Clinical and experimental wound closure using a skin stretching device

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Chapter 2

Review of the literature
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One of the earliest reports of wound closure was the use of large soldier ants by South American Indians long before the first Portuguese and Spanish explorers discovered the great Amazon basin. Eciton Buchelli ants were placed on margins of open wounds and dug their claws promptly into the wound. The edges of the wound were then drawn together and the rear claws of the ants dug in the other side of the wounds. The ants were then beheaded and the shriveling body kept the wound closed because the ants did not release their grip, even when dead (Fig. 1).

Figure 1. The jaws of the Eciton buehelli holding together the edges of a wound (left) in an experiment on a dead rat. In the second step of the clamping process (right), the body of the ant is twisted off. Scale in mm.

Gradual tension may induce expansion of the skin and subcutaneous tissue as is demonstrated physiologically during pregnancy, obesity and growth. Among the first applications of non-physiological skin stretching have been neck-stretching customs of Padaung women in Burma (Fig. 2) and stretching of the lips and earlobes by means of wooden disks or rings by women in the village of Madecongo in the Territory of Chad in French Equatorial Africa, as has been described in the National Geographic Magazine (Fig. 3).

In 1920, Sir Harold Gillies described closure of a war injury of the left cheek by means of skin stretching. Approximation of the skin edges was performed with dress
hooks sewn to pieces of blanket flannel fixed with collodium to each edge of the wound and then united by rubber bands.\textsuperscript{4}

In 1957, Neumann\textsuperscript{5} described the principle of tissue expansion by gradual application of pressure with a subcutaneous rubber balloon. An area of skin was expanded for ear reconstruction. It was not until the 1980s that Radovan\textsuperscript{6,7} reintroduced the technique of skin expansion in reconstructive surgery to overcome shortage of skin tissue and this study was followed by the studies of Austad and Rose,\textsuperscript{8} Argenta,\textsuperscript{9} and Manders et al.\textsuperscript{10} Since then, skin expansion has become a well-accepted technique for closing large defects.

It was the pioneering contribution of Gibson and Kennedi\textsuperscript{11-13} to the understanding of biomechanical properties of skin that made plastic surgeons increasingly familiar with the application of engineering principles in their reconstructive work. Exploitation of the viscoelastic properties of skin, known as mechanical creep and stress relaxation, enables larger defects to be closed primarily. Mechanical creep occurs when a constant stretching force is applied to skin. The skin will gradually extend beyond the limits of its inherent extensibility. Stress relaxation, the corollary of creep, occurs when skin is stretched over a given distance and that distance is held constant, whereas the force required to keep the skin stretched gradually decreases.

Hirschowitz et al. were the first to describe a method to gain skin tissue for wound closure by stretching.\textsuperscript{14} It became possible to gain skin tissue without disrupting edges of skin flaps by hooks. It appeared that the most efficient way to stretch skin with the use of skin hooks was cycle loading, intermittent stretching of skin followed by short periods of relaxation.\textsuperscript{12,14}

Besides undermining the skin edges of wounds, other techniques were developed on the basis of mechanical creep to close larger skin defects. In 1986, Liang et al.\textsuperscript{15}
described a technique of presuturing the skin with nylon sutures one day before excision. As a result, a significantly lower force was required to close 8 x 8 cm large standard-size wounds in pigs without undermining surrounding skin. To gain tissue by expansion in a shorter period of time, Sasaki\textsuperscript{16,17} reported an intraoperatively-sustained limited expansion to exploit the biomechanical properties of skin. When expanding skin flaps adjacent to defects to facilitate wound closure, a surface increase up to 30 percent was obtained. However, it was questioned whether skin stretching with this technique was merely the result of undermining wound edges.\textsuperscript{18,19} MacKay et al.\textsuperscript{18} demonstrated a significantly decreased wound closure tension in undermined wounds as compared with not undermined wounds but differences were not observed in undermined wounds versus intraoperative tissue expansion. Tension decrease depends primarily on the extent of skin mobilization and not on short-term expansion. Therefore, it was not considered to be a result of "creep" behavior.\textsuperscript{16}
The use of skin traction beyond a ‘normal’ degree of tension for the treatment of acute military wounds has been reported by Bashir who inserted 4 Kirschner pins in the edges of a wound and looped silver wires around their points of crossing. The wires were twisted on a daily basis. Furthermore, staples were applied to the skin edges to which rubber bands were attached.

In 1993, Hirshowitz et al. introduced a skin-stretching device for wound closure, the Sure-Closure system. This new device was designed to harness viscoelastic properties of skin by incremental traction and can be employed preoperatively, intraoperatively and postoperatively. After the first application of the Sure-Closure skin-stretching system, many clinical studies followed, that gave more insight in the possibilities of this technique. A series of indications were formulated to apply the Sure-Closure skin-stretching system after excision of tumors and tattoos, for scar revisions, for closure of traumatic injuries involving skin loss, open fasciotomies, amputations and for intraoperative closure of free-flap donor sites.

Besides the Sure-Closure system, which is the most popular skin-stretching device, various other intradermally-used skin-stretching devices have been designed and used for skin stretching such as the Frechet Extender, the External Tissue Extender and the Proxiderm. These systems have been applied successfully for wound closure in clinical settings but animal studies have not been reported yet to objectively determine the usefulness of these skin-stretching devices. The Sure-Closure system is in comparison with the other devices the only device that can be used intraoperatively in a time span of 30 minutes to close a large defect. The other skin-stretching devices are applied for at least several days up to many weeks postoperatively. Therefore we have selected the Sure-Closure system to establish what the effects are of intraoperative skin stretching for the closure of large defects.
REFERENCES

32 Futran, N. D. Closure of the fibula free flap donor site with the Sure-Closure skin-stretching device. Laryngoscope 106: 1487, 1996.
39 Ger, R. The management of neuropathic ulcers by the application of constant tension: a preliminary report. Minim. Invas. Ther. 4: 179, 1995