Reconstruction of Burn Scar of the Upper Extremities with Artificial Skin

Taiwan, Republic of China

The management of upper-extremity burn contractures is a major challenge for plastic surgeons. After approval by the Food and Drug Administration, artificial skin (Integra) has been available in Taiwan since 1997. From January of 1997 to July of 1999, the authors applied artificial skin to 13 severely burned patients for the reconstruction of their upper extremities, resulting in an increased range of motion in the upper-extremity joints and improved skin quality. An additional benefit was the rapid reepithelialization of the donor sites. There were no complications of infection throughout the therapeutic course, and the overall results were satisfactory. During the 2-year study, scar condition was monitored between 8 and 24 months, and a good appearance and pliable skin were obtained according to the Vancouver Scar Scale. According to this evaluation of Oriental skin turgor, normal pigmentation was restored about 6 months after the resurfacing procedure. For patients with severe burns in whom there is insufficient available skin for a full-thickness skin graft or another appropriate flap for scar revision, Integra is an alternative. The two major concerns in dealing with artificial skin are (1) a 10- to 14-day waiting period for maturation of the neo-dermis, necessitating a two-stage operation, and (2) prevention of infection with antibiotics and meticulous wound care. (Plast. Reconstr. Surg. 108: 378, 2001.)

In reconstructive surgery, timing is important and should depend on scar maturation, not the edematous or erythematous condition of the tissue. The waiting time for scar maturity may vary from several months to several years. In extensive burns, insufficient donor sites for full-thickness skin grafting after the scar release are troublesome. A variable depth in the defect is usually encountered and resurfaced with flap coverage to get a good result. When local flaps are not available because of adjacent scarring, and no suitable pedicle, distant, or free flaps are available, skin grafting is the simplest and the most reliable way to obtain by Yannas and Burke, which is acellular and composed of two skinlike layers. The upper layer of the Silastic sheet is an epidermis-like structure, which is sufficient to control water loss and prevent the invasion of microbes. The lower layer has a highly porous structure and is composed of cross-linked coprecipitate of bovine collagen and chondroitin 6-sulfate, which is derived from shark cartilage. There is no lining cell in the artificial skin. Another extremely important design consideration of the material is the pore size (20 to 125 μm) design of the lower dermal layer. Optimal pore size allows the migration of the patient’s endothelial cells and fibroblasts to the matrix. The authors’ hypothesis is that the anatomic structure and chemical composition of the grafted artificial dermis wound act as a model for the synthesis of a dermis-like structure whose physical properties resemble dermis more so than scar.

From the Division of Plastic Surgery, Department of Surgery, Tri-Service General Hospital; the National Defense Medical Center; and Yee-Zen Hospital. Received for publication May 4, 2000; revised October 10, 2000. Presented at the Third Asia-Pacific Burn Conference, Taipei, Taiwan, April 2 through 5, 2000.
wound coverage. To prevent the need for additional reconstruction, it is essential to install enough dermal tissue in the treatment of scar contracture. Our study used a two-stage reconstruction for upper-extremity burn scarring with a combination of artificial skin and an ultrathin split-thickness skin graft. We achieved acceptable and functional results for the scar reconstruction and a good quality of skin character. The donor site healed quickly with no complications.

MATERIALS AND METHODS

Artificial skin is composed of a porous collagen-chondroitin 6-sulfate fibrillar mat covered with a thin sheet of silicon. The material is designed to provide optimal wet and draping physicochemical properties, leading to dead space elimination, surface adherence, and control of bacterial invasion and fluid loss while inducing cellular and vascular ingrowth to form a dermal matrix. Integra was manufactured by Marion Laboratories (Kansas City, Mo.) in accordance with the specifications of Burke and Yannas.

This study included 13 patients (eight male, five female), ranging in age from 12 to 59 years (average, 32.8 years) (Table I). All patients had suffered from extensive burns and scar contracture of the upper extremities. The patients gave written informed consent as required by the standard medical institutional review board.

Surgical Technique

The burn scars around the joints of the upper extremities were excised deep into normal subcutaneous tissue to achieve complete release of the scar. After meticulous hemostasis was obtained by fine-needle cautery, the artificial skin was tailored to fix the open wounds and was sutured in place with staples.

Next, a surgical net was used to keep Integra in the site to fix the artificial dermis. Care was taken to prevent wrinkling by suturing the artificial skin under slight tension. Routine checking of the artificial dermis was done every other day. Removal of hematoma underneath the template is necessary to prevent bacterial overgrowth and allow neovascularization of the dermis template. Vascularization of the artificial skin will be obvious by blanching on the

<table>
<thead>
<tr>
<th>Patient No.</th>
<th>Sex</th>
<th>Age</th>
<th>Burn Area</th>
<th>Scar Reconstruction Site</th>
<th>Scar Area</th>
<th>Vancouver Scale Preoperative</th>
<th>Vancouver Scale Postoperative</th>
<th>ROM Increment (degrees)</th>
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<td>1</td>
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<td>Elbow, forearm</td>
<td>20% 2nd-degree, 35% 3rd-degree TBSA</td>
<td>7</td>
<td>3</td>
<td>Extension 30</td>
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<td>2</td>
<td>F</td>
<td>24</td>
<td>Flame burn, trunk/face/4 extremities, deep 55% 2nd- to 3rd-degree TBSA</td>
<td>Axillary</td>
<td>20% 2nd-degree, 35% 3rd-degree TBSA</td>
<td>10</td>
<td>3</td>
<td>Abduction 90</td>
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<td>3</td>
<td>M</td>
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<td>Electrical burn, face/trunk/4 extremities, 40% 2nd-degree, 35% 3rd-degree TBSA</td>
<td>Elbow</td>
<td>20% 2nd-degree, 35% 3rd-degree TBSA</td>
<td>11</td>
<td>3</td>
<td>Extension 10</td>
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<td>Wrist</td>
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<td>45</td>
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<td>48</td>
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<td>Forearm</td>
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<td>8</td>
<td>2</td>
<td>30</td>
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<td>Wrist</td>
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<td>2</td>
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<td>Upper arm, forearm</td>
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<td>2</td>
<td>30</td>
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<td>Forearm</td>
<td>40% 3rd-degree TBSA</td>
<td>9</td>
<td>2</td>
<td>30</td>
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<td>F</td>
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<td>Dorsal hand, wrist</td>
<td>10% 2nd-degree TBSA, 25% 3rd-degree TBSA</td>
<td>10</td>
<td>3</td>
<td>30</td>
</tr>
</tbody>
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*ROM, range of motion; TBSA, total body surface area.
artificial skin in 3 to 5 days. A splint was applied for immobilization and to protect the skin graft from shearing force.

The artificial dermis was kept in the wound site as the template for the ingrowth of host cells and vessels. The neo-dermis matured in 10 days to 2 weeks. We removed the Silastic epidermis as the neo-dermis formed and replaced it with supra-thin autograft skin. The thickness was set at 0.004 to 0.006 inch for a very thin graft, containing epidermis with a scant amount of dermis by Zimmer dermatome. The neo-dermis appeared slightly yellow to red in color. The whole neo-dermal wounds were resurfaced after grafting in 2 to 3 weeks. Postoperative care of the graft followed the burn center’s protocol.

Evaluation

The patients were followed up at our clinic at 3-month intervals for at least 1 year after discharge. We checked the skin character with the Vancouver Scar Scale, including pigmentation, vascularity, pliability, and scar height. The goniometer was used to document postoperative improvement of range of motion. The $t$ test was used for burn scale comparison between the preoperative and 6-month postoperative conditions. Statistical significance was determined by $p$ values less than 0.001.

RESULTS

We included 13 patients who had sites requiring artificial skin to resurface the defect after scar release. The results were satisfactory, and skin graft take was smooth with no complications. All donor sites healed within 14 days. Data on the patients’ demographics and their improvement in range of joint motion are shown in Table I. The $p$ value for comparing the preoperative and postoperative evaluations was less than 0.001 (Fig. 1), which is statistically significant. The following case examples illustrate the application and results of the artificial skin.

CASE REPORTS

Case 1

A 15-year-old boy had sustained a 55-percent total body surface area burn at the age of 5. Postburn contracture was noted over the left elbow region with partial limitation of motion (Fig. 2, above, left). After the scar tissue was excised and the joint was completely released, artificial skin was applied to the defect site. After a 2-week period of maturation, we removed the silicon sheet used for temporary epidermis protection. The yellow-orange to reddish color of the neo-dermis was recognized (Fig. 2, above, right). An ultrathin skin graft was harvested from the scalp (Fig. 2, center, left) and was fixed with Hypafix (Smith & Nephew, Largo, Fla.) for immobilization with staples (Fig. 2, center, right). At 3 days after surgery, fluid was drained from under the graft or blister. A rehabilitation program was resumed about 10 days after grafting. The functional result was excellent after 13 months of follow-up (Fig. 2, below).

Case 2

A 24-year-old woman sustained a severe burn injury, with a 55-percent total burn surface area and postburn syndesis of the right axillary region with limitation of abduction function (Fig. 3, above, left). We replaced the surrounding tissue over the axillary region with artificial skin, fixed with a surgical net (Fig. 3, above, right). After the neo-dermis formed, grafting was performed and secured by the tie-over method. The result was satisfactory, with normal skin turgor seen more than 1 year after grafting (Fig. 3, below).

DISCUSSION

In 1981, Burke first began using artificial skin on thermal burns. The initial indication for the use of artificial skin was the goal of early excision of devitalized tissue and immediate wound closure in major burn patients. The benefits of Integra are its low antigenicity and decreased host inflammatory response. In the dermal template, cellular interaction in wounds will increase fibroblast attachment and secrete new connective tissue matrix. The neo-dermis will biodegrade at a controlled rate and will be replaced with normal host collagen matrix without scar tissue.

Integra is a porous collagen chondroitin 6-sulfate fibrillar mat with an epidermis-like Silastic sheet. It can provide a good matrix for cellular and vascular replacement. The neo-dermis will form as the degradation of the
original matrix occurs. Integra can be a very durable dermal matrix, but the epidermis must be replaced with an ultrathin skin graft at a second operation to ensure closure of the wound bed. Some researchers have suggested incorporating the mature dermal matrix with cultured autologous keratinocytes to achieve the goal of wound coverage, which can save more skin for the donor site.\textsuperscript{12–14}

In extensive deep superficial or full-thickness burn wounds, patients lose most portions of the skin. This is a formidable problem, because the wounds cannot be resurfaced with a meshed, split-thickness autograft. Usually, full-thickness skin is not sufficient to solve the problem, and widely meshed skin will leave a scar formation over the interstices that heal by secondary intention. This results in unsightly markings for patients with major burns, especially those with pigmented skin. Application
of artificial skin can solve the problem of a deficit in the dermis portion in such patients. Restoration of the epidermis portion of the skin is achieved by using an ultrathin split-thickness skin graft (4/1000 inch). Another advantage is the quick healing of the donor site without obvious scar appearance.

With regard to the immunologic response of the host, the artificial skin presented few problems for the patients. The human skin collagen was not immunologically significant. The antibody activity to bovine skin collagen, bovine skin collagen with chondroitin sulfate, was small. The histologic findings in the artificial skin were examined in a serial biopsy. Initially, the inflammatory cells infiltrated the wound bed and were replaced with macrophages, which played an active role in the biodegradation of the product. There was no sign of tissue rejection, and collagen fibers built up in a regular pattern. No scar formation appeared during the healing process.

The frozen cadaver allograft is the most commonly used temporary cover. The availability of acellular, immunologically inert dermal transplants with ultrathin autografts to resurface the wound site is deemed reasonable. The quality and safety of the skin depend on the skin bank. Problems of bacterial infection, hepatitis, and transmission of other viruses are likely to arise. Although the banked skin is metabolically active, there is doubt as to whether the epidermal cells can reproduce themselves.

We used the Vancouver Scar Score for objective assessment of the scars postsurgically; the final result was very satisfactory and showed statistical significance. The Oriental skin of our patients displayed hyperpigmentation after the skin grafting. Skin turgor was expected to normalize about 6 months after the procedure. Pliability was also excellent (Fig. 3, below, right), and good functional results were obtained in the joints 2 weeks after surgery. Normal skin structure had replaced the scar tissue, so there was no scar elevation problem.

Itching is another problem usually encountered with burn scars but rarely mentioned in
the literature. Even after maturation of the burn wounds, itching still disturbed the patients. Sometimes, antihistamine drugs (histamine receptor type 1 blocker) can partially treat the symptom. According to the clinical survey, our patients were satisfied with their new skin. Their itching over the grafting site resolved, possibly because the neo-dermis is similar to normal skin, whereas sensory nerve endings are different in scar tissue. Nevertheless, we need more research to confirm this point.

In a recent study, the inhibition of scar contraction was attributed to several factors. The artificial dermis is like a dermal template, restoring the wound defect and preventing the wound from healing by vigorous contraction, which forces closure from the wound edges of the skin. The contraction of myofibroblasts is inhibited by grafting with the dermal template in the healing process. Only a few dermal fibroblasts (<10 percent) were found—as myofibroblasts in the wound tissue grafted with keratocytes that seeded the dermal template for the full-thickness skin wound. By contrast, in ungrafted wounds, more than 50 percent of dermal fibroblasts were identified as myofibroblasts. In addition, the neo-developed dermal template can establish early connection with the contractile cells of the wound bed, thereby preventing the eventual formation of cell-extracellular matrix connection, which is capable of undergoing contraction.23

Another concern regarding artificial dermis is whether or not it is suitable for tendon or other important tissue coverage. We preserved the paratenon tissue while excising scar tissue and did not expose the tendons or bone. The neo-dermis can get good vascularity from the wound bed and surrounding tissue. It is mandatory to retain the healthy vascular tissue, except the scar portion, during operations. The vascular channels will be restored from underneath the paratenon and surrounding tissues. With this procedure, there was no problem with tendon adhesion in our study.

Conclusions

We conclude that artificial skin can restore the dermis connective tissues to some extent after scar excision. The technique we describe here can provide a method of scar reconstruction that is different from the ladder concept of reconstruction. Further investigation is needed to determine the cost-effectiveness of the method.

REFERENCES


