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The UQ Flap: A Novel Modification of the Keystone Flap

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Summary: Wound closure following excisions on the leg (between the knee and ankle), including the distal leg, is challenged by limited skin laxity. The keystone flap, first described by Behan in 2003, was proposed as one solution, but with a significant complication rate on the distal leg. This pilot study introduces a novel modification of the keystone flap, named the UQ flap, differing from other modifications, with an un-incised portion on one flap border and a unique curved leading-edge to absorb tension and distribute shearing forces in different directions, providing improved flap security and vascularization. The UQ flap was performed on 10 patients in two formats of "U" and "Q" also with two different orientations as base-proximal and base-distal. Other variations including minor deviation from the longitudinal axis, and double flap, were also performed. Except for one case with minor infection, there were no complications, and the results were favorable. No fasciotomy or undermining was required. The UQ flap proved to be a safe and convenient method of wound closure on the leg, including the distal leg. Compared with the keystone flap, there were reduced incisions leading to improved vascularity and less healthy tissue trimming. Its unique shape provided flap flexibility facilitating easy adjustment to the defects. The order and direction of wound closure after the excision of the lesion and incision of the flap are critical. *(Plast Reconstr Surg Glob Open 2022;10:e4619; doi: 10.1097/GOX.0000000000004619; Published online 24 October 2022.)*

INTRODUCTION AND METHOD

Repair of lower extremity defects remains challenging due to limited local tissue laxity[1] and vascular insufficiency.[2] Closure following excision of skin cancers, when primary closure is not possible, is ideally achieved by transposing local tissue of similar quality, with flaps generally preferable to skin grafts due to better color and contour, without donor site morbidity.[3] The keystone island flap (KF) is one useful solution with a high success rate for lower extremity defects.[1] There are four main types of KF,[3,4] two of which are relevant to this paper. Type I involves no division of the deep fascia, whereas type II does, to enhance mobility. This article introduces a novel modification of the KF, named the "UQ" flap (UQF), with comparison to type I and type II KF.

Figure 1 depicts a comparative example of a lesion with a given diameter of 16mm and a defect width of 20 mm (2 mm margin), the defect being closed by a UQF (Fig. 1A and B) or KF (Fig. 1C). In the classical UQF (format "U"; UQF-U) on the leg, the lesion is excised with a partial ellipse (about two-thirds of a typical ellipse) with the truncated base of the ellipse in the horizontal plane and the flap orientated vertically, parallel to the truncated ellipse. To achieve this, an incision is made parallel to the lesion, on the "calf" (not "shin") side of the lesion, to make the "greater side-edge" of the flap (Fig. 1A, line CG), meeting with a curved incision (the leading-edge) on the distal border of the flap (Fig. 1A, line FG). In some situations, the format "Q" or UQF-Q (Fig. 1B) can be used, in which the bridge is on the proximal part of the greater side-edge. (**See figure, Supplemental Digital Content 1,** which shows nomenclature in UQF and dimensions of the UQ and keystone flaps for a skin defect size of

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Received for publication August 22, 2022; accepted August 31, 2022.

DOI: 10.1097/GOX.0000000000004619

Disclosure: *The authors have no financial interest to declare in relation to the content of this article.*

Related Digital Media are available in the full-text version of the article on www.PRSGlobalOpen.com.

"X". http://links.lww.com/PRSGO/C225.) To improve the flap's vascularity, the width of the leading-edge should be 5 to 10 mm wider than the defect size, and in U-format, the un-incised bridge (the base) of the flap even slightly wider.

With any excision, the "maximum tension axis" (MTA) is at the level of the widest part of the excision, the challenge being to close the gap at this level. The robust tension absorption by suture "A" and multi-directional tension splitting by the curved leading-edge are the cornerstones of the UQF. The bridge should never be at the same level of the lesion (MTA) or close to the leading-edge. To preserve the blood supply through the perforators, in the UQF (like KF), the flap is not detached from underlying tissue ("the bed").

After ethics approval by the University of Queensland, Australia, 10 patients with confirmed skin malignancies on the leg were sequentially selected from a general practice (of author MH) and assessed, and then were operated on by a plastic surgeon (author IH), utilizing the UQF for wound closure (defect sizes: 17–30 mm), with clinical- and photo-documentation of each case. The operating plastic surgeon

Takeaways

Question: Is there a simple and safe flap for closure of leg defects apart from the keystone flap?

Findings: The UQ flap in two formats and different variations is performed on 10 cases as a pilot study and is presented as an improved method for defect closures on the leg, including distal leg.

Meaning: The UQ flap is demonstrated as a safe and easy-to-perform method of wound closure on the leg, with advantages over the keystone flap, reduced incisions leading to improved vascularity, and significantly less trimming of healthy tissue.

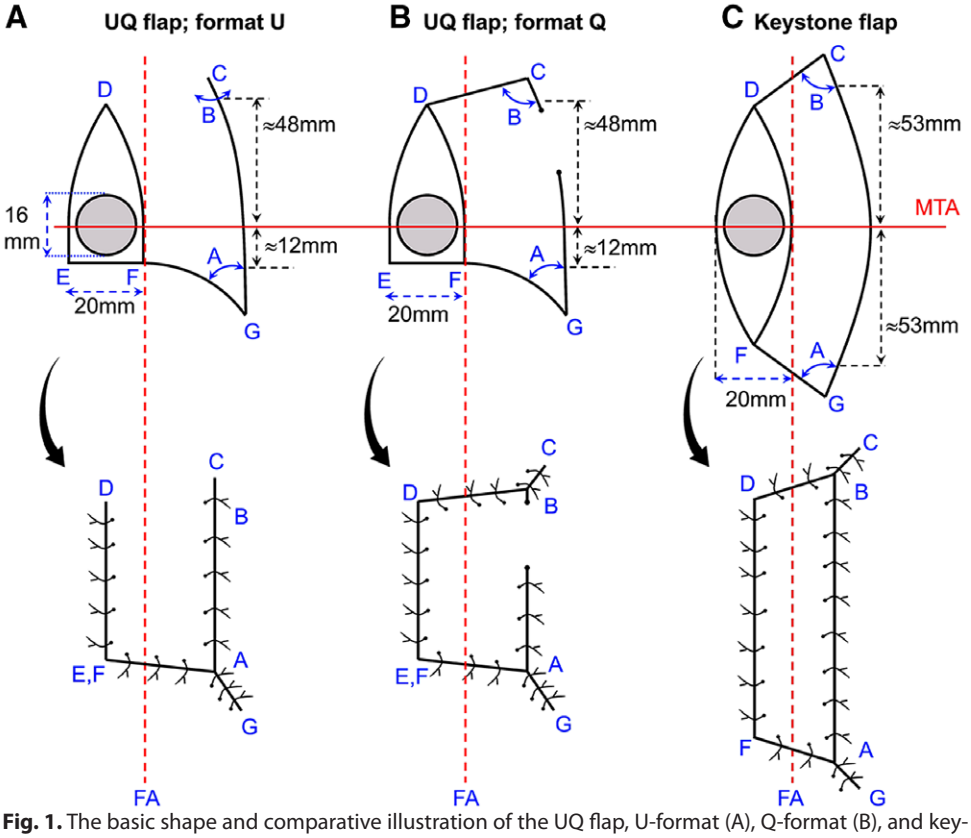

Fig. 1. The basic shape and comparative illustration of the UQ flap, U-format (A), Q-format (B), and keystone flap (C) for a given lesion with the size of 16 mm and the defect size of 20 mm (upper panel). In the KF and all previous modifications, the closer the sutures A and B are to the MTA, the more tension absorption and advancement occur. The length of a complete ellipse is three times of the width of the defect. The distance of the suture A from MTA is approximately 12 mm for both UQF-U (A) and UQF-Q (B), which is much closer to the MTA compared with 53 mm in the KF (C). Suture A plays an essential role in tension absorption and advancement in the UQF. Suture B in the UQF is slightly closer (48 mm) to the MTA compared with its counterpart in the KF. It is like an anchor and absorbs tension in U-format but with an advancement effect in Q-format as well. A critical part of the UQF is the "curved" incision line of the leading-edge (FG), which is convex toward the MTA in contrast to the straight line in the KF. This curved leading-edge distributes or divides the maximum horizontal/transverse tension force in different directions. However, in the KF, the tension absorption is done only in the orthogonal axis. The outcome shape after the procedure for each method is shown on lower panel. FA = flap axis; KF = keystone flap; MTA = maximum tension axis.

assessed the lesions to make sure the defects could not be closed by simple closure. U-format was deployed on nine cases and Q-format on one case. All patients received prophylactic antibiotics for 7 days. Wound care advice to keep dry for 2 days, as well as an elevation and management plan for potential complications was given to patients. All patients were reviewed by the general practitioner (author MH) on day 3–4. Other standard wound-care instructions were provided. Removal of sutures was performed on day 14. Nine cases were completed without complication, but one case was complicated by wound infection and controlled with antibiotic therapy. There were no instances of flap failure, either partial or complete.

Figure 2 photodocuments a UQF U-format. Both "order" and "direction" play crucial roles in successful wound closure. Before the incision, the laxity of the skin around the lesion should be checked, and the decision for the best format option (U or Q) has to be made because after the incision of the flap margins it is not possible to change the format.

Because the blood supply of the leg is from proximal to distal and from deep to superficial via perforators, as a rule, the base of the flap is preferentially located proximally; however, in some situations, it can be distal. On the leg, the parts with wider diameter have higher skin laxity; so if the lesion is located on the distal part of the leg, the flap can be designed as "base-distal", so that the leading-edge is oriented toward areas with larger diameter (ie, mid-calf). A detailed demonstration of the UQF is shown in the supplemental video. **(See Video [online],** which shows the UQF deployment, for the classic version, variations, undermining and dressing application.)

DISCUSSION

Despite proposed advantages for the KF (including safety, cost-effectiveness, and relatively superior results[5]), there are limitations, with the highest complication rate (up to 40%) on the leg.[6,7] Due to vascular dependence on perforators, caution is necessary in areas surgically or traumatically dissected.[4,8]

KF type I is suitable for closure of defects up to 2 cm,[3] and its execution is challenging over knee or distal leg due to reduced skin laxity.[5] For leg lesions, some surgeons routinely use KF type II with fascial division to facilitate mobility of the flap.[5] Other published modifications in the literature have similar basics.[9] Douglas et al demonstrated that tissue movement in KF type I is just a stretch, not an advancement, and the amount of increased orthogonal stretch was in the order of 1 mm, a dubious benefit, raising doubt about the rationale for the use of KF type I.[10,11] Also, the net vascular benefits of a keystone closure, relative to primary closure under tension, remain unknown.[10,12,13]

With the Sydney Melanoma Unit (SMU) modification, a skin bridge is left intact along the greater arc of the flap,

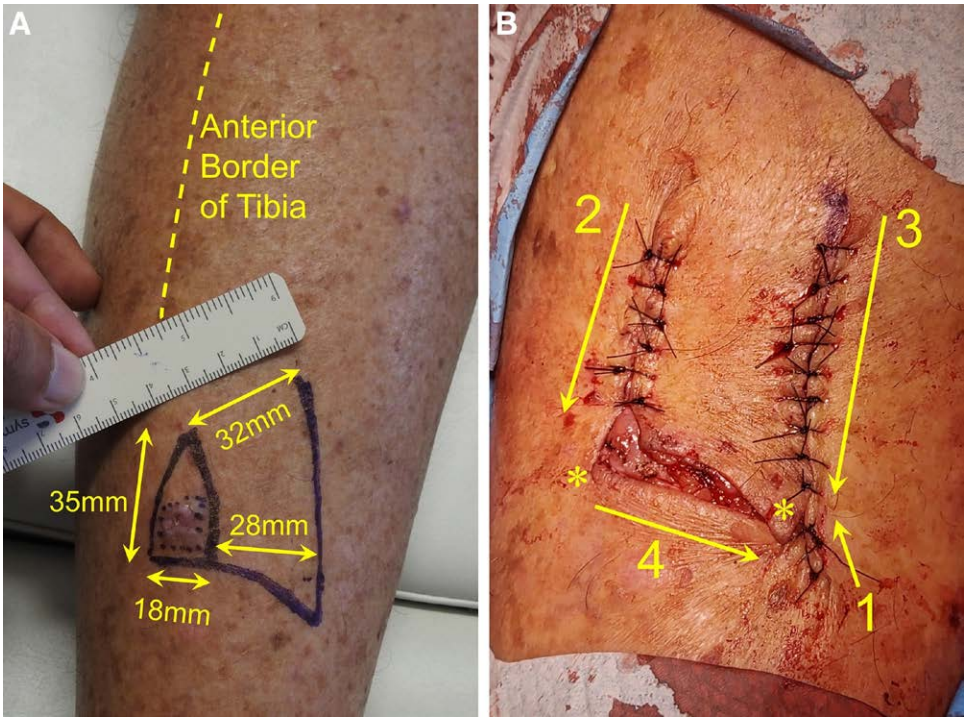

Fig. 2. Typical UQ Flap, U-format, on the leg. A: 18 mm defect size on the shin. B: Photo just prior to final closure. The "order" and the "direction" of wound closure are shown with numbers and arrows, respectively. The first step is closure of the very distal part of the greater side-edge with closely spaced sutures while the triangle at the tip of the leading-edge is lifted. The next step is the closure of the defect from apex to base of the defect followed by the greater side-edge. It is crucial to close the defect in the shown order and directions because while the sutures are added in those directions, the skin tension and forces are gradually absorbed, and the flap adjusts with the defect progressively. The closure of the leading-edge followed by its two corners (*) is the last step.

affording additional vascularity and decreased major complication rate,[14] but a lateral "fasciotomy" is performed along the entire length of the lateral arcs, including under the skin bridge.[14,15] Paul described biodynamic excisional skin tension lines (BEST) on the lower limb and the technique of elliptical excision of lesions followed by vertical closure with a parallel relaxing incision[16]; however, defect closure without fascial incision was applied for very few cases. Fasciotomy makes KF, the SMU modification, and relaxing parallel incisions more practical and effective but introduces additional increased risk of complications, including infection, tissue damage causing loss of nerve or muscle function, tendon tethering, and muscle herniation.[17,18]

The UQF is presented as a safe and convenient method of wound closure on the leg, with advantages over the KF, significantly less trimming of healthy tissue, and reduced incision of the skin. Although fasciotomy was not employed in the current study, it could potentially be used to facilitate closure of wider defects. Any proposed dissection should be very limited and within the subcutaneous fat layer or at a maximum up to, but not penetrating, the level of fascia. Also, in this study, no doppler or angiography assessment of the perforators was deemed necessary because of the un-incised border (base).

As a perspective for future study, the authors suggest that a variation of the UQF could be a better alternative to many transposition or rotation flaps, in areas where blood supply is more favorable than on the distal leg. In these cases, using the rhomboid flap as an example, when alternatively applying a modified UQF, the flap would be "detached" from the bed and moved toward the defect.

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