One-stage skin grafting of the exposed skull with artificial dermis after cancer removal: long-term experiences

WI Sohn, SH Han, SN Jung*

Abstract
Various surgical procedures claim to show a high success rate in scalp reconstruction. However, it is still difficult to cover the wide range of scalp defects accompanied with skull exposure after cancer removal. Between March 2007 and March 2010, one-stage skin grafting with artificial dermis was performed in 8 patients with scalp defect accompanied with skull exposure after malignancy resection. A burr hole was made with several millimetre gap to the skull’s outer table; thus, vascular diploic space was exposed. After the application of artificial dermis to the exposed vascular diploic space, the split-thickness skin graft was performed. As artificial dermis, AlloDerm, was used in 5 patients, whereas Matriderm was used in 3 patients. All patients were males and their mean age was 60.7 years. All patients had post-oncologic surgery defects. The mean defect size was 247.9 cm². In all patients, skin graft was well-taken and radiation-induced skin defects occurred in 2 of 3 patients in whom a post-operative radiotherapy was performed, but these were cured by secondary intention. Average follow-up period was 19.6 months and all patients demonstrated stable coverage without having complications such as breakdown of skin graft or osteomyelitis that requires reoperation. To this end, our report on one-stage skin grafting with artificial dermis presents a reliable, simple and safe technique to cover exposed skull after cancer removal.

Introduction
Exposed skull has been covered by various methods such as skin graft, local flap, free flap and tissue expansion technique. When scalp reconstruction is difficult to perform either by free flap due to old age and multiple medical problems or by local flap due to too large a defect, skin graft can be useful.

However, when performing a skin graft to bare calvarial bone, it is difficult to be taken. Therefore, to ensure that a skin graft is taken, the outer table of the calvarial bone is removed in the first place to allow the granulation tissue to grow. Subsequently, the skin graft is performed as a second stage procedure. In scalp wounds with adequate vascularity, some literature has reported cases of immediate reconstruction with skin grafting without time in between for wound bed preparation. But in cases where poor vascularity is highly suspected due to malignancy or history of previous cancer treatment, two-stage reconstruction is almost mandatory. However, two-stage approach is time consuming and raises the overall morbidity and complication rate, making the graft not only vulnerable to infection or osteomyelitis but also interfering with the overall treatment plan by delaying post-operative radiotherapy.

To cope with such shortcomings of skin graft in patients with scalp defect accompanied by exposed skull, we introduced a technical advancement of one-stage skin graft that used acellular human dermis in 2008. We punctured a burr hole on the outer table of cortical bone that caused exposure of diplopic space, then performed a single-stage skin graft and fixed the skin graft using vacuum-assisted closure (VAC); this assisted in graft take.

To this end, we present the clinical outcomes of one-stage skin grafting of the exposed skull with artificial dermis in 8 patients through long-term follow-ups over at least 13 months after the procedure.

Materials and methods
The eight patients with scalp defect were treated from March 2007 to March 2010. All 8 patients were male and of 38–90 years of age. Six patients had undergone removal of malignant tumour and had full-thickness scalp defect, with absence of periosteum (Table 1).

Surgical technique
Under general anaesthesia, tumour was completely excised, with confirmation through frozen tissue biopsy. A burr hole was made every several millimetres, exposing the vascular diploic space. To maximise the area of the vascularised bed, we removed newly formed bone bridges between burr holes with a rongeur forceps. To maximise the effects of revascularisation, artificial dermis was applied to the exposed vascular diploic space. A split-thickness skin graft was performed at a thickness of 0.012 inch. We used VAC for four days post-operatively and then applied continuous pressure of 100–125 mmHg to enable drainage of discharge as well as simultaneously achieving good compression on the graft.

Case 1
A 44-year-old patient was admitted with recurred epithelioid sarcoma on occiput. The patient had undergone...
radiotherapy several times, which led to calvarial bone exposure with irregular wound margin. We performed wide excision and ensured that complete resection was achieved by frozen section (Figure 1). The size of defect was $25 \times 18$ cm$^2$ with bare bone exposure as the periosteum was removed with wide resection. We removed the outer table of calvarium using an electrical burr and applied AlloDerm (LifeCell Corp, Branchburg, NJ) to exposed vascular diploic space; thereafter, a split-thickness skin graft was performed (Figure 2).

We ensured and maintained a sound pressure of 125 mmHg in the use of VAC for 4 days. Tiny hematoma was formed, but the split-thickness skin graft was well-maintained. At post-operative day 11, the grated skin showed good bio-integration without any specific complication. After 3 months, the patients received radiotherapy (3000 cGy/10 fx/16 days). Radiation-induced partial skin defect was observed, but it was cured by secondary healing. The patient showed a well-taken skin graft for 30 months; nevertheless, he died of lung and bone metastasis (Figure 3).

### Case 2

A 65-year-old man was admitted with non-metastatic sebaceous carcinoma only limited to the right parietal scalp. Having a safety margin of 4 cm, we entirely removed the sebaceous carcinoma, including periosteum, and confirmed that complete resection was done at frozen section. The size of the defect was $20 \times 15$ cm$^2$ and since the patient did not want to have a free flap operation and was not keen about the aesthetic aspect, we planned to perform a one-stage skin graft. After puncturing multiple round holes on the outer tables with a burr, a one-stage skin graft was performed using the same method by applying Matriderm (Dr Suwelack Skin & Health Care AG, Billerbeck, Germany); subsequently, split-thickness skin graft was performed (Figure 4).

Considering the histological characteristics, no additional radiotherapy was performed and there was no specific finding from positron emission tomography–computed tomography (PET-CT), which was performed later. From a long-term post-operative follow-up for 30 months, there was no finding of ulceration or skin Table 1  Treatment and results of the patients

<table>
<thead>
<tr>
<th>Patient no.</th>
<th>Age</th>
<th>Sex</th>
<th>Mechanism of injury</th>
<th>Defect size (cm$^2$)</th>
<th>Post-operative radiotherapy</th>
<th>Applied artificial dermis</th>
<th>Follow-up (months)</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>44</td>
<td>M</td>
<td>Cancer (epithelioid sarcoma)</td>
<td>450</td>
<td>Yes</td>
<td>AlloDerm</td>
<td>30</td>
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<tr>
<td>2</td>
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<td>M</td>
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<td>Matriderm</td>
<td>30</td>
</tr>
<tr>
<td>3</td>
<td>90</td>
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<td>48</td>
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<td>AlloDerm</td>
<td>18</td>
</tr>
<tr>
<td>4</td>
<td>45</td>
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<td>Cancer (basal cell carcinoma)</td>
<td>140</td>
<td>No</td>
<td>AlloDerm</td>
<td>15</td>
</tr>
<tr>
<td>5</td>
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<td>350</td>
<td>Yes</td>
<td>Matriderm</td>
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<tr>
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<td>No</td>
<td>Matriderm</td>
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<tr>
<td>7</td>
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<td>Yes</td>
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<tr>
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<td>Cancer (basal cell carcinoma)</td>
<td>140</td>
<td>No</td>
<td>AlloDerm</td>
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</tr>
</tbody>
</table>

Mean (SD) 60.7 247.9 19.6

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Results
Except for 1 patient who died of distant metastasis, all patients were discharged without complication after 19 days on an average (range, 13 days to 1 month). There were tiny hematoma or seroma observed from the site of the skin graft, but they all were eventually found as well-taken. All three patients to whom Matriderm was applied developed seroma unlike those who to whom AlloDerm was applied; however, none of the cases led to graft loss. Two of three patients who were treated with radiotherapy had partial skin sloughing, which led to skin necrosis. This was treated with serial conservative debridement and frequent wet dressing, which resulted in it healing completely. Mean follow-up period was 19.6 months and during this period, all patients demonstrated long durability without having any breakdown of the skin graft (Table 1).

Discussion
The full thickness scalp defect can occur mainly after the removal of a malignant tumour on the scalp. In case of a malignant tumour on the scalp, wide excision is performed with a certain safety margin, which should include removal of the scalp in full-thickness. Since development of an invasion on the pericranium is highly likely, the periosteum should also be removed. Therefore, denuded skull is exposed after complete excision.

When the size of defect is less than 3 cm, direct closure is performable, but if the size is larger than 3 cm, then the defect can be covered by a local applying split-thickness skin over a layer of AlloDerm (Figure 6).

Considering the histological characteristics, no additional radiotherapy was performed and there was no specific finding from PET-CT, which was performed later. From a long-term post-operative follow-up for 13 months, there was no ulceration or sign of recurrence (Figure 7).

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Removal of the outer cortex and application of artificial dermis as well as split-thickness skin graft can be performed as one-stage; we reported a successful case of one such one-stage performance in 2008\(^8\). Ever since, several studies similar to ours were conducted\(^17,19\). However, to the best of our knowledge, this is the first study to report cases of successful skin graft takes with a long-term follow-up of more than 13 months.

For successful take of skin grafts, no haematoma or seroma should be present between artificial dermis and skin. In this aspect, drainage of fluid collection can be simultaneously achieved by compression with VAC. VAC is already proven to improve local blood flow, granulation tissue formation and reducing bacterial colonisation, thereby resulting in a vast amount of successful cases\(^20,21\).

The reason of using artificial dermis is to increase durability and promote revascularisation of skin graft\(^1\). This is because when skin graft performed without artificial dermis, short-term result may be good, but long-term follow-up shows inferior results. Additional cancer surgery or radiation therapy may lead to breakdown of the graft skin and cause ulceration. Use of several types of artificial dermal templates had shown good results, because they have very similar features to healthy human tissues in terms of histological characteristics. After completion of skin grafting, recipient fibroblasts invade into matrix network and synthesize neodermis. Revascularisation begins within 2–3 weeks, and consequently, ultra-thin epidermal graft covers the area from above. Moiemenn et al.

Local flap has some advantages such as simple wound management, fast healing and excellence in terms of aesthetics. Nevertheless, this procedure requires intra-operative manipulation such as additional incision and undermining. There is also some possibility of developing complications such as infection or haematoma. In addition, it is recommended not to use local flaps for wound bed that has a potential of residual tumour. When the size of the defect is even larger, distant flap procedures can be used such as anterolateral thigh flap, latissimus dorsi muscle flap, radial forearm free flap and transverse rectus abdominis muscle flap\(^6,8\).

However, if there is any medical problem that may not support general systemic condition for the distant flaps’ operation or if the patient wants to minimise morbidity of the donor site or minimise the operation-related risks, other alternatives should be considered. Tissue expansion method could be applied, but it is disadvantageous by the fact that it must go through an expansion period of 2–3 months and when the defect coverage is >50% of the scalp, the density of hair loss becomes noticeable\(^9,10\).

A skin graft has disadvantages, which include poor cosmetic result and donor site pain, but it can be a good alternative since it can definitely cover large defects with a comparatively simple method and it is also good in detecting cancer recurrence\(^1,11\).

In early days, application of skin to bare bone had very poor success rates; several modifications were attempted to overcome this problem. Wilensky and colleagues had induced the skin to be taken well by direct application of a bovine collagen to bare bone. Other authors partially resected the outer cortical bone and implanted the graft after sufficient granulation had grown. This resulted in higher take rates\(^4,12\). In addition, when acellular dermis and removal of outer cortical bone was simultaneously performed, acellular collagen matrix was more tightly fit to the granulating wound bed and supply of nutrients or vascularisation was more facilitated; this resulted in higher take rates\(^4,13,16\).

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identified sequential histological characteristics of skin graft site after using Integra (Integra Life Sciences Corporation, Plainsboro, NJ, USA) for implantation. In this study, we used AlloDerm and Matriderm. AlloDerm is obtained from human cadaver through a procedure of separating epidermal layer and freeze-drying it after removing cells. Such process is impossible for xenogeneic skin but possible for allogeneic skin because allogeneic skin is able to establish vascular linkage within 3–4 days only. Therefore, when autograft is simultaneously performed, mutual bio-integration happens, thereby increasing the take rates. Recently, simultaneous use of AlloDerm was presented as having better take rates than conventional skin graft, and it was known to have excellent texture and elasticity of the engrafted skin. Matriderm is composed with three-dimensional structure coated by elastin, a native and structurally intact collagen fibre that helps dermal regeneration. Such collagen matrix is extracted from bovine dermis and is composed with collagen type I, III and V. Elastin is obtained from hydrolysis of bovine nuchal ligament, sterilised by gamma irradiation and stored at room temperature. From our experience, when Matriderm was used, more seroma formation was experienced in comparison when AlloDerm was used. It is considered that this may be due to the characteristics of Matriderm; its collagen component is not cross-linked, which makes it more quickly hydrolysed. Nevertheless, both AlloDerm and Matriderm had no difference in the overall take rates of skin graft. Mechanism of promoting revascularisation in AlloDerm is similar to that in Matriderm. Both materials serve as a three-dimensional scaffold that leads to faster revascularisation. AlloDerm is more afford able in terms of cost. Both materials cannot be used in allergic patients. When receiving radiation treatment after oncologic operation during follow-up examination, some skin exfoliation or ulceration was found, but they were cured by secondary healing. The patients examined with a long-term follow-up over 2 years also showed very good durability. Such long-term follow-up is rarely reported.

Conclusion
Reconstruction of wide scalp defect after cancer removal is a challenging problem. When either the wound site has a poor vascular bed or the patient has poor systemic conditions, local or free flap is not recommended. In such cases, it may be possible to perform a delayed two-stage split-thickness skin graft with various allograft materials, but this procedure shows engraftment at an early stage by implanting to the periosteum-absent bare bone of the pericranium; however, in long-term, it shows deterioration of durability. Later, skin grafts were performed after application of various allografts, thereby allowing growth of granulation tissues; however, this may have disadvantages such prolonging the morbidity period and insufficient vascularity. We performed simultaneous application of artificial dermis template (AlloDerm/Matriderm) and split-thickness skin after partial removal of the outer table using burr holes in 8 elderly patients with full thickness scalp defect accompanied with exposure of the skull; it was difficult to perform a distant flap in these patients. We observed that the skin graft take rates were maximally elevated by applying VAC and good durability was achieved from a long-term follow-up observation. Since there are rare long-term follow-up studies on such skin graft procedures, herein, we have presented the advantages/disadvantages of different artificial dermis along with individual clinical cases and literature reviews.

References