Clinical and experimental wound closure using a skin stretching device

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Chapter 1

Introduction
INTRODUCTION

Plastic and Reconstructive surgeons are on a regular basis confronted with skin defects that cannot be closed primarily. Many techniques have been developed for closure of large defects, varying from split skin grafts to free revascularised flaps. Free skin grafts often provide an aesthetically unacceptable color and texture match and can even lead to functional impairment. Besides, the cosmetic appearance of donor sites is not always satisfactory. Flaps can be unreliable and wound closure with flaps is time consuming and technically demanding.

Tissue expanders turned out to be an important help in plastic and reconstructive surgery\(^1\-\(^9\) to create optimal matching and to avoid unacceptable donor sites. With the help of this artificially-created skin surplus, adjacent defects can be closed. The use of tissue expanders has many advantages over conventional methods of closing large defects, but unfortunately there are also some disadvantages. The major disadvantages of tissue expanders are the need for multiple-staged surgical interventions and frequent visits to the out-patients department in-between operations. Furthermore, every implantation followed by inflations carries the risk of infection and leakage of the expander.

In 1993, a new technique was introduced based on the use of the Sure-Closure\(^\text{TM}\) skin-stretching system (Life Medical Sciences, Princeton, NJ, USA).\(^1\) This skin-stretching device was designed to harness the viscoelastic properties of skin by applying controlled and evenly-distributed tension along the wound margins. The biomechanical properties of skin, known as mechanical creep and stress relaxation,\(^1\)\(^2\)\(^3\) allow skin to stretch beyond its inherent extensibility in a short period of time. As a result of skin stretching, wound closing tension decreases allowing primary closure of large defects.

Immediate attempts to apply these principles to wounds were frustrated in the past by the inability to grasp wound edges without damaging the skin. Application of towel clips or large clamps results in either tearing or crushing the wound edges that have to be approximated.\(^1\)\(^4\) Using the Sure-Closure skin-stretching system the stretching force is distributed evenly over approximately 8-cm long pins that are inserted in the dermis. With this method, substantial forces can be applied to the entire wound edge without undermining, tearing or crushing the skin. Tissue damage is also prevented because the device has a safety clutch which disengages the tension should the force applied to the wound become too high (more than 2.5 kg).
When this technique is used, donor defects and associated morbidity could be avoided. Sensate reconstructions with maintenance of cosmetic appearance of the skin without disadvantages of the use of tissue expanders could be within reach. After the first application of the Sure-Closure skin-stretching system by Hirshowitz et al. in 1993 many clinical studies were performed that gave more insight in the potentials of the system.14-24 A series of indications was formulated for its use such as wound closure after excision of tumors, tattoos, broad scars, open fasciotomies and amputations and closure of traumatic cutaneous defects with or without exposed bone, joint or tendon. However, solid experimental studies on the application of the system are still lacking. Furthermore, prospective clinical studies with long-term results are essential to determine the functional and aesthetic outcome of wound closure with the use of the skin-stretching system. Finally, benefits and consequences of undermining or not undermining of stretched skin have to be established because there is a controversy, whether undermining of wound margins is a useful strategy in closing large defects.27-29

Besides, many fundamental histological and cell biological questions remain to be answered. What histological changes occur when skin is stretched using the Sure-Closure skin-stretching system? So far, only a few studies have been published on the histological changes in rapidly-expanded skin but only after immediate intraoperative tissue expansion and not after skin stretching.30,31 The results of these studies are controversial as well. Another issue is how the microcirculation of skin is behaving during stretching and how viability of the skin margins is effected.

To address these questions, animal experiments are justified to provide a scientific base and an objective insight in the potentials of the skin-stretching system. The studies described in the present thesis were designed to elucidate the above mentioned fundamental and clinical issues related to the use of the Sure-Closure skin-stretching device in experimental and clinical settings.
Aims of the Study

Developments in plastic and reconstructive surgery usually have an empirical background. The development of the Sure-Closure skin-stretching technique is no exception. However, issues have been raised that justify animal experiments to provide a scientific base for the use of the skin-stretching system. An analysis of the histological backgrounds of the effects of skin stretching, tension measurements and a study of the effects on vascularization and oxygenation will provide better and more objective insights in the potentials of skin stretching in general and the skin-stretching device in particular. Therefore, the aim of the present study was to address the following questions about skin stretching.

1. Is undermining of wound margins a more useful strategy in closing large skin defects as compared with skin stretching with a skin-stretching device?
2. What is the tension decrease during skin stretching using a skin-stretching device in undermined and not undermined wounds?
3. Does the use of a skin-stretching device impair the immediate or long-term viability of skin?
4. When a large defect is closed using the technique of skin stretching, is it wise to undermine the surrounding skin?
5. Is there a quantitative method to determine changes in the orientation of collagen fibers in the dermis due to mechanical stress?
6. What are the histomorphological changes in the dermis in undermined and not undermined skin under influence of 30 minutes of skin stretching?
7. What happens to the skin-microcirculation and oxygenation of undermined and not undermined wound edges that are, cyclic loaded, closed by means of a skin-stretching device? Is it possible to give an objective advise what the safest way is to perform skin stretching?
8. How are the short-term and long-term clinical results of closure of large skin defects using a skin-stretching device? These questions are divided in the subquestions: how long does it take to achieve successful closure, what is the frequency of complications, how is the residual scar at different locations of the body and what is the patient's impression?
OUTLINE OF THE THESIS

In Chapter 1, the Sure-Closure skin-stretching system is introduced. Background on treatment options of large skin defects are given.

In Chapter 2, the different methods of wound closure by means of skin stretching are reviewed.

In Chapter 3, the principles of the Sure-Closure skin-stretching system and its use are explained.

In Chapter 4, the efficacy of skin stretching with the skin-stretching device is tested by quantifying the tension decrease during stretching of undermined and not undermined wounds. The viability of skin margins is examined in both situations. The tension decrease as a result of skin stretching is compared with the tension decrease after undermining of the skin margins.

In Chapter 5, the development of a quantitative microscopical method is described to determine objectively changes in the extracellular matrix of the dermis as a result of skin stretching.

In Chapter 6, the histomorphological changes in stretched skin are described that explain the decreased wound-closing tension during stretching and explain how skin can stretch beyond its inherent extensibility.

In Chapter 7, the microcirculation in undermined and not undermined skin is assessed using laser Doppler flowmetry (LDF) and transcutaneous oximetry (tcpO₂) simultaneously during the application of the skin-stretching device.

In Chapter 8, the use of the skin-stretching device for closure of a large groin defect after inguinal lymphadenectomy for penile cancer is discussed.

In Chapter 9, applications of the skin-stretching device on a series of patients are described and long-term functional and aesthetic results of wound closure with the device are evaluated.

A summary in English and Dutch concludes this thesis.
REFERENCES


