International Journal of Medical and Health Research
ISSN: 2454-9142, Impact Factor: RJIF 5.54
www.medicalsciencejournal.com
Volume 3; Issue 8; August 2017; Page No. 69-72

The Tension wound closure device system, forskin closure ofexcessive tension wounds

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Abstract

The principle of stretching wound margins for primary wound closure is commonly practiced and used for excessive tension and complicated during wound closure. They were invasive by nature and associated with relatively high localized tissue pressure, frequently leading to necrosis, damage and tearing of skin at the wound margins. To assess the clinical effectiveness and performance and, to determine the safety of Tension wound closure device for gradual, controlled, temporary, noninvasive and invasive applications for skin stretching and secure wound closing, the Tension wound closure devicedevice was applied to 10 patients for secure closure of a variety of wound sizes. Tension wound closure device was reinforced with adhesives, staples and/or surgical sutures, depending on the circumstances of the wound and the surgeon's judgment. Following surgery, it was used to secure closure of wounds under tension, thus improving wound aesthetics.

Keywords:wound closure, skin stretching, tissue expansion, viscoelastic properties of skin, mechanical creep, stress relaxation

1. Introduction

Many techniques have been applied for closure of large skin defects: skin grafts, local flaps, tissue stretching and expansion, free flaps and closure by secondary intention. Some of these modalities carry considerable morbidity, complexity and risks associated with lengthy healing time.

Mechanical forces play a significant role in the formation and structuring of tissues, mainly the skin, during human development, through life and during repair processes, determining their three-dimensional shape, as well as structural and remodeling properties affecting tissue on cellular and subcellular levels [1–3]. Shear stress, tension, compression and hydrostatic pressure are conducted through the extracellular matrix or extracellular fluid to individual cells. It has been proposed that cells convert these mechanical stimuli into electrical signals through biochemical mechanoreceptors (mechanosensors) such as mechanosensitive ion channels, cell adhesion molecules including integrins and actin filaments in the cytoskeleton [4–6]. It was also proven that there is a vast intracellular effect created by mechanical stretching—for example, mechanical stretching modulates growth direction and MMP-9 release in human keratinocyte monolayer [7]. The mechanical properties of soft tissues have been widely investigated [8]. Tension is a principal force experienced by the skin, and with optimal amplitude and waveform, it may aid in facilitating its growth and expansion for early wound closure. Extensible connective tissues (e.g. skin, blood vessels, fascia) contain networks of fibrous collagen and elastin within the extracellular matrix and in an amorphous matrix, and are affected during mechanical loading [9]. Skin exhibits load history-dependent behavior. The epidermal and dermal layers of skin consist largely of collagen (about 75% of dry weight) and elastin (4% of dry weight) fibers embedded and floating in a gel-like base [10].

The reorientation of this interwoven network of elastin and mainly collagen fibers provides the skin with the ability to stretch and expand [11], hence displaying a viscoelastic nature with their nonlinear stress–strain curves [12]. Biomechanical properties of the skin, specifically mechanical creep and stress relaxation, allow skin to stretch beyond its inherent extensibility within a relatively short period of time. Mechanical creep is the phenomenon where skin will stretch and elongate with time as long as force is applied. If the skin is stretched to a constant distance in a state of stress relaxation, it will expand, leading to a gradually reduced tension on the skin. As a result of skin stretching and elongation, wound closing tension decreases, allowing primary closure of relatively large defects [13]. In 1993, a new technique was introduced by Hirshowitz *et al.* [14] based on the use of the Sure-Closure® skin-stretching system. This skin stretching device was designed to harness the viscoelastic properties of skin by invasively applying controlled and evenly distributed tension along the wound margins, using incremental traction over a period of time, thereby allowing primary closure of relatively small-to medium-size skin defects. However, some of the main drawbacks of this device and similar ones [15, 16] are the sole invasive nature of their use and the application of relatively high stress close to the wound edges, leading at times to pressure ischemia, necrosis and tearing of tissue. The Tension wound closure device, an innovative, simple, skin stretching and wound closure-secure system designed to harness both mechanical creep and stress relaxation principles. This new concept uses distribution of the force necessary to stretch the skin over a relatively wide area of adherence, away from the traumatized wound edges, using selective vector-oriented forces, continuously or cyclically, in both noninvasive and invasive manners. [17] In this study, we compare the effectiveness of tension wound closure over conventional method for closure of different tension wound like burst abdomen wound, trauma wound over knee and foot, surgical wound over spine, amputation stump, trochanteric wound etc.

2. Materials and Methods

Device structure and mechanical characteristics The Tension wound closure device comprises two attachment plates (AP) that are interconnected by a long, flexible approximation strap (AS). The AS links the opposing APs, enabling approximation and advancing the APs by incremental pull on the AS. The AS is completely inserted through the lock/release ratchet mechanism (L/RM) on the proximal AP until being secured by the AS's wings. Next, it is inserted into the L/RM on the opposing AP to allow gradual controlled stretching of the underlying skin. The AS is locked or released by lightly pressing or lifting the L/RM's lever.

Invasive Application

In most circumstances, Tension wound closure device may have to be secured to the skin by invasive means. Once the APs are firmly adhered to the skin, the attachment can be further secured by staples or sutures using the designated pairs of oval openings on each plate. The AS is then inserted into the L/RMs of the plates and tightened gradually to enable skin stretching. Additional staples or sutures may be applied when indicated. The AS is then inserted into the L/RMs of the plates and tightened gradually to allow skin stretching. Measurement of stress implication by sutures and Tension wound closure device [17].

3. Results & Discussion

The Tension wound closure devices were tolerated well by all patients and remained comfortable and mobile with the device in situ. There was progressive reduction in the size of the wound and possible for the primary closure of skin tissue was evident in all cases. Precise measurement of wound closure was not possible as the skin laxity depend on the surrounding skin, type of skin, tension pressure. Removal of the tension closure device system was done after a median of 14(range 9-28) days. 2 patients were discharged home with a Tension wound closure device in situ and managed on an outpatient basis, where the treatment lasted for a median of 7.5 (range 5-9) days. The median hospital stay after initiation of Tension wound closure device therapy was significantly shorter (15, range 10 - 30 days) than on conventional treatment prior to Tension wound closure devices(23, range 17-45 days) . There were no Tension wound closure device related complications and complete healing was achieved in all 10 patients.

Mechanism of action

The Tension wound closure device has been designed and applied to harness the viscoelastic properties of the skin by both mechanical creep and stress-relaxation principles in both noninvasive and invasive manners. Tension wound closure device was also useful in acute skin stretching by stress relaxation through intraoperative, invasive, cyclical skin elongation and for postoperative invasive tension release to secure wound closure

Application of mechanical creep for skin stretching

Qualitative microscopic analysis of the skin covering the tissue expander revealed a rapid thinning of the dermis and the panniculuscarnosus muscle, mainly in the first 2 weeks, with no significant change in the epidermis. More compact and larger bundles of collagen fibers were observed in the thinned expanded dermis [18]. The Tension wound closure device can, in many instances, replace tissue expanders by using gradual and slow skin stretching paced over a few days to several weeks. This is achieved by utilizing the mechanical creep properties of tissues but with much more flexible distance, close to and/or distant from the lesion's edges. Tension wound closure device can be applied to stretch skin in various body sites and in multidirectional, multi force vectors, more specifically applied to affect the needed stretch direction, for skin relaxation, elongation and expansion.

Application of stress relaxation for skin stretching

Stress relaxation is another biomechanical property of soft tissue behavior which describes the time-dependent decay of stress as the applied strain is held constant. The quasi-linear viscoelastic constitutive model is one of the methods of characterizing stress relaxation behavior of skin. Stress relaxation allows skin to stretch intraoperative beyond its inherent extensibility in a short period of time. As a result of skin stretching, wound closing tension decreases over time, allowing primary closure of relatively large defects [19]. It has been shown that cyclical stretching of the skin can result in biochemical changes within a short period of time.

Ryan's [20] research manifests an immunohistochemical analysis for epidermal proliferation, which showed a strong response to cyclical stretch as soon as one hour following stimulation, and significantly greater EGF elevation occurred in the cyclical stretch group. These results support previous suggestions that cyclical force is preferable for stimulating growth than static force.

We learn that cyclically stretched skin led to increased tissue oxygenation and improved skin viability. Due to the structural composition of the skin, the resultant viscoelastic capability produces a unique mechanical behavior when subject to repeated mechanical loading. Preconditioning of skin, therefore, should be considered a necessary step toward optimal tissue stretching and elongation [21]. Such a procedure orients the molecular structure of the skin to its optimal in vivo alignment, allowing tissues to gradually adapt to loading, resulting in low-tension wound closure.

Tension wound Closure device was applied during surgery to acutely, tangentially stretched skin over a period of 20–30 min, in intermittent, repetitive cycles of 3-min stretching, applying a constant strain with an apparent period of tissue blanching (ischemia), followed by 1-min relaxation with capillary refilling (reperfusion). By using intermittent application of tension to the skin, this preconditioning multivector cyclic loading led to an incremental skin elongation through the stress relaxation mechanism, facilitating primary skin closure.

In trauma settings, Tension wound Closure device enabled a selective distribution of a minimal load on the injured skin edges to meet its specific clinical condition. It is recommended that the least possible tension be applied to the injured skin, to position the APs away from wound edges or at various distances, and to adhere the APs to the underlying skin with staples or sutures to allow for thorough cleansing of the wound during and following surgery. Tension wound Closure device is of special merit in surgery in those cases where a second look is indicated for exploration and treatment of wounds after primary surgery. AS can be detached by releasing the lever of the L/RM and can be reapplied if indicated. Local skin irritation and blistering can be avoided by slow, gradual skin stretching in the noninvasive mode of preoperative skin stretching and by the application of minimal pull on the skin for postoperative wound securing. Topical skin irritation from the adherent glue could be easily detected under the semitransparent AP and could be treated early by releasing tension, topical cream and/or relocation of AP with the use of staples if indicated.

The Tension wound closure device System is an innovative device, having been designed to closure of critical wound by both mechanical creep and stress relaxation principles.Application of Tension wound closure device can be utilized to modify and improve the current practice of wound closure by enabling skin to gradually adapt to loading,applying minimal stress to the skin away from thedamaged wound edges, using flexible, multidirectional force vectors and versatile methods of attachment to the skin, using method of skin stretching, elongation, securing wound edges, and improved scar aesthetics.(figure 1,2,3,4)

4. Conclusion

Tension wound closure device may provide a more consistent and efficacious way to manage critical wound like burst abdomen wound, amputation stump, fasciotomy wound, over joint area and surgical tension wound because it starts approximating the edges at earlier time. We notice that tension wound closure device is easy to use and close the critical tension wound. In our institution, when such type of wound not amenable to primary closure, the Tension wound closure device system is the preferred alternative method in our institution

5. Tables and Figures

Fig 1&2: Pre and Post photos of trochantric wound.

Fig 4 & 5: Pre and Post photos of dehiscence post laparotomy wound

6. References

1. Reichelt J. Mechanotransduction of keratinocytes in culture and in the epidermis. Ear J Cell Biol. 2007; 86:807-816.
2. Gormar FE, Bernd A, Bereiter-Hahn J, Holzmann H. A new model of epidermal differentiation: induction by mechanical stimulation. Arch Dermatol Res.1990; 82:22-32.
3. Nasca MR, Shih AT,West PD, Martinez WM, Micali G, Landsman AS. Intermittent pressure decreases human keratinocyte proliferation in vitro. Skin PharmacolPhysiol2007; 20:305-312
4. Ryan TJ. Biochemical consequences of mechanical forces generated by distention and distortion. J Am AcadDermatol. 1998; 21:115-130.
5. Chin MS, Ogawa R, LancerottoL, Pietramaggiori G, SchomackerKT, Mathews JC, *et al.* In vivo acceleration of skin growth using a servo-controlled stretching device.

Tissue Eng.Pt C-Meth. doi:10.1089/ten.tec.2009.0185. 2010; 16(3):397-405

6. Ryan TJ. Biochemical consequences of mechanical forces generated by distention and distortion. J Am AcadDermatol. 1989; 21(1):115-30.
7. Renò F, Traina V, Cannas M. Mechanical stretching modulates growth direction and MMP-9 release in human keratinocyte monolayer. Cell AdmirePub. 2009; 3(3):239-242.
8. Woo SLY, Gomez MA, Akeson WH. The time and history-dependent viscoelastic properties of the canine viscoelastic characteristics, which could be a result of fluid flow and/or structural medial collateral ligament. J BiomechEng. 1981; 103:293-298.
9. Purslow PP, Wess TJ, HukinsDWL. Collagen orientation and molecular spacing during creep and stress-relaxation in soft connective tissues. J ExpBiol. 1998; 201:135-142.
10. Hsu S, Jamieson AM, Blackwell AM. Viscoelastic studies of extracellular matrix interactions in a model native collagen gel system. Biorheology. 1994; 31:21-36.
11. Elsner P, Wilhelm KP, Maibach HI, Berardesca E. Bioengineering of the skin: skin biomechanics. CRC Press, New York, 2001.
12. Wainwright SA, Biggs WD, Currey JD, Gosline JM. Mechanical design in organisms. Edward Arnold, London, 1976.
13. Liang MD, Briggs P, Heckler FR, Futrell JW. Presuturinga new technique for closing large skin defects: clinical and experimental studies. PlastReconstr Surg. 1988; 81(5):694-702.
14. Hirshowitz B, Lindenbaum E, Har-Shai Y. A skin-stretching device for harnessing of the viscoelastic properties of the skin. PlastReconstr Surg. 1993; 92:260.
15. Marek DJ, Copeland GE, Ziowodzki M, Cole PA. The application of dermatotraction for primary skin closure. Am J. 2005; 190:123-126.
16. Abramson DL, Gibstein LA, Pribaz JJ. An inexpensive method of intraoperative skin stretching for closure of large cutaneous wounds. Ann PlastSurg. 1997; 38:540-542.
17. Moris Topaz, Narin-Nard Carmel, AdiSilberman, Ming Sen Li, Yong Zhong Li. The TopClosure® 3S System, for skin stretching and a securewound closureEar J PlastSurg 2012; 35:533-543
18. Pasyk KA, Austad ED, McClatchey KD, Cherry GW. Electron microscopic evaluation of guinea pig skin and soft tissues “expanded” with a self-inflating silicone implant. PlastReconstrSurg. 1982; 70(1):37-45.
19. Marek DJ, Copeland GE, Ziowodzki M, Cole PA. The application of dermatotraction for primary skin closure. Am J Surg. 2005; 190:123-126.
20. Ryan TJ. Biochemical consequences of mechanical forcesgenerated by distention and distortion. J Am AcadDermatol. 1998; 21:115-130.
21. Liu Z, Yeung K. The preconditioning and stress relaxation of skin tissue. J BiomuchEng. 2008; 2(1):22-28.