

Utilization of Novel Keystone Flap Modification on Various Anatomic Sites

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ABSTRACT

We describe our proposed modification of the keystone flap, which adds a V-Y advancement in 3 directions, further optimizing the redistribution of tension forces. This new approach not only improves the overall stability of the flap but also reduces the risk of wound dehiscence and enhances the potential for better healing outcomes. We describe its use in 15 patients treated at our center (mean age of 58 years [range, 18-77 y]) with mean follow-up time of 14 months (range, 6-24 mo). All flaps survived, and no early or late complications were encountered. The keystone flap's flexibility, combined with its multiple modifications, continues to expand its applicability across diverse anatomical locations, making it a vital tool in reconstructive surgery for complex defects.

KEY WORDS: Burn, Defect, Perforator, Reconstruction

INTRODUCTION

Originally described by Behan¹ in 2003, the keystone flap is a curvilinear trapezoidal advancement flap designed with a robust vascular supply, making it particularly suitable for anatomical sites within perforator vascular zones. This technique has become increasingly favored by reconstructive surgeons, particularly for the repair of lower extremity defects, where tissue mobility is often limited and vascularity is poor. In these challenging areas, the keystone flap's reliance on vertically oriented subcutaneous, musculocutaneous, and fasciocutaneous perforators enhances

flap survival, offering a substantial advantage over other reconstructive techniques that may carry a higher risk of tension necrosis, prolonged healing times, or less favorable aesthetic outcomes.²

The keystone flap's success is largely due to its ability to release longitudinal tension and increase the laxity of the flap, allowing it to advance toward the defect without compromising the surrounding tissues.¹ This mechanism makes it particularly advantageous in reconstructive surgery, as it reduces the invasiveness of procedures, preserves healthy tissues, and promotes fast healing with fewer postoperative complications. As the keystone flap evolved, various modifications have been introduced to address different anatomical sites and defect types. These include deep fascial release (type II), adjacent bilateral advancement (type III), and subfascial rotation and advancement (type IV), each designed to enhance tissue mobilization and improve flap versatility.¹

Our proposed modification of the keystone flap builds on these advances by adding a V-Y advancement in 3 directions, further optimizing the redistribution of tension forces. This new approach not only improves the overall stability of the flap but also reduces the risk of wound dehiscence and enhances the potential for better healing outcomes. The keystone flap's flexibility, combined with its multiple modifications, continues to expand its applicability across diverse anatomical locations, making it a vital tool in reconstructive surgery for complex defects.

MATERIALS AND METHODS

Fifteen modified keystone flaps were performed between 2020 and 2023. The applications were as follows: 6 cases on the lower extremity, 5 cases on the trunk, 3 cases on the upper extremity, and 1 case neck reconstruction.

Surgical technique

Similar to that performed at the beginning of the traditional keystone flap design, the flap is drawn at a 90-degree

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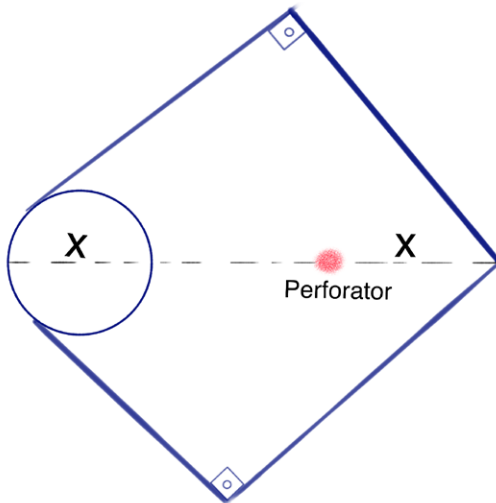
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angle from both apexes of the elliptical defect created with a width of x (Figure 1). The perforator is determined with the help of a handheld Doppler. The distance from the marked perforator to the width of the defect (x) is determined (Figure 1). The 90-degree flaps drawn from both ends of the defect are connected in the same way with a red

FIGURE 1. Keystone Flap Drawing



Perforator was determined with handheld Doppler. The X represents the defect size. Red dot shows perforator nourishing the flap.

dot to form a 90-degree angle. After the flap is advanced to the defect, the superior, inferior and lateral limbs are closed as in V-Y advancement.

RESULTS

The mean age of patients was 58 years (range, 18-77 y), and mean follow-up time was 14 months (range, 6-24 mo). All flaps survived. No early or late complications were encountered (Figure 2).

DISCUSSION

The modified keystone flap, as described in this study, builds on the foundational principles established by Behan¹ in 2003 and incorporates a V-Y advancement technique that aims to further optimize tissue tension redistribution and enhance flap stability. As demonstrated in our results, all 15 modified keystone flaps survived without any early or late complications, highlighting the robustness and reliability of this approach in reconstructive surgery. The key advantages of the modified keystone flap are its ability to address medium- to large-sized defects, its minimal invasiveness, and its capacity to provide reliable, tension-free healing, which is critical for areas with limited tissue mobility or poor vascularity.

FIGURE 2. Intraoperative Design, Flap Adaptation, and Postoperative Results



One of the most notable advantages of the keystone flap, and by extension, its modification, is its relatively straightforward planning. The flap design, although more complex than simple linear flaps, allows for easy execution and adaptation based on the defect's location and size. The introduction of the V-Y advancement in 3 directions further enhances the flap's ability to distribute tension forces across the wound site. This modification is especially valuable for challenging defects on anatomical sites where tissue elasticity and mobility are compromised, such as the lower extremity or trunk.^{2,3} By its ability to release longitudinal tension through careful flap design, this method reduces the likelihood of tension necrosis and improves the overall aesthetic outcome. The flexibility of the keystone flap in reconstructing defects in diverse anatomical locations is a distinct advantage, which, in turn, minimizes the need for more invasive reconstructive methods that might involve grafting or larger tissue excision.^{4,5}

Furthermore, the technique's reliance on perforators from subcutaneous, musculocutaneous, and fasciocutaneous layers can substantially enhance flap survival. The robust vascular supply in perforator zones ensures that the flap maintains an adequate blood supply, reducing the risk of necrosis and promoting faster healing. This is particularly advantageous in lower extremity defects, where vascularity can often be a limiting factor in wound healing. The tension-free nature of the modified keystone flap also contributes to a quicker recovery time, reducing both the length of hospital stay and postoperative complications. The high success rate, as evidenced by the survival of all flaps in our study, further underscores the efficacy of this approach.

However, like all surgical techniques, the keystone flap, including its modification, can present certain limitations that should be considered. A large drawback in our study was the relatively short follow-up time. Although positive short-term outcomes were shown over the mean follow-up of 14 months (ranging from 6 to 24 months), longer follow-up periods are essential to better understand the long-term durability of the flap and its potential for late complications, such as hypertrophic scarring, flap contraction, or the development of trap door deformities. The lack of data on these long-term outcomes is a noted gap in the existing literature on the keystone flap technique.

Moreover, although the V-Y advancement modification is designed to optimize the tension redistribution, research

remains insufficient on the potential risks associated with trap door deformity with this specific technique. Trap door deformities, which involve raised and box-like tissue formations, can occur when tissue is poorly mobilized or improperly aligned, leading to an undesirable cosmetic outcome. Although none of the patients in our study developed such deformities, the absence of extensive research on this risk factor presents a gap in our understanding of the technique's long-term aesthetic outcomes. In addition, the modification introduces greater complexity to the flap design, which may increase the technical difficulty of the procedure, particularly in more challenging anatomical regions.

CONCLUSIONS

The modified keystone flap offers numerous advantages, including reduced invasiveness, minimal tissue undermining, and the ability to address larger defects with a tension-free, like-with-like reconstruction. The added V-Y advancement in 3 directions further optimizes the technique, ensuring better tissue mobilization and flap stability. However, as with any surgical procedure, it is essential to consider the limitations, such as the relatively short follow-up period and the lack of long-term data on potential complications like trap door deformity. Further studies with longer follow-up times and larger patient populations are necessary to fully evaluate the long-term effectiveness and safety of the modified keystone flap in diverse clinical settings.

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