Many various types of operative techniques have been performed used to treat make-up for sacral defects. Perforator-based flaps with flap transposition, but achieving an optimal flap design and tension-free flap closure without skeletonizing the perforator requires a great deal of clinical experience. In this study, we demonstrate perforator selection based on considerations of the relaxed skin tension line (RSTL), which has proven to be a suitable method of achieving an efficient flap design that enables primary closure.

Twenty-five perforator-based flap procedures were performed on 25 patients at a single institution from February 2018 to January 2021. The medical records of patients were retrospectively reviewed. Twenty-three flaps survived completely. Two flaps developed partial tip necrosis but recovered after secondary healing, and 1 patient developed temporary congestion, which resolved spontaneously. No recipient or donor site recurrence or dehiscence was identified during follow-up.

We report our clinical experiences of perforator-based flap use in the sacral region. When selecting an appropriate perforating vessel, 2 important points should be considered, that is, a flap long axis parallel to RSTLs and defect shape. According to the method presented in this paper, perforator-based flaps can be transposed safely and easily with few complications and serve as useful practice models to cover sacral defects.

**Abbreviations:** RSTL = relaxed skin tension line.

**Keywords:** design, flap, relaxed skin tension line, sacral defect

### 1. Introduction

The sacrum is the most common location of decubitus ulcers in bedridden patients. Many treatment methods have been devised, though perforator flap and V-Y advancement operations are commonly conducted to cover sacral defects due to reliability and relative simplicity. However, the restricted advancement range of the procedure because of extreme tension at defect mid-portions constricts its application to small and medium-sized defects. Perforator flaps have gained popularity because they can be used to make a large flap and be reused for recurrent decubitus ulcers. However, skeletonization of a proper perforator can be boring, and pedicle torsion or postoperative compression can lead to arterial ischemia and venous congestion.

Perforator-based flaps with the perforator placed close to the ulcer and stopped flap elevation at the surrounding selected perforator have been performed to prevent vascular compromise and reduce the need for fastidious dissection. However, the optimization of flap design to ensure successful surgical outcomes requires much clinical experience; other methods are being tried to avoid wound dehiscence.

The sacrococcygeal area has many perforating vessels on which flaps may be raised, and design changes depend on which perforating vessel is selected and defect shape. Here, we report our experiences selecting a perforator based on considerations of relaxed skin tension lines (RSTLs) that have provided efficient flap designs that enable primary closure.
2. Patients and methods

We retrospectively reviewed the medical records of patients who underwent reconstruction of sacral defects at our institution from February 2018 and January 2021. This study was pre-approved by the Institutional Review Board of our hospital and performed according to the principles of the Declaration of Helsinki. Twenty-five perforator-based flap operations were conducted on 25 patients (22 males and 3 females) with a mean age of 59.6 years (range 33–88 years). All sacral defects were caused by pressure ulcers. Defect sizes ranged from 3 x 4 cm to 15 × 18 cm. The parasacral artery perforator was used in 22 patients, and the superior gluteal artery perforator in 3 patients. The mean follow-up period was 13.1 months, during which no recurrence of surgically treated pressure ulcers occurred. A summary of relevant patient information is provided in Table 1.

2.1. Operative techniques

Locations of perforators around sacral defects were identified by preoperative evaluation using a handheld acoustic Doppler. Several suitable perforators were selected in each case. When designing flaps, distance between the selected perforator to the distal tip of the defect was measured and defined as flap length. Flap width was determined as defect width as determined by the pinch test (Fig. 1). A flap design with the long axis of the flap parallel to RSTLs and a narrow width allowing for donor site primary closure was selected. For example, if the defect was oval with a slightly longer craniocaudal direction, designs A or B provided a narrower flap width than designs C or D, which is advantageous for primary closure. Finally, when considering designs A and B, the design with a long axis more parallel to RSTLs (design B) was chosen.

After marking out the flap design, flap elevation was conducted toward the pivot point. Flaps were generally lifted at the subfascial level but elevated in the suprafascial plane with or without included muscle in accordance with wound depth. The dissection was halted when the distal flap portion could be transferred to the wound without tension. Importantly, a distance of at least 1–2 cm should be maintained between the dissection margin and the selected perforator because soft tissues encircling the perforator help prevent kinking, compression, or twisting. When a flap could not be transferred to the sacral defect, added muscular dissection around the basal portion was performed to allow further rotation without added skeletonization of the selected perforator. The lifted flap is then transferred to the wound and repaired, and the donor site of the first lobe enables primary closure without tension.

3. Results

Flaps of dimensions 4 × 8 cm to 15 × 20 cm were elevated, and 23 of the 25 flaps survived (Table 1). Partial tip necrosis occurred in two patients but recovered with secondary healing. One patient developed temporary congestion, which resolved spontaneously. No complications such as recurrence or dehiscence occurred during follow-up (range 2–24 months, mean 13.1 months). Below, we report clinical cases in which the mentioned procedure in this paper was performed to cover wounds.

3.1. Case 1: Patient number 2

A 72-year-old quadriplegic male had a sacral ulcer that had deteriorated for 6 months. A 10 × 8-cm-sized defect remained after radical debridement. Locations of perforators around the wound were detected by preoperative evaluation using a handheld acoustic Doppler. A 9 × 18-cm-sized flap was designed as described in Figure 2. The dissection of the lifted flap in the

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Table 1

| No. | Age | Sex | Defect size (cm) | Flap size (cm) | Location | Perforator | Complication | Operation time (min) | Follow up (month) |
|-----|-----|-----|-----------------|----------------|----------|------------|--------------|---------------------|------------------|
| 1   | 47  | M   | 10 × 15         | 12 × 18        | Sacrum   | PSAP       | None         | 90                  | 24               |
| 2   | 72  | M   | 10 × 8          | 9 × 18         | Sacrum   | PSAP       | None         | 75                  | 24               |
| 3   | 55  | M   | 12 × 9          | 10 × 14        | Sacrum   | PSAP       | None         | 90                  | 20               |
| 4   | 44  | M   | 15 × 12         | 15 × 20        | Sacrum   | PSAP       | None         | 80                  | 18               |
| 5   | 68  | F   | 15 × 18         | 15 × 18        | Sacrum   | PSAP       | Partial necrosis (secondary healing) | 75 | 18 |
| 6   | 49  | M   | 12 × 8          | 18 × 10        | Sacrum   | PSAP       | Temporary congestion | 85 | 17 |
| 7   | 58  | M   | 13 × 13         | 20 × 10        | Sacrum   | PSAP       | None         | 85                  | 17               |
| 8   | 75  | F   | 10 × 10         | 17 × 9         | Sacrum   | PSAP       | None         | 75                  | 16               |
| 9   | 68  | F   | 15 × 15         | 17 × 15        | Sacrum   | PSAP       | None         | 80                  | 16               |
| 10  | 62  | M   | 17 × 12         | 25 × 9         | Sacrum   | PSAP       | None         | 80                  | 15               |
| 11  | 59  | F   | 4 × 6           | 4 × 10         | Sacrum   | PSAP       | None         | 80                  | 15               |
| 12  | 62  | M   | 4 × 7           | 5 × 10         | Sacrum   | PSAP       | None         | 75                  | 13               |
| 13  | 33  | M   | 4 × 7           | 6 × 10         | Sacrum   | PSAP       | None         | 85                  | 13               |
| 14  | 33  | M   | 4 × 8           | 12 × 5         | Sacrum   | PSAP       | None         | 80                  | 13               |
| 15  | 82  | F   | 5 × 6           | 10 × 7         | Sacrum   | SGAP       | None         | 75                  | 12               |
| 16  | 59  | M   | 9 × 10          | 18 × 10        | Sacrum   | PSAP       | Partial necrosis (secondary healing) | 75 | 11 |
| 17  | 61  | M   | 8 × 8           | 9 × 15         | Sacrum   | SGAP       | None         | 90                  | 10               |
| 18  | 49  | M   | 10 × 8          | 11 × 15        | Sacrum   | PSAP       | None         | 80                  | 10               |
| 19  | 44  | M   | 12 × 12         | 20 × 13        | Sacrum   | PSAP       | None         | 85                  | 9                |
| 20  | 57  | F   | 7 × 7           | 8 × 10         | Sacrum   | PSAP       | None         | 80                  | 9                |
| 21  | 88  | M   | 5 × 3           | 15 × 10        | Sacrum   | PSAP       | None         | 85                  | 9                |
| 22  | 77  | F   | 6 × 7           | 14 × 7         | Sacrum   | PSAP       | None         | 75                  | 7                |
| 23  | 79  | F   | 8 × 9           | 18 × 10        | Sacrum   | PSAP       | None         | 80                  | 6                |
| 24  | 50  | M   | 6 × 10          | 7 × 20         | Sacrum   | PSAP       | None         | 90                  | 4                |
| 25  | 61  | M   | 3 × 4           | 4 × 8          | Sacrum   | PSAP       | None         | 80                  | 2                |

M, male; F, female; PSAP, parasacral artery perforator; SGAP, superior gluteal artery perforator.
subfascial plane was halted 2 cm away from the selected perforator, and the flap was transferred to the defect. The recipient and donor were primarily closed. Over a 2-year monitoring period, no complications such as ulcer recurrence or surgical wound dehiscence occurred.

3.2. Case 2: Patient number 6

A 49-year-old quadriplegic male had a sacral ulcer that had deteriorated over 3 months. A 12 × 8-cm-sized defect remained after radical debridement. An 18 × 10-cm-sized flap was designed...
as described in Figure 3. All wounds were closed primarily. Temporary congestion immediately after the operation was resolved over time. No complication occurred over a 17-month follow-up.

4. Discussion

Various surgical options have been developed for the reconstruction of sacral defects, and since Koshima et al. first described perforator flaps in 1993,[5] several designs have been suggested to treat pressure ulcers.[3,4,6,12] The main advantage of perforator flaps is that they enable a longer pedicle and a greater arc of rotation while maintaining the gluteus maximus muscle, and coverage of large defect areas using remote flaps. However, harvesting of a long pedicle is cumbersome, and isolation of the vessel poses a risk of vascular injury, which can lead to venous congestion or arterial ischemia and jeopardize flap survival.

We designed a flap that can be placed adjacent to a defect such that the flap can be transferred without perforator skeletonization to avoid potentially fatal complications and shorten operative times. Perforator-based flaps can reduce operative time and complications but increase donor site tension compared to perforator flaps. Although Kim et al reported tensionless closure may be accomplished by designing an optimal perforator-based flap,[19] this requires considerable practical experience, and surgical wound dehiscence is often experienced due to elevated donor site tension.

Various attempts have been made to decrease wound dehiscence by modifying flap designs.[10,11] In both of these studies, a second lobe was used to reduce donor site morbidity. However, we found that as experience increased, the second lobe became unnecessary in most cases. Due to a high recurrence rate, re-operability is an indispensable consideration when treating pressure ulcers.[13,14] Furthermore, low donor site morbidity and small incisions facilitate subsequent reconstruction even for ipsilateral buttocks.

When perforator-based flaps are designed, two important points should be considered when selecting an appropriate perforating vessel, because the sacrococcygeal area has many perforating vessels on which flaps may be raised.[15,12] First, we design the long axis of flap parallel to RSTLs, which greatly reduces wound tension and scar formation.[15,16] Second, since defects are rarely circular and the direction of pinch testing results in differently shaped defects. In the range that satisfies the ideal ratio of flaps,[17] narrower, longer flaps are more efficient and economical for primary closures.

As described above in Figure 1, when perforator A or B is selected, the flap design is advantageous for primary closure as pinch testing showed the defect to be long and narrow. If perforator C or D is selected, the flap and defect widths widen, which is disadvantageous for donor site closure. Choices between perforator A and B are based on considerations of RSTL directions (as much as possible). In this case, perforator B was selected.

Our study is limited by its non-randomized, non-comparative, retrospective design, and thus confounding and selection bias are inevitable. Additionally, the limitations of the present study are moderately sized defects and an arc of rotation of less than 90 degrees. We plan to perform a prospective study following this procedure as a routine elective surgical option in our hospital for the reconstruction of the sacral defect. In this study, we describe a method for selecting a perforator based on the consideration of RSTLs and producing an efficient flap design that enables primary closure. The merits of this procedure are that it provides tension-free closure, acceptable esthetic reconstruction, and is straightforward and safe to perform. Furthermore, the described procedure could serve as a useful practice model for surgeons who lack experience of perforator skeletonization. In conclusion, the described method enables perforator-based flaps to be transposed safely and easily with less surgical complications such as wound dehiscence and could be considered a useful surgical option for sacral defects.

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Figure 3. Photographs of a sacral ulcer (grade 4, size 12 × 8 cm) in patient number 6: (A) a 18 × 10 cm sized flap was designed as described in this paper. (B) Photograph taken immediately after surgery.
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