

Pediatric Wound Closure by a Tension-Relief System

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Abstract

Surgical reconstruction in pediatric patients can often be complex. Primary wound closure is almost always the preferred technique in the reconstructive ladder; however, it is not always possible in pediatric patients. We report the pediatric use of the TopClosure Tension-Relief System, an innovative skin-stretching technique for secure primary wound closure of large defects. We modified the technique by fixing it to a protective dressing instead of the patient's skin, thus avoiding both staple scars and pain. A retrospective review of 112 patients aged 7 days to 18 years who underwent Tension-Relief System-assisted surgery at a tertiary medical center from 2010 to 2020 was conducted. Cases included congenital deformities, traumatic wounds, burn scars, and complicated-wounds, with or without hardware or deep tissue exposure. The use of the system avoided the need for multiple surgical sessions and for local or regional flaps. The technique was simple to use, with few complications, and led to satisfactory aesthetic and functional outcomes. The findings support using the technique in children and adolescents with challenging tension wounds. Herein, we report on our experience with the Tension-Relief System and detail four cases in which early or immediate closure was successfully achieved.

Keywords

- ▶ Tension-Relief System
- ▶ pediatric tension wound
- ▶ TopClosure for pediatric use
- ▶ challenging pediatric wounds

Surgical wound closure is often a challenging procedure, particularly in children. Beginning with immediate primary closure and running through serial excisions, skin grafting, tissue expansion, flap placement, and secondary closure, the

reconstructive ladder offers guidance for everything from the simplest to the most complex situations.^{1–4} It is important to select the appropriate treatment option as reconstructive wound closure surgeries in children may adversely affect organ growth and development,⁵ both at the donor and the primary surgical sites. While the adult medical literature contains descriptions of various techniques that were

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designed to facilitate primary wound closure, and to minimize and improve scarring.^{6–15} All of them aim to reduce tension from the wound margins and disperse it over a wider area. Few if any of the techniques have been investigated in pediatric patients. Those available are often restrictive in terms of mechanical creep, stress relaxation of stretched skin, and a lengthy period needed to secure closure. The aim of the present report was to describe our experience in pediatric patients with large skin defects with the use of a novel Tension-Relief System (TRS).

Primary Closure

Although its use is not always feasible, immediate primary closure is usually the preferred technique, especially in pediatric patients as it naturally circumvents the need for patient cooperation, multiple surgeries, and the need for general anesthesia at every stage of the surgical procedure.⁹ Furthermore, it eases postoperative surgical pain, dressing changes, and complications; these are much harder for children than adults.^{16,17} Primary wound closure is also associated with optimal aesthetics, which is very relevant to growing children and adolescents, for whom scarring may have major psychosocial implications.^{17,18} Finally, by minimizing the number of surgeries, primary wound closure enables young patients and their parents or caregivers to return more quickly to their familiar environments and everyday routines.

Materials and Methods

Study Procedure

A retrospective study of patients younger than 18 years who underwent surgery with primary wound closure using the TRS at a single tertiary pediatric medical center during 2010 to 2020 was performed. Patients were selected for treatment with the TRS based on the presence of a high-tension wound that could not be closed by primary intention, requiring alternative steps of the reconstructive ladder, and were amendable for stress relaxation closure. The clinical characteristics of the patients and surgical outcomes were collected from their medical files. A descriptive statistical analysis was performed.

TRS Procedure

The TopClosure Tension-Relief System (IVT Medical Ltd., Ra'anana, Israel) is a novel, noninvasive technique designed to temporarily stretch epidermal tissue and to facilitate early or immediate primary closure of diverse and complex surgical wounds. Based on the natural biomechanical properties of the skin, the technique allows for the widespread distribution of tensile forces away from the wound, reducing the risk of ischemia.¹⁹

The TRS (→Fig. 1) comprises several pairs of specially designed, flexible polypropylene polymer attachment plates, interconnected by long approximation straps. Each plate is lined with a series of horizontal slits that allow them to be bent to the appropriate curvature prior to placement on the

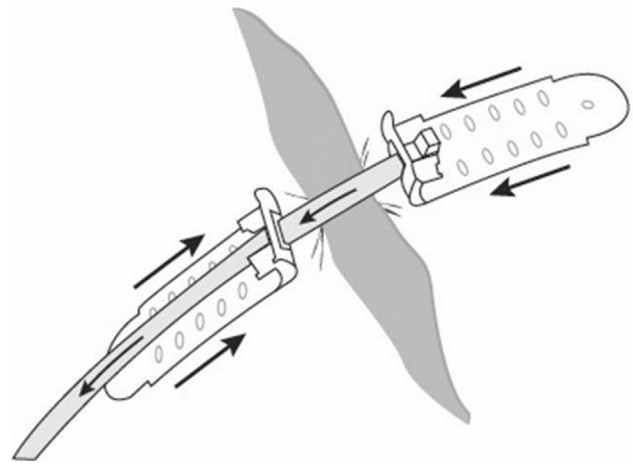


Fig. 1 The TopClosure Tension-Relief System.

skin. Once shaped, the plates are adhered to the skin, perpendicular to the wound, by a hypoallergenic biocompatible adhesive along their undersurface and then reinforced with staples or sutures via pairs of oval openings placed along their longitudinal axis. By gradually pulling on the approximation straps linking the opposing plates, the surgeon can align the plates with the desired vector. The extent of pulling is decided clinically, until mild tension is observed. When moderate or severe tension is observed, several Ethilon 1 (Johnson & Johnson International, New Brunswick, NJ) tension relief sutures, protected by silicone sleeves, can be used to further reduce tension away from the suture line for each pair of plates used (→Fig. 2). Alternatively, some indications necessitate the attachment of the system prior to surgery where it can be gradually tightened to gain excess skin needed to achieve a low-tension closure.

Once closed, several dressings may be applied to the suture line such as antibiotic ointment, paraffin gauze,

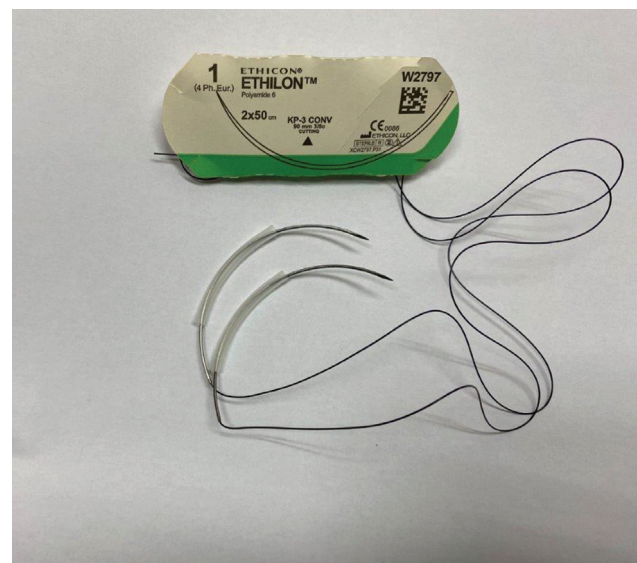


Fig. 2 An Ethilon 1 tension relief suture.

alginate dressing, and negative pressure wound dressing, depending on the wound type and location. Dressing above the system is usually not needed, other than to hide the system from the child or protect it from the surroundings. To prevent staple-induced scarring, we elect to modify the plate attachments by applying a moisture retentive hydrocolloid adherent dressing to the wound margins. The dressing formed a protective barrier, preventing the staples from penetrating the skin.

Results

The cohort included 112 pediatric patients, with a mean age of 7.3 years, ranging from 7 days to 18 years. Male patients were more represented than females at a ratio of 2.8:1. Most of the patients had no systemic comorbidities with the exception of some patients being treated with immunosuppressant therapy prior to living donor liver transplants.

Within our cohort, the most common use of TRS was for wound repair. Just over half of the cases (52%) presented for the management of complicated wounds with and without hardware or deep tissue exposure, with an additional 27% treated for traumatic wounds. Of the remaining uses of TRS, 14% were congenital deformities such as congenital nevi, vascular malformations, or other skin lesions, 5% burn scars, and 2% others causes. Reconstruction of the extremities was common, with the TRS applied to the upper and lower limbs in 23 and 18% of cases, respectively. Other notable locations included the head and neck (17%), abdomen (16%), chest (14%), and back (12%). Drains were not indicated in the majority (91%) of cases.

Regarding the overall perioperative timeline, the TRS was applied for an average of 27 days, out of which an average of ~2 days hospitalization. The time ranged from 5 to 66 days with variations secondary to both the diagnosis being treated and the character of the individual wound on a case-by-case basis. Each case was followed weekly with a mean follow-up period of 1.6 years.

The most common adverse events following primary closure supported by the TRS were minor wound complications and unfavorable scarring. As the primary endpoint of our reconstructive technique was the resolution of high-tension open wounds with an acceptable straight-line clo-

sure, unfavorable scarring was considered separately from wound complications. Unfavorable scarring such as wide, hypertrophic, or keloid scars were observed in ~18% of cases, but there was no continuous follow-up with a longer period of scar treatment.

Wound complications were observed in an additional 18% of cases. Twelve percent of cases experienced partial superficial dehiscence that was treated conservatively, while 4% developed a more profound deep dehiscence that need debridement and a new application of the device. Seven percent experienced either hematoma, seroma, or surgical site infection, while only 3% required alternative reconstructive surgery, such as skin grafting, local regional, or free tissue transfer, likely due to careful selection of soft tissue defects amendable to stress relaxation. Of note, none of the patients were observed with local functional deficit due to this reconstructive method.

Case 1: Limb

A 12-year-old female presented with a congenital nevus on the right thigh. As excessive tension was expected with direct primary closure, the TRS was applied to gradually stretch the skin over a period of 5 days before surgery. The lesion was excised and closed in layers under minimal tension. To secure the wound closure and improve scar aesthetics, the TRS was applied for an additional 2 weeks postoperatively. The result was a narrow, aesthetically pleasing scar (► Fig. 3).

Case 2: Scalp

A 7-year-old female presented with recurrent dehiscence following surgical revision of craniosynostosis repair. The initial repair was performed during infancy for unicoronal craniosynostosis and was repeated at 5 years of age. Following the second procedure, recovery was complicated by dehiscence of the scar and hardware exposure, necessitating additional debridement and closure using a local flap. The patient returned at 7 years of age due to recurring dehiscence. Another debridement was performed and the TRS and tension sutures were used to achieve primary closure of the wound. The lateral attachment plates were removed on postoperative day 14, and the medial attachment plates on postoperative day 21. Follow-up 1 year later showed no dehiscence (► Fig. 4).

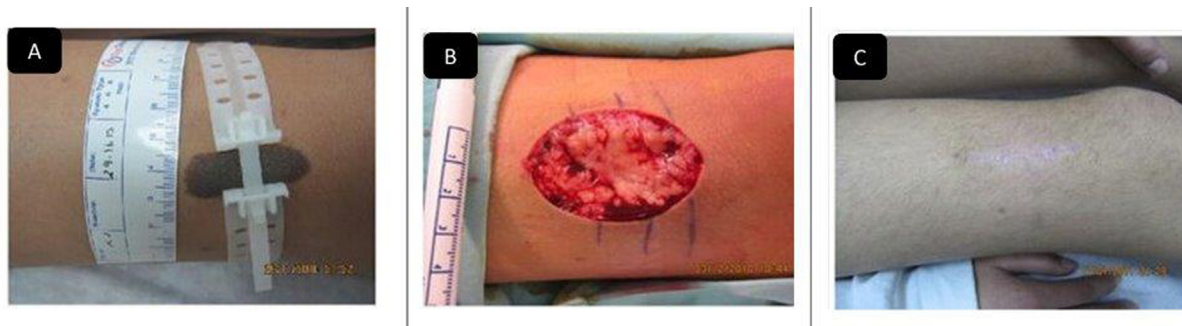


Fig. 3 Case 1. A 12-year-old female with a congenital nevus on the right thigh, treated by Tension-Relief System-assisted closure. (A) Before excision. (B) During surgery. (C) After excision.

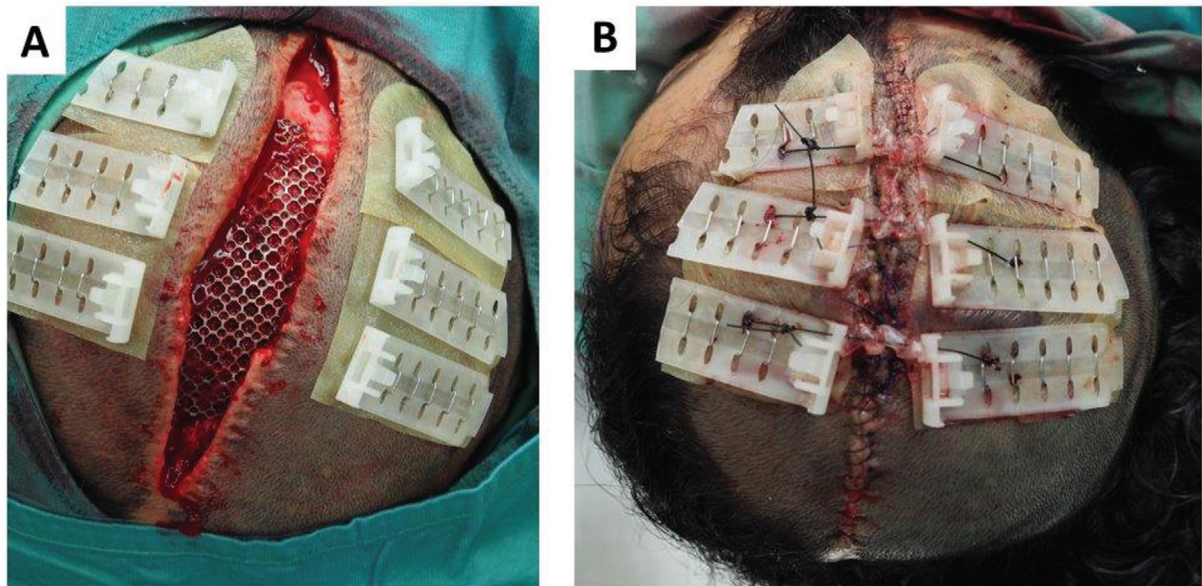


Fig. 4 Case 2. A 7-year-old female after recurrent dehiscence and hardware exposure of a craniosynostosis repair scar, treated by debridement and primary Tension-Relief System closure with tension sutures. (A) After debridement, before closure. (B) After surgery.

Case 3: Nuchal Area

An 11-year-old female presented with imminent hardware exposure following spinal surgery. The patient was initially diagnosed with an aneurysmal bone cyst in the C2 vertebra, and was managed surgically with vertebral osteotomies, laminectomies, fusion with internal fixation, and prolonged use of a halo traction brace for neck support. At the time of

presentation, the surgical scar on the posterior neck exhibited significant instability and concern for impending failure. The scar was debrided, however, as the patient lacked sufficient laxity of the skin to support a tension-free closure, the TRS and tension sutures were used to facilitate adequate closure. The sutures were removed on postoperative day 25, and the entire system was removed on

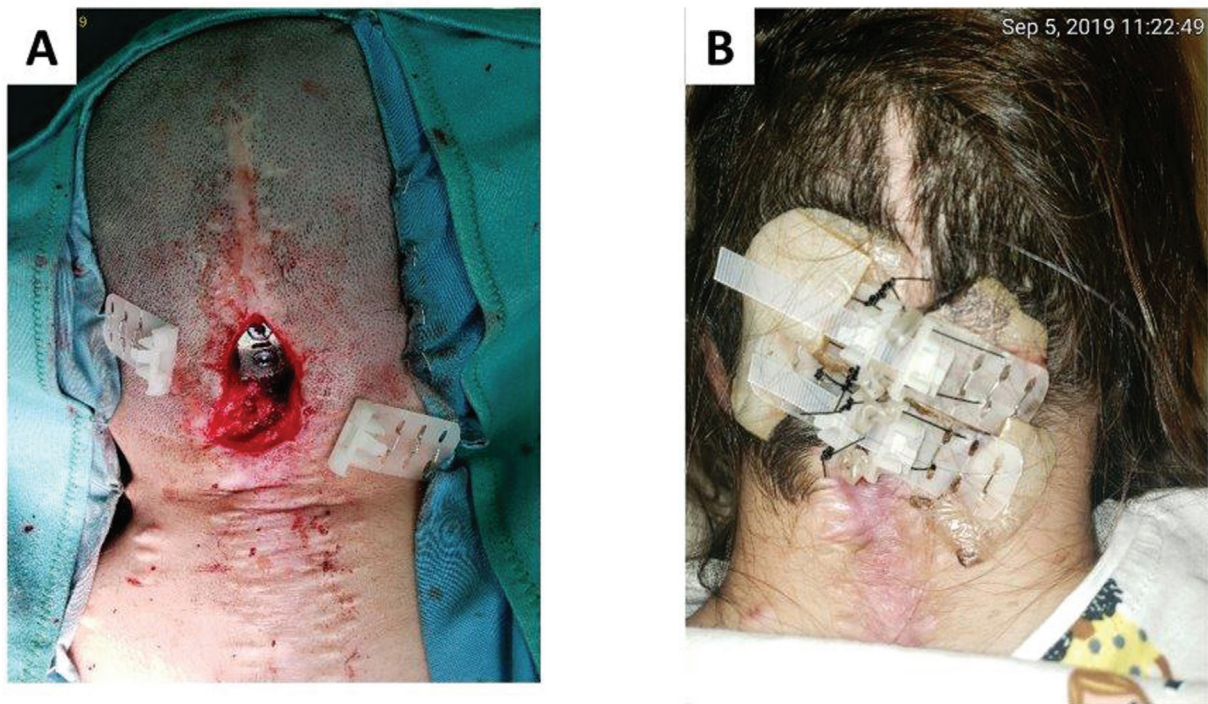


Fig. 5 Case 3. An 11-year-old female after several surgeries in the nuchal area due to an aneurysmal C2 bone cyst, followed by an unstable scar above hardware. She was treated by scar debridement and primary Tension-Relief System-assisted wound closure with tension sutures. (A) During surgery, before placement of the plates. (B) Postoperative day 21.

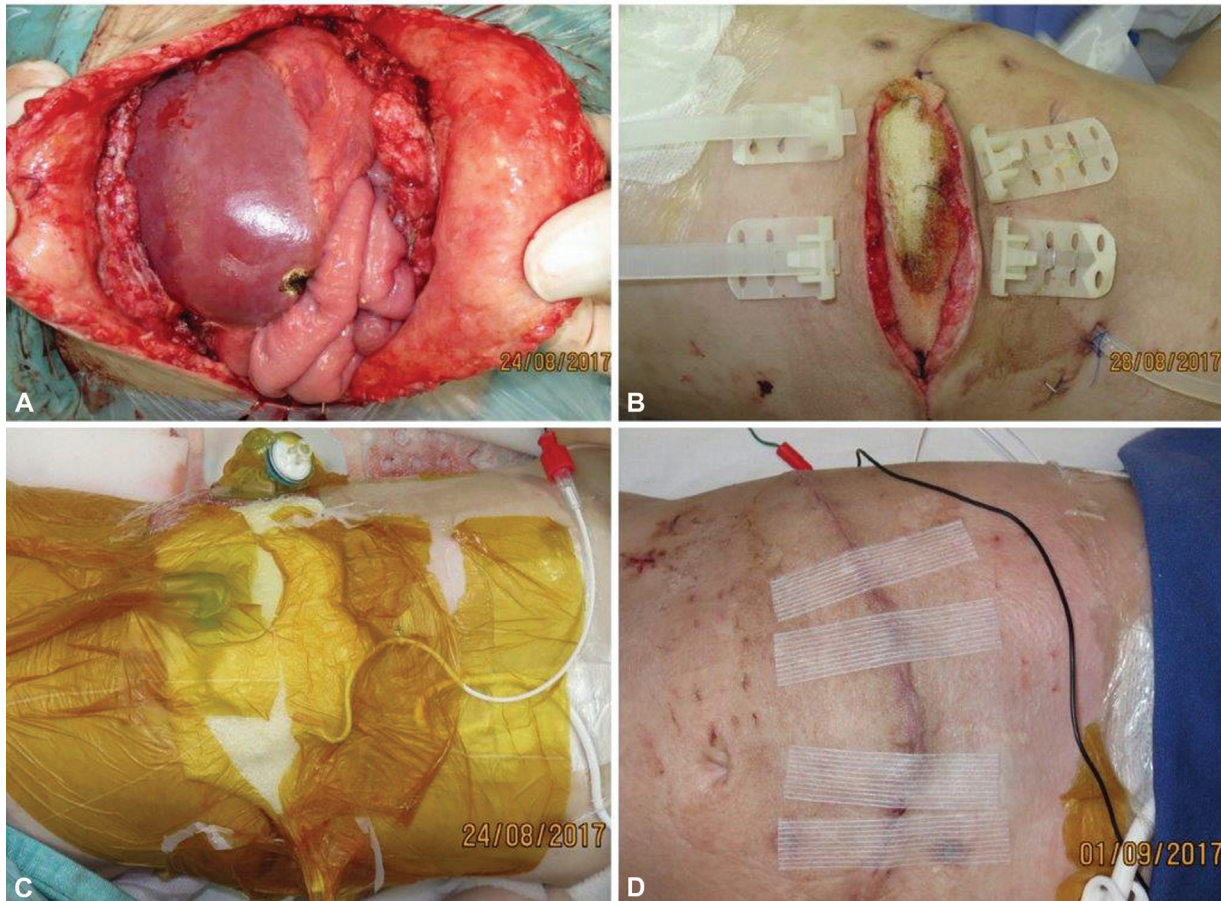


Fig. 6 Case 4. A 20-month-old female with propionic academia syndrome underwent a living donor liver transplant. (A) Due to size mismatch. (B) The Tension-Relief System (TRS) sets were applied over the inner sponge and another sponge covered by a drape provided air-tight wound insulation. (C) The wound was initially covered by a Bogota bag that was replaced by Vcare. (D) Release of the TRS lock/release mechanism allowed for wound exploration and complete abdominal wall closure a few days later.

postoperative day 27, revealing a straight-line closure and stable scar (► Fig. 5).

Case 4: Abdomen

A 20-month-old female with propionic academia syndrome was seen by our surgeons for closure following a living donor liver transplant. Immediate closure of the abdominal wall (► Fig. 6A) was impossible due to size mismatch, and the wound was initially covered by a Bogota bag that was later replaced by a Vcare (IVT Medical Ltd., Ra'anana, Israel) wound dressing sponge kit for wound drainage. The TRS sets were applied over the inner sponge (► Fig. 6B) to avoid wound edge retraction or slow approximation of the wound edges. Another sponge was then applied and covered by a drape to provide an air-tight covering wound insulation (► Fig. 6C). A few days later, release of the TRS lock/release mechanism enables wound exploration and complete abdominal wall closure, with minimal tension on the scar line (► Fig. 6D).

Discussion

Wound closure in pediatric patients can be complicated. While primary closure is often the most desirable recon-

structive modality, in many cases, it may not be possible, without the use of a supplementary system, to distribute the tension over a wider area and relieve stress along the surgical wound margins.^{10,15,19} Other common techniques used to avoid high tension closures in pediatric patients include serial excisions, skin expansion, flaps, and grafts.¹⁻³ The common downside of these procedures is the requirement for multiple staged surgeries, each with inherent risks, in addition to repeated clinic visits and possible donor site morbidity.^{16,20}

In our experience, the TRS has proven useful in managing a wide variety of pediatric conditions such as congenital skin defects, large skin lesions, complicated surgical wounds secondary to burns, trauma, and hardware exposure. In the cases described above, without the availability of the TRS device, primary closure would not have been possible. Instead, the patients would have required more aggressive reconstructive procedures, including serial excision, skin grafting, local, regional, or free flaps. Use of the TRS reduced the number of surgical procedures and minimized the exposure to the additional risk of scarring, donor site morbidities.²¹ We found this technique may be more beneficial than other techniques described for wound closure in the literature, especially when primary intention closure is not

possible; however, large randomized trials are needed to determine the superior technique.^{6–15} Overall, the technique was simple to use with few complications and led to satisfactory aesthetic and functional outcomes. Its potential advantages included a short operative period and hospitalization, fewer surgeries and associated anesthesia, less inconvenience and distress to patients and their families, the surgical site is less extensive, and there is no donor site morbidity. Additionally, there is a reduced need for special settings, equipment, and skills compared with microsurgical techniques. Furthermore, unlike the earlier techniques reported, the TRS is accessible off the shelf and might also serve as a bedside procedure.

While there are no absolute contraindications to the use of TRS, some relative contraindications include skin damage at the planned site of application, compromise to the local blood supply, injured or undermined tissue, or a history of local irradiation, and other systemic conditions that restrict wound closure. Furthermore, it is not suitable for reconstruction of inelastic body areas such as the heel of the foot or over scar tissue. Of note, the stress relaxation technique should be approached with care on various regions of the body. Employing the stress relaxation technique on the scalp may lead to alopecia. When used for closures involving the limbs, abdominal wall, or chest wall, it can cause compartment syndrome. Therefore, patients should be monitored, and if indicated, the tension should be released immediately.

Conclusion

Our study demonstrates the safety and feasibility of the TopClosure System to close challenging tension wounds in pediatric patients of a wide age and at diverse anatomical locations. In our experience, application of the TRS is painless, simple, and takes only a few minutes to apply, making the system ideal for use at the patient's bedside or in outpatient clinics. Although the duration of treatment can vary depending on the treatment location, type of wound, and status during follow-up, use of the TRS overall effectively facilitated adequate wound healing in a variety of complex cases.

Conflict of Interest
None declared.

References

- Janis JE, Kwon RK, Attinger CE. The new reconstructive ladder: modifications to the traditional model. *Plast Reconstr Surg* 2011; 127(Suppl 1):205S–212S
- Braun TL, Hamilton KL, Monson LA, Buchanan EP, Hollier LH Jr. Tissue expansion in children. *Semin Plast Surg* 2016;30(04): 155–161
- Buchanan PJ, Kung TA, Cederna PS. Evidence-based medicine: wound closure. *Plast Reconstr Surg* 2014;134(06):1391–1404
- Caniano DA, Ruth B, Teich S. Wound management with vacuum-assisted closure: experience in 51 pediatric patients. *J Pediatr Surg* 2005;40(01):128–132
- Arnon Z, Hanan H, Mogilner J. The effect of a hypnotic-based animated video on stress and pain reduction in pediatric surgery. *Int J Clin Exp Hypn* 2018;66(02):123–133
- Cohn BT, Shall J, Berkowitz M. Forearm fasciotomy for acute compartment syndrome: a new technique for delayed primary closure. *Orthopedics* 1986;9(09):1243–1246
- Baum TP, Strauch B. Delayed primary closure using silastic vessel loops and skin staples: description of the technique and case reports. *Ann Plast Surg* 1999;42(03):337–340
- McKenney MG, Nir I, Fee T, Martin L, Lentz K. A simple device for closure of fasciotomy wounds. *Am J Surg* 1996;172(03):275–277
- Janzing HM, Broos PL. Dermatraction: an effective technique for the closure of fasciotomy wounds: a preliminary report of fifteen patients. *J Orthop Trauma* 2001;15(06):438–441
- Narayanan K, Futrell JW, Bentz M, Hurwitz D. Comparative clinical study of the sure-closure device with conventional wound closure techniques. *Ann Plast Surg* 1995;35(05):485–491
- Molea G, Schonauer F, Blasi F. Progressive skin extension: clinical and histological evaluation of a modified procedure using Kirschner wires. *Br J Plast Surg* 1999;52(03):205–208
- Yontar Y, Tatar S, Aydin A, Coruh A. Delayed primary closure of traumatic tension wounds using plastic straps and Kirschner wires. *Plast Surg (Oakv)* 2019;27(01):29–37
- Urbaniak RM, Khuthaila DK, Khalil AJ, Hammond DC. Closure of massive abdominal wall defects: a case report using the abdominal reapproximation anchor (ABRA) system. *Ann Plast Surg* 2006; 57(05):573–577
- Verdam FJ, Dolmans DEJGJ, Loos MJ, et al. Delayed primary closure of the septic open abdomen with a dynamic closure system. *World J Surg* 2011;35(10):2348–2355
- Cheng LF, Lee JT, Hsu H, Wu MS. Simple skin-stretching device in assisted tension-free wound closure. *Ann Plast Surg* 2017;78(03, Suppl 2):S52–S57
- Shay T, Belzberg M, Asemota AO, et al. Risk of complications in primary versus revision-type cranioplasty. *J Craniofac Surg* 2020; 31(02):423–427
- Yildirim S, Calikapan GT, Akoz T. Reconstructive microsurgery in pediatric population—a series of 25 patients. *Microsurgery* 2008; 28(02):99–107
- Diseth TH, Emblem R. Long-term psychosocial consequences of surgical congenital malformations. *Semin Pediatr Surg* 2017;26 (05):286–294
- Topaz M, Carmel NN, Silberman A, Li MS, Li YZ. The TopClosure® 3S System, for skin stretching and a secure wound closure. *Eur J Plast Surg* 2012;35(07):533–543
- Voinchet V, Magalon G. [Repair of skin defects by skin extension procedures]. *Ann Chir Plast Esthet* 1996;41(05):563–571
- Adams DC, Ramsey ML. Grafts in dermatologic surgery: review and update on full- and split-thickness skin grafts, free cartilage grafts, and composite grafts. *Dermatol Surg* 2005;31(8 Pt 2):1055–1067