmth, but reported no pain during the procedure. Epidermal skin grafts were placed on a Tegaderm<sup>™</sup> Film (3M Company, Minneapolis, MN) following the 30-minute harvesting procedure with the CELLUTOME<sup>™</sup> Epidermal Harvesting System. No bleeding was noted on the donor site after removal of the device (Figure 19C). The donor site was covered with Tegaderm<sup>™</sup> Film, and the patient was instructed not to remove the dressing. During the time it took to harvest the epidermal skin grafts, the chronic wound was sharply debrided and copiously irrigated with normal sterile saline. The wound measured 1.5cm x 1.5cm x 0.3cm following debridement. Immediately following lifting of the epidermal skin grafts from the harvesting device, the Tegaderm<sup>™</sup> Film was perforated with an 18 gauge needle to allow for drainage of potential transudate (Figure 19D), and the epidermal grafts were applied to the wound, followed by a non-adherent layer, a modified bolster dressing, and an instant total contact cast. The patient was instructed to leave the dressing intact and to return to clinic in five to seven days.

Five days following application of epidermal skin grafts, the patient scheduled a return visit, and the film dressing was removed. The wound was significantly smaller, measuring 0.5cm x 0.5cm x 0.2cm (Figure 19E). Closer examination of the wound revealed adherence of epidermal skin grafts on the base of the wound (Figure 19F). A non-adherent layer followed by a dry sterile dressing and an instant total contact cast were re-applied, and the patient was instructed to return for follow-up evaluations every one to two weeks. The wound measured 0.3cm x 0.3cm x 0.1cm one week later (12 days following epidermal grafting: Figure 19G) and was completely closed at 24 days post-epidermal skin-grafting (Figure 19H).

The CELLUTOME<sup>™</sup> Epidermal Harvesting System allowed epidermal skin grafts to be harvested easily in the outpatient setting without requiring anesthesia. Because only the epidermal skin layer was removed from the donor site, there was no bleeding, scarring or donor site pain.

Figure 19. Wound on 5th Metatarsal Head Area of Right Foot

![](_page_25_Picture_6.jpeg)

A. Non-healing DFU plantar 5th metatarsal head area of right foot

![](_page_25_Picture_8.jpeg)

E. Wound 5 days following epidermal grafting

![](_page_25_Picture_10.jpeg)

**B.** Microdomes of epidermal grafts formation noted after 30 minutes

![](_page_25_Picture_12.jpeg)

F. Close-up of wound at 5 day follow-up

![](_page_25_Picture_14.jpeg)

C. Donor site following harvesting procedure

![](_page_25_Picture_16.jpeg)

**G**. Wound at 12 days post epidermal grafting

![](_page_25_Picture_18.jpeg)

D. Perforation of Tegaderm<sup>™</sup> Film with 18 gauge needle

![](_page_25_Picture_20.jpeg)

H. Wound closed at 24 days post epidermal skin graft application

## Case Study 9: Venous Leg Ulcer

Patient was a 50-year-old male with a recurrent venous leg ulcer of six-weeks duration on the medial left ankle area (Figure 20A). The ulcer had previously healed using a bio-engineered skin replacement, but the wound re-opened six weeks later. In addition to venous insufficiency, the patient also had gastroesophageal reflux disease and type 2 diabetes for 16 years.

Epidermal grafts were obtained from the medial thigh area using the CELLUTOME<sup>™</sup> Epidermal Harvesting System. No anesthesia was required before or during the harvesting procedure. The patient felt a little tingling and warmth, but he reported no pain during the procedure. Epidermal skin grafts were placed on a Tegaderm<sup>™</sup> Film (3M Company, Minneapolis, MN) following the 30-minute harvesting procedure with the CELLUTOME<sup>™</sup> Epidermal Harvesting System. No bleeding was noted at the donor site after removal of the device. The donor site was covered with Tegaderm<sup>™</sup> Film, and the patient was instructed not to remove the dressing. During the time it took to harvest the epidermal skin grafts, the chronic wound was sharply debrided and copiously irrigated with normal sterile saline. The wound measured 1.0cm x 1.5cm x 0.2cm following debridement. Immediately following lifting of the epidermal skin grafts from the harvesting device, the Tegaderm<sup>™</sup> Film was perforated with an 18 gauge needle to allow for drainage of potential transudate, and the epidermal grafts were applied to the wound (Figure 20B). This was followed by a non-adherent layer, a modified bolster dressing, and four-layer compression. The patient was instructed to leave the dressing intact and to return to the clinic in five-to-seven days.

Five days following application of epidermal skin grafts, the patient scheduled a return, and the film dressing was removed. The wound was significantly smaller, measuring 0.8cm x 0.5cm x 0.1cm (Figure 20C). A non-adherent layer followed by a dry sterile dressing and four-layer compression was re-applied, and the patient was instructed to return for follow-up evaluations every one to two weeks. The wound was 90% epithelialized one week later at 12 days post-epidermal grafting and completely closed at 17 days post-epidermal skin grafting (Figures 20D and 20E).

The CELLUTOME<sup>™</sup> Epidermal Harvesting System allowed epidermal skin grafts to be harvested easily in the outpatient setting without requiring anesthesia. Because only the epidermal skin layer was removed from the donor site, there was no bleeding, scarring or donor site pain.

#### Figure 20. Wound on Medial Left Ankle Area

![](_page_26_Picture_6.jpeg)

A. Presentation of venous leg ulcer on medial left ankle area

![](_page_26_Picture_8.jpeg)

B. Application of epidermal grafts to recipient site

![](_page_26_Picture_10.jpeg)

C.Wound 5 days following application of epidermal skin grafts

![](_page_26_Picture_12.jpeg)

D. Wound 12 days post epidermal grafting

![](_page_26_Picture_14.jpeg)

E. Wound completely closed 17 days post epidermal skin graft

### **Case Study 10: Pressure Ulcer on Sacrum**

Patient was a 48-year-old paraplegic male who presented with two Stage 1 pressure ulcers (PU) to the sacrum (Figure 21A). Medical history included paraplegia secondary to gun shot wound with bullet fragments lodged near his spine, chronic nerve pain, chronic renal failure, Stage V on hemodialysis, chronic anemia, hypertension, and urinary retention with urinary catherization. The patient is wheelchair bound, sleeps on an air mattress, and turns himself every two hours per offloading protocol.

The CELLUTOME<sup>™</sup> Epidermal Harvesting System was used to harvest epidermal grafts from the patient's right inner thigh. Hair was removed from the donor site using a razor, and the skin was prepped with isopropyl alcohol. No anesthesia was required before or during the procedure. After the harvesting procedure, the epidermal grafts were placed on Mepitel<sup>®</sup> One (Mölnlycke Healthcare, Göteborg, Sweden) and subsequently applied to recipient site. A dressing using foam and a gauze bolster was used over the epidermal grafts, and dressings were changed weekly.

One week following application of epidermal grafts, the dressing was removed from the recipient site (Figure 21B). As demonstrated in the series of photos (Figures 21C-21E), the wound continued to heal steadily with only one application of epidermal micrografts. No complications were reported, and the wound was completely closed at 6 weeks (Figure 21F). Patient reported minimal pain during the procedure, and the donor site healed within 1 week with no visible scarring.

The patient's wound had been present for 2 weeks prior to the application of the epidermal grafts. Concurrently, the patient also has a Stage 4 pressure ulcer on the right ischium. Therefore, once the superficial ulcers did not respond to local wound care, the need to close these recent wounds was essential. The use of epidermal micrografts harvested with the CELLUTOME<sup>™</sup> Epidermal Harvesting System was successfully used to close superficial pressure ulcers in this patient.

## Figure 21. Wound on Buttock

![](_page_27_Picture_6.jpeg)

A. Initial presentation on 1/21/14 with two superficial wounds on the buttock. (2.5×2.0×0.1cm inferior buttock PU and 1.0×0.2×0.1cm inferior lateral buttock PU).

![](_page_27_Picture_8.jpeg)

**B**. At postgraft week one, patient's two wounds merged into one wound (2.5×2.5×0.1cm).

![](_page_27_Picture_10.jpeg)

C. Wound at 2 week postgraft follow up.

![](_page_27_Picture_12.jpeg)

D. Wound at 3 week postgraft follow up.

![](_page_27_Picture_14.jpeg)

E. Wound at 5 week postgraft follow up.

![](_page_27_Picture_16.jpeg)

F. Wound completely closed at 6 week postgraft follow up.

## **Case Study 11: Right Breast Burn Wound**

A 56-year-old obese female presented with a third-degree burn on her right radiated breast, sustained from a heating pad 6 weeks prior. Patient was obese with a medical history of bilateral mastectomy followed by right chest wall radiation and delayed reconstruction (tissue extender, implant, and latissimus flap) 3 years prior. At presentation, area of necrosis was debrided, and silver sulfadiazine 1% cream was applied (Figure 22A).

After two debridements and treatment with silver sulfadiazine cream (at 2 months), the CELLUTOME<sup>™</sup> Epidermal Harvesting system was used to harvest an epidermal graft from the patient's right medial thigh after prepping the donor site with alcohol. The epidermal microdomes were secured to a Tegaderm<sup>™</sup> Film Dressing (3M<sup>™</sup>, Minneapolis, MN), harvested, and then placed over a well-granulated wound (Figure 22B). One month after epidermal grafting, wound was 100% reepithelialized (Figure 22C). At 5-month follow up, wound remained closed and demonstrated excellent aesthetic results (Figure 22D). There was full graft take with no complications, and donor site healed completely.

The use of epidermal grafting on this patient proved to be an effective treatment on a wound that had not responded to previous treatment. Epidermal grafting was a good alternative for this recipient site needing epidermal coverage.

#### Figure 22. Wound on Right Breast

![](_page_28_Picture_5.jpeg)

A. Necrosis was debrided, and silver sulfadiazine was applied

![](_page_28_Picture_7.jpeg)

C.One month after epidermal grafting, wound was 100% reepithelialized

![](_page_28_Picture_9.jpeg)

B. At 2 months after two debridements and treatment with silver sulfadiazine cream, epidermal graft is applied to well-granulated wound

![](_page_28_Picture_11.jpeg)

D. At 5-month follow-up, wound remained closed with excellent aesthetic results

## **Case Study 12: Scalp Wound**

A 42-year-old male patient presented with a right scalp defect following wide local excision of melanoma (Clark's level V with Breslow's depth 4.5mm). Wound had been present for 4 weeks and covered with a dry dressing and bilaminate skin substitute. The silicone layer of the bilaminate skin substitute remained on the wound for 4 to 5 weeks and was removed on the day of grafting **(Figure 23A)**.

The CELLUTOME<sup>™</sup> Epidermal Harvesting system was used to harvest an epidermal graft from the patient's right medial thigh after prepping the donor site with alcohol (Figures 23B and 23C). The epidermal microdomes were secured to a Tegaderm<sup>™</sup> Film Dressing (3M<sup>™</sup>, Minneapolis, MN) (Figure 23D), harvested, and then placed over the recipient site. A reticulated open-cell foam was used as a bolster followed by an occlusive dressing to cover the recipient site. Dressings were changed twice. Seven days after placement of epidermal grafts, wound epithelialization was present (Figure 23E). There were no complications, and there was full graft take. Donor site completely healed with no scarring or loss of pigmentation. Scalp wound remained closed at 6-month follow-up with minimal defect (Figure 23F). The use of epidermal grafting provided an effective therapy treatment in this patient's wound.

The use of epidermal harvesting for epidermal grafting was a minimally invasive procedure that did not require the use of anesthesia at the donor site. Epidermal grafting was simple, convenient and effective in treating this patient's scalp wound.

#### Figure 23. Right Scalp Defect

![](_page_29_Picture_5.jpeg)

A. Silicone layer of the bilaminate artificial skin substitute was removed on the day of grafting

![](_page_29_Picture_7.jpeg)

D. A film dressing was used to transfer epidermal grafts to the recipient site

![](_page_29_Picture_9.jpeg)

B. 4 weeks following initial surgery, epidermal grafts were harvested from right thigh

![](_page_29_Picture_11.jpeg)

E. 7 days post-placement of epidermal grafts

![](_page_29_Picture_13.jpeg)

C.Donor site after harvesting of epidermal grafts

![](_page_29_Picture_15.jpeg)

F. At 6-month follow-up, wound remained closed with minimal defect

## Case Study 13: Post Mohs Surgery Ear Defect

An 80-year-old male presented with a squamous cell carcinoma in situ on the helical rim of the ear. Patient was an ex-smoker on 81mg aspirin daily. Mohs surgery was performed on the lesion (0.7cm), and clear margins were confirmed after one stage (Figure 24A). Traditional repair options included second intention healing or full-thickness skin grafting.

Epidermal micrografts were obtained from the patient's thigh using the CELLUTOME<sup>™</sup> Epidermal Harvesting System without use of anesthesia at the donor site. After approximately 40 minutes, the micrografts were raised using the CELLUTOME<sup>™</sup> Vacuum Head, and a film dressing was inserted into the CELLUTOME<sup>™</sup> Harvester, which was used to secure the tops of the micrografts. By actuating the CELLUTOME<sup>™</sup> Harvester handle, the micrografts were harvested from the thigh, captured onto the film dressing, and then placed on the recipient site. In order to facilitate drainage of any potential transudate, perforations were made in the film dressing using an 18g needle. The recipient site containing the micrografts/film dressing was covered with pressure bandaging for 1 week. A new film dressing was applied to cover and protect the donor site (Figure 24D) after removing the CELLUTOME<sup>™</sup> Harvester.

Follow up occurred at 2 (Figure 24B), 4 (Figures 24C and 24E), and 6 (Figure 24F) weeks post micrograft placement. Reepithelialization of the donor site was seen at two weeks, and pain scores provided evidence of minimal discomfort associated with harvesting of these grafts.

#### Figure 24. Post Mohs Surgery Defect

![](_page_30_Picture_5.jpeg)

A. 3 days post surgery

![](_page_30_Picture_7.jpeg)

D. Donor site on day of treatment

![](_page_30_Picture_9.jpeg)

B. 2 weeks post micrograft

![](_page_30_Picture_11.jpeg)

E. Donor site at 4 weeks post micrograft

![](_page_30_Picture_13.jpeg)

C. 4 weeks post micrograft

![](_page_30_Picture_15.jpeg)

F. Donor site at 6 weeks post micrograft

![](_page_31_Picture_0.jpeg)

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![](_page_31_Picture_26.jpeg)