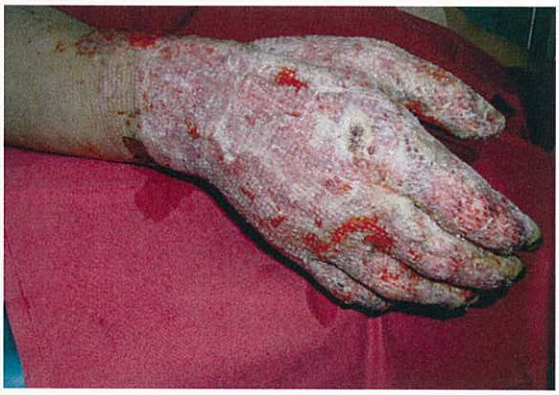
Mesh Graft



THE V.A.C.®
VACUUM ASSISTED CLOSURE™

KCI
Wolfgang Imendörffer
Marketing Manager CEE
15 April, 2009

KCI
The Clinical Advantage

Spalthautfixation mit VAC-ATS nach schwerer Verbrennung im Kleinkindesalter- mehr als nur mechanische Wirkung ?

Schintler M.V. [1], *Trop M.* [2], *Spendel S.* [1], *Hellbom B.* [1], *Scharnagl E.* [1], *Klinische Abteilung für Plastische Chirurgie*[1], *Universitätsklinik für Chirurgie, Intensiv- und Brandverletzteneinheit* [2], *Universitätsklinik für Kinder und Jugendheilkunde, Medizinische Universität Graz*

Einleitung

Unmittelbar nach einem Verbrennungstrauma ist die Wundfläche im allgemeinen als steril anzusehen. Innerhalb der folgenden 48 Stunden kommt es zur bakteriellen Besiedelung der großen offenen Wundflächen, wobei das Wundexsudat einen idealen Nährboden für die Keime darstellt. Durch das Einschwemmen von Toxinen und Aktivierung verschiedenster Entzündungsmediatoren kann trotz adäquater und früher intensivmedizinischer Maßnahmen eine Sepsis mit hoher Letalität resultieren. Als Pfeiler einer erfolgreichen Therapie bei tief- und ganzdermalen Verbrennungen ist die Frühnekrektomie und Spalthautdeckung anzusehen. Bei zirkulären Verbrennungsarealen an den Extremitäten sowie im Thoraxbereich ist in der Akutphase oft eine Escharotomie erforderlich. Die VAC system wird zur Sicherung der Spalthauttransplantate insbesondere bei anatomisch problematischen Zonen angewandt.

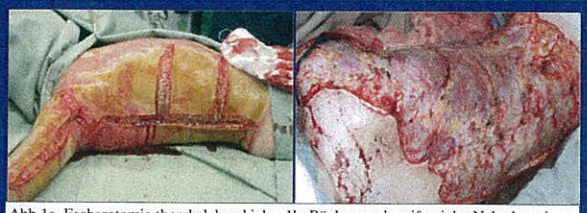


Abb 1a. Escharotomie thorakal, brachial 1b. Rücken nach epifascialer Nekrektomie

Material und Methoden

Wir berichten über einen 5-jährigen Knaben der sich an einer brennenden Kerze durch Entflammung der Kleidung eine 40 prozentige großteils ganzdermale Verbrennung von Thorax, Hals, Axilla Rücken, und der rechten oberen Extremität zuzog. Nach initialem Hautdebridement erfolgte die Escharotomie an Thorax und rechtem Arm. Bereits 24 Stunden nach der Aufnahme erfolgte die epifasziale Nekrektomie und Defektdeckung mit 1:2 gemeshter Spalthaut sowie Fixation und Sicherung der Transplantate mit einem XXL-Polyurethanschwamm und kontinuierlichem Sog eines VAC-ATS.

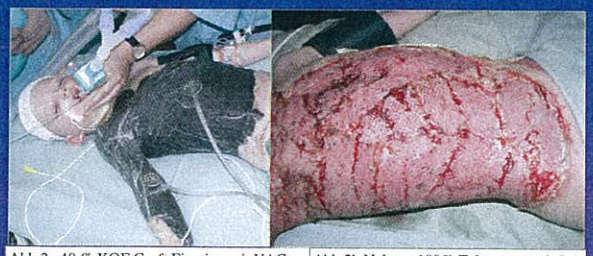


Abb 2a 40 % KOF Graft Fixation mit VAC Abb 2b Nahezu 100% Take-rate nach 7 d

Datum	7.5. 04	8.5.	9.5.	10.5.	11.5.	12.5.	13.5.	14.5.	21.5.	4.6.
Leuko(5-13x10³/µl)		20,4	12,6	8,7	11,3	13,6	11, 9	11.7	14,8	9,4
Protein (5,8-8,0 g/dl)		3,6	4,1	4	4,4	5,1	5		5,5	6,1
Albumin (3,5-5,5g/dl)		1,5	2,8	2,1	2,4	2,6	2,6	2,6	2,6	
CHE (4500-12000U/l)		6592	3558	3431	3307	4165	4104		4966	6160
CK (-160 U/l)		630		858		321		104		
CRP (-8 mg/l)		10	55	57	34	14	7		8	5
GOT (-43 U/l)		31	46	49	33	35	26		27	18
GPT (-45 U/l)		24	31	37	36	34	32		58	15
	Unfall	Aufnahme Escharatomie	Excision VAC	VAC	VAC	VAC	VAC	VAC		
Flüssigkeit (ml)			350	700	220	140	100	50		

Tab.1 Laborwerte und TNP-Flüssigkeitsmengen

Ergebnisse

Nach Abnahme des VAC-systemes am 6. postoperativen Tag war der Erfolg der gleichmäßigen Kompression der Transplantate erkennbar. Auch in der Axilla konnten wir eine Takerate von 95 % erzielen. Der lokale mechanische Effekt des VAC-systemes konnte uns weniger beeindrucken, als der begleitende systemische. Bei einem schwer brandverletzten Kind konnte 48 Stunden postoperativ eine Extubation erfolgen. Trotz 40- prozentiger Körperoberfläche drittgradiger Areale waren keine Spuren der erwarteten Verbrennungskrankheit, der eingeschränkten oder drohenden Störungen der Organfunktion erkennbar. Weder klinisch noch laborchemisch waren Zeichen der sonst üblichen schweren Störung der Organfunktionen bemerkbar.

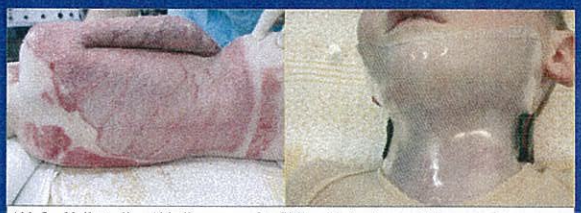


Abb 3a. Vollständige Abheilung 3b. Silikon-Halsstütze und Kompressionsanzug

Schlussfolgerungen

Die Frühnekrektomie und Spalthautdeckung ist die Therapie der Wahl bei tief- und ganzdermalen Verbrennungen. Das VAC- System findet zur Fixation und Sicherung von Spalthauttransplantaten Anwendung. **Die systemische Wirkung durch kontinuierlichem Abtransport der interstitiellen Flüssigkeit, wie bei unserem schwerbrandverletzten Patienten, der keinerlei SIRS symptome entwickelte, wurde bis dato nicht beschrieben. Wir meinen, daß die VAC – Therapie in Zukunft einen vielversprechenden systemischer Therapieansatz in der komplexen Behandlung von Schwerbrandverletzten darstellt.**

Literatur

1. Argenta LC, Morykwas MJ Vacuum assisted closure : a new method for wound control and treatment : clinical experience. Ann Plast Surg 1997; 38: 563-576 2. Banwell P, Musgrave M. Topical negative pressure (TNP) therapy: Mechanisms and indications. Proceedings European Tissue Repair Society London 2003: 73-88 3.Barret JP, Herndon DN. Modulation of inflammatory and catabolic response in severely burned children by early burn wound excision in the first 24 hours. 3. Dyess DL, Ferrera JJ, Luterman A, Curreri PW. Subeschar tissue fluid: a source of cell-mediated immune suppression in victims of severe thermal injury. J Burn Care Rehabil 1991;12: 101-105 3.Ferrera JJ, Dyess DL, Luterman A, Curreri PW. The suppressive effect of subeschar tissue fluid upon in vitro cell-mediated immunologic function. J Burn Care Rehabil 1988; 9: 584-588 5. Jing C, Yi-Ping Z, Xin-Zhou R. An experimental study on systemic inflammatory response syndrom induced by subeschar tissue fluid. Burns 2000; 26:149-155 6. Kremer B, Allgöwer M, Graf M, Schmidt KH, Schoelmerich J, Schoenberger GA. The present status of research in research of burn toxins. Intensive Care Med 1981; 7: 77-87. 7. Morykwas MJ, Argenta LC, Shelton. Brown EI, McGuirt W (1997)Vacuum Assisted Closure: A New Method for Wound Control and Treatment: Animal Studies and Basic Foundation. Ann of Plast Surg Vol.38 Nr 6 8. Schneider AM, Morykwas MJ, Argenta LC (1998) A new and reliable method of securing skin grafts to the difficult recipient bed. Plast Reconstr Surg 102: 1195-1198 9. Sheridan RL, Ryan CM, Yin LM, Hurley J Tompkins RG. Death in the burn unit:sterile multiple organ failure. Burns 1998, 24; 307-311 10. Sherwood ER, Traber DL. The systemic inflammatory response syndrom. 2002 Total Burn Care-Second Edition, David Herndon. W.B. Saunders 257-270 11. Tang Y-W The effect of burn subeschar tissue fluid on skeletal muscle and hepatic amino acid uptake in an experimental system in vitro. Burns 1999 ;25: 137-144

Hauttransplantation zur finalen Deckung chronischer Wunden, gesichert durch die Vakuumtherapie

D. S. Mahmud

Meshgraft for the Final Covering of Chronic Wounds, Secured by V.A.C.® Therapy

Einleitung

Die Idee der Vakuumtherapie hat in den letzten Jahren zunehmend an Bedeutung in der Behandlung vor allem chronischer Wunden gewonnen. Gerade bei der Behandlung von chronischen Wunden ist ein therapeutisches Konzept notwendig, um einen Heilungserfolg zu gewährleisten. Die Vakuumtherapie wird nach chirurgischen Wunddebridements erfolgreich zur Behandlung chronischer Wunden eingesetzt. Seit der Einführung der Vakuumtherapie durch Argenta und Morykwas hat sich das Therapieverfahren in mehreren Fachgebieten als eine wirksame Option zur Behandlung von akuten und chronischen Wundheilungsstörungen etabliert.

Anhand von Tierexperimenten und klinischen Studien konnten Argenta und Morykwas nachweisen, dass durch die Applikation von negativem Atmosphärendruck die lokale Gewebesituation deutlich verbessert wird. Zunächst erfolgt durch eine Verminderung des interstitiellen Ödems eine Wiedererweiterung komprimierter Arteriolen. Dadurch wird die örtliche Durchblutungssituation und Sauerstoffsättigung des Gewebes gesteigert. Die Vakuumtherapie (Vacuum Assisted Closure) hat in Literatur und klinischer Praxis gute Heilungserfolge bei der Behandlung von chronischen Wunden mittels Hauttransplantation. Nach zufrieden stellender Konditionierung des Wundgrundes wurde auf dem gewachsenen Granulationsrasen ein Meshgraft-Implantat aufgelegt. Mit Hilfe des angelegten Unterdrucks konnte sowohl der Grenzzonenkontakt zwischen Transplantat und Wundgrund optimal gehalten-, als auch das entstandene Wundexsudat aus dem Wundbereich entfernt werden. Der Pflegeaufwand reduzierte sich auf einen 2-maligen Verbandwechsel bis zum vollständigen Einheilen des Transplantates.

Fallbericht

Eine 80-jährige Frau nach Mofa-Unfall stellte sich am 14.5.2005 in unserer Klinik vor. Bei dem Unfall sei das rechte Bein der Patientin unter den hinteren Reifen eines Wagens geraten. Nachdem Wegfahren des Autos konnte sie noch auf beiden Beinen stehen. Sie kam erst 2 Stunden nach dem Unfall zur Behandlung in unsere Klinik wegen zunehmender Schmerzen und Schwellung im betroffenen Bein. Aufgrund einer Herzrhythmusstörung war die Patientin marcumarisiert. Eine Fraktur war radiologisch ausgeschlossen worden. Zuerst wurde die Patientin konservativ behandelt. Es kam allmählich zu einer Verflüssigung des Blutergusses.

Es bestand weiter ein großes Hämatom im Wadenbereich rechts mit Schwellung, Schmerzen und Druckschmerzen (30×15 cm im Durchmesser). Zusätzlich oberflächliches Hämatom im Bereich des rechten Oberschenkels. Das Hämatom im Wadenbereich wurde am 20.5.05 operativ ausgeräumt, danach kam es zu einer Wundheilungsstörung und einer Nekrosestelle von 30×15 cm im Durchmesser. Die operative Sanierung erfolgte mittels Nekrosenabtragung und Debridement, eine Vakuumeinlage mit einem PU-Schwamm (schwarzer Schwamm) und initialem kontinuierlichem Sog von 125 mm Hg. Ein Fett-Gaze-Streifen wurde als Wundrandschutz eingelegt.

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Bibliografie
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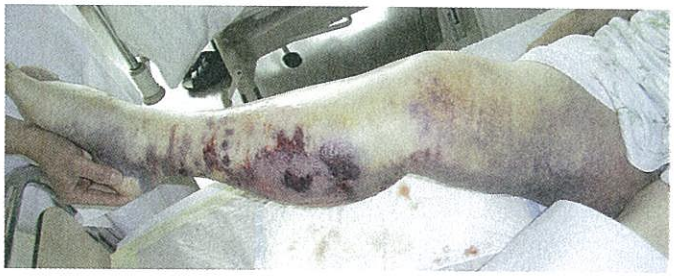

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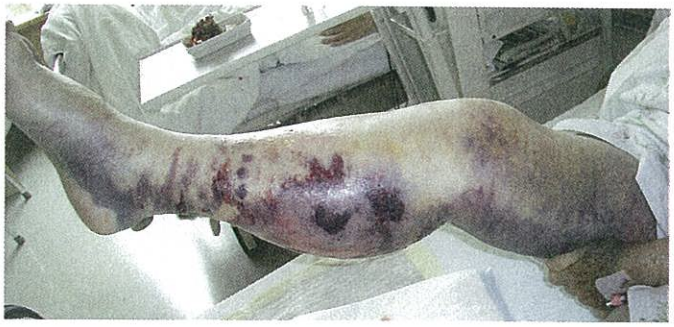

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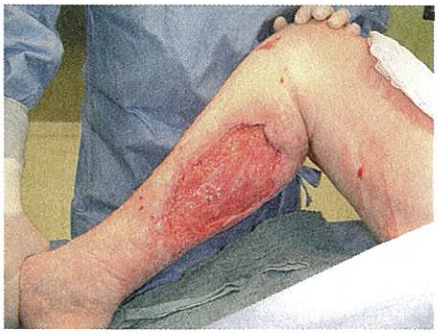

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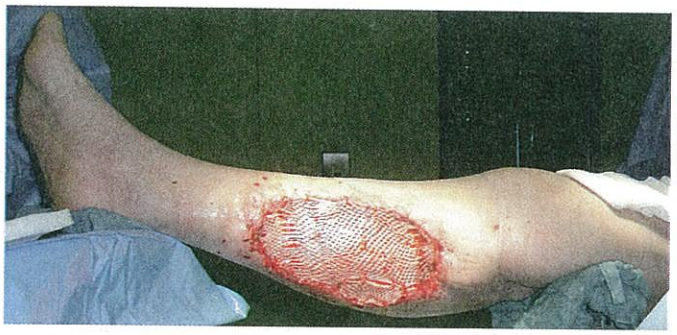

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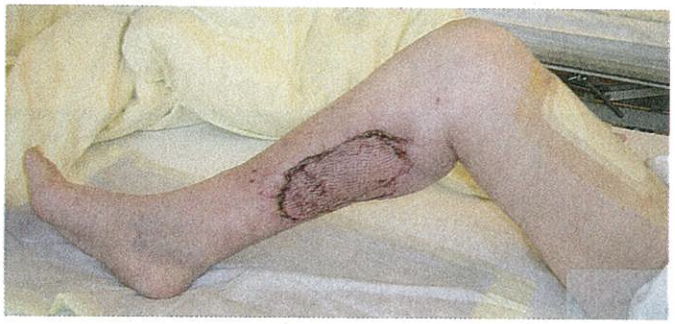

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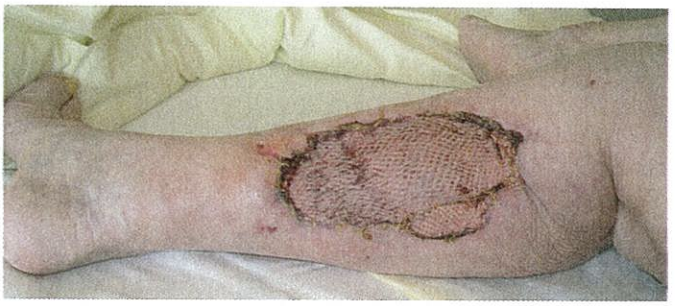

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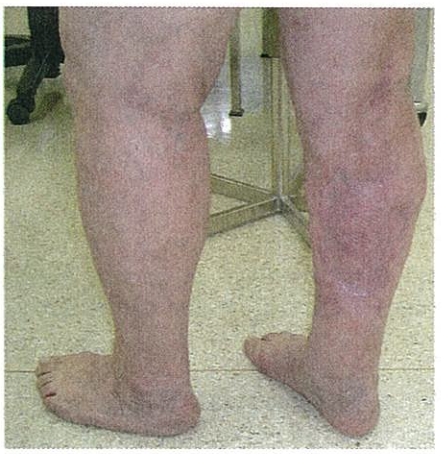

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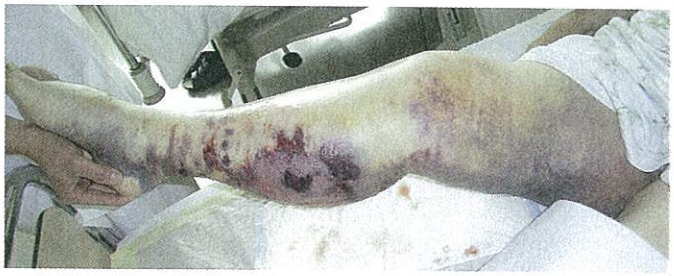
Nach erfolgreicher weiterer Konditionierung mit Hilfe der Vakuumtherapie konnte eine Meshgraft-Deckung mit einem Transplantat (Schichtdecke 0,3 mm) vom rechten Oberschenkel erfolgen, gesichert durch Vakuumtherapie mittels weißem Schwamm aus PVA, Sog-Stärke 75 mm Hg, Sogmodus kontinuierlich für 5 Tage wurde angeschlossen. Nach 5 Tagen wurde die V.A.C.®-Therapie beendet und das mittlerweile ausreichend vaskularisierte Transplantat heilte problemlos spontan ein.

Die Patientin war während der gesamten Behandlungszeit mobilisierbar. Nach Abschluss der klinischen Behandlung genoss die Patientin wieder neue Lebensqualität.

Fallbericht

Eine 80-jährige Frau wurde bei uns am 12.7.2005 mit Hilfe der Sanitäter in die Notaufnahme gebracht. Die Patientin befand sich in einem stark verwahrlosten Zustand, voll mit Kot beschmiert und am linken Unterschenkel fand sich ein riesiges Gamaschenulkus mit massivem Madenbefall. Bei der Patientin war eine pAVK vom Unterschenkeltyp bds. links-betont bekannt. Es



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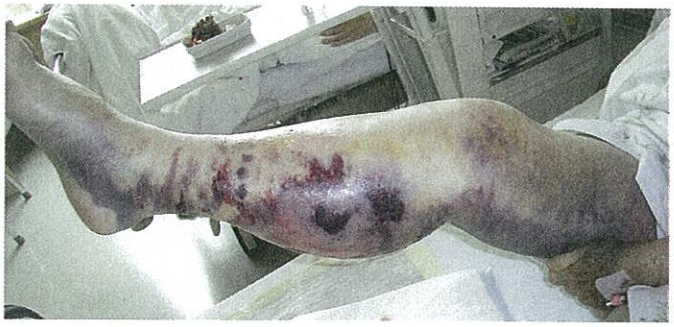

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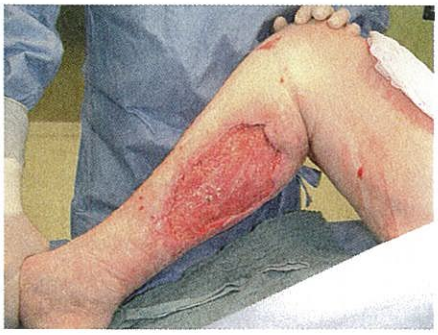

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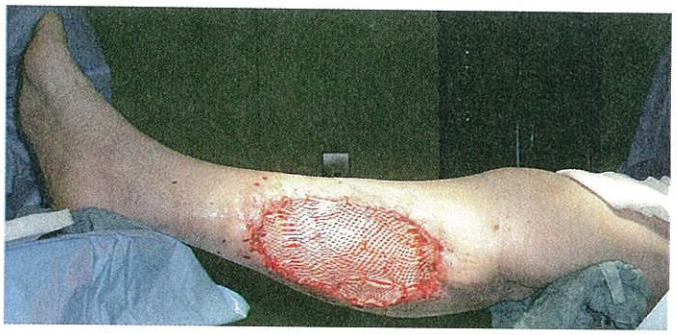

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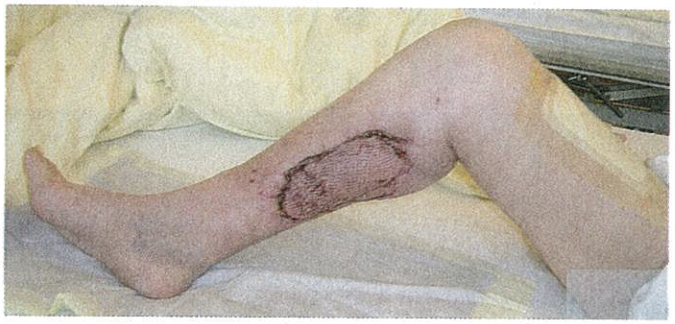

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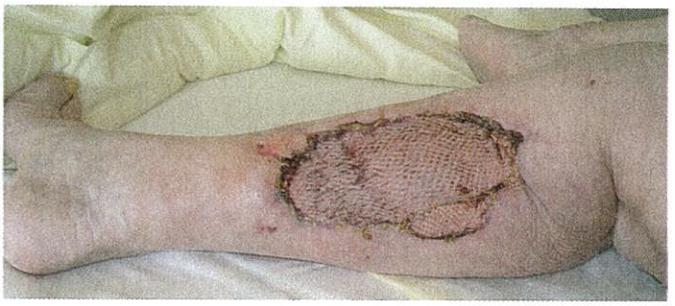

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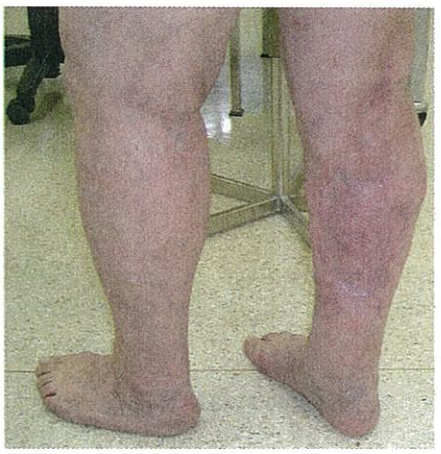

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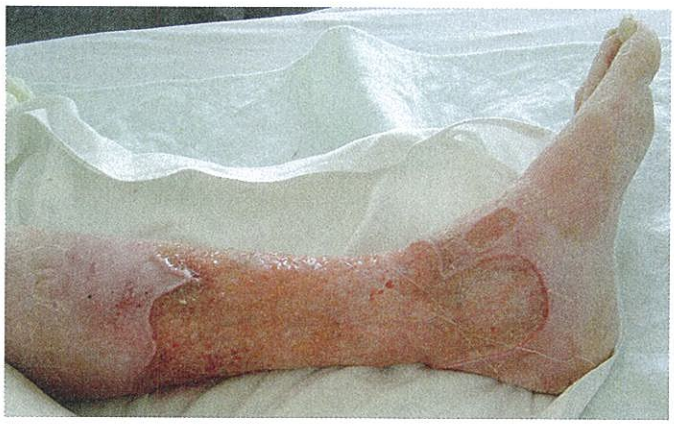

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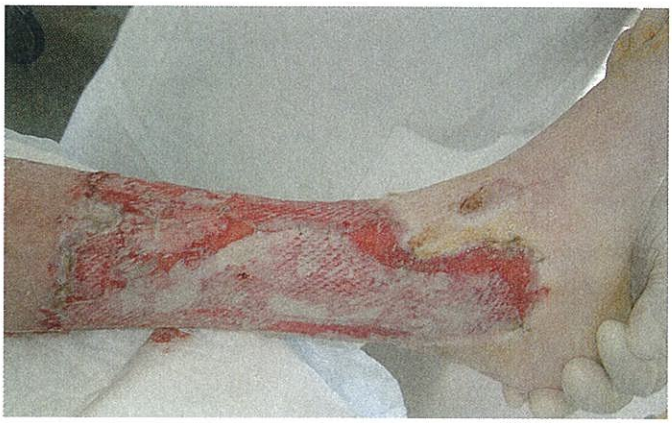

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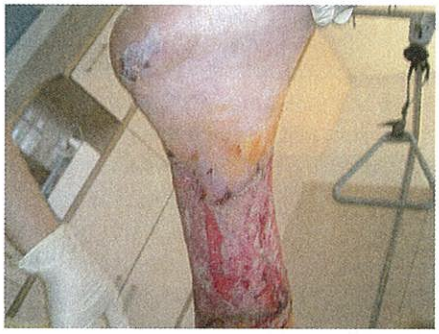
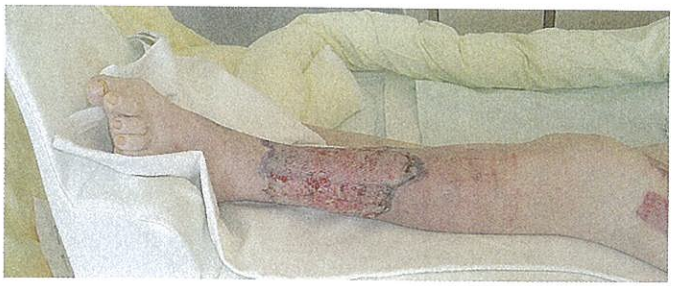


Abb. **11**

bestand eine Stuhl- und Harninkontinenz sowie eine Altersdemenz. Das Ulkus bestand seit fast 2 Jahren und wurde als therapieresistent eingestuft.

Das Ulkus wurde 2 × wöchentlich mit Kolloidverbänden versorgt. Auf die rasche Verbesserung des Wundbefundes erfolgte nach 2 Wochen eine Meshgraft-Transplantation, gesichert durch Vakuumtherapie mit PVA-Schwamm – V.A.C.®-Vers-Foam (Sogstärke 75 mm Hg, Sogmodus kontinuierlich) für 5 Tage. Zwischen die Haut und den Schwamm wurde ein Fett-Gaze-Streifen eingelegt.

Nach dieser Zeit wurde die Vakuumtherapie beendet und auch eine ausreichende Revaskularisation des Transplantats erzielt. Das Transplantat heilte problemlos und spontan ein.



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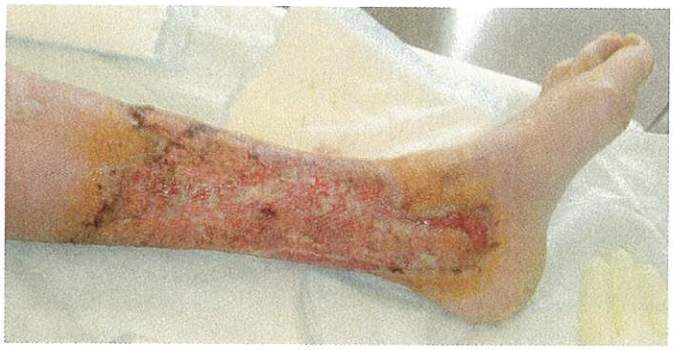

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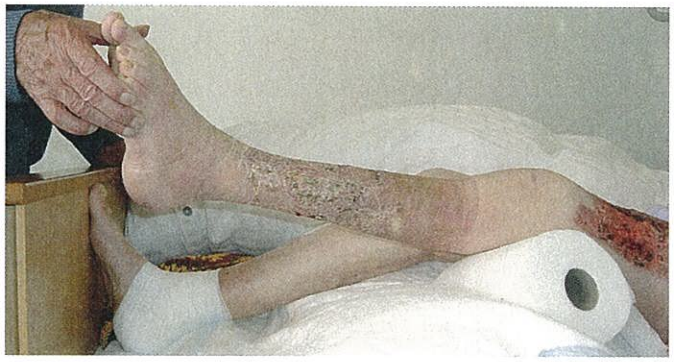

Abb. **14**

Ergebnisse

Beide Patientinnen tolerierten den Vakuumverband gut, es kam bei keiner zu einem Vakuumverlust, beide Patientinnen benötigten keine weitere Spalthauttransplantation und konnten jeweils mit lokaler Wundpflege vollständig in Abheilung gebracht werden.

Schlussfolgerung

Die Fixierung von Spalthauttransplantaten mit dem V.A.C.®-System ist ein sicheres und einfach zu handhabendes Verfahren und wird von den Patienten gut vertragen, besonders im Bereich der unteren Extremität, aber auch bei alten Patienten mit schlechter Wundheilung hat sich diese Art der Verbandsanordnung als vorteilhaft herausgestellt.

Mit der Anwendung des Vakuumsystems bei der Spalthauttransplantation ist durch die integrierte Drainage eine Absonderung des Wundsekretes möglich. Das Auflegen von Fett-Gaze-Streifen

erleichtert das Abnehmen des Verbandes und verhindert das unbeabsichtigte Entfernen des Hauttransplantates. Man muss das aufgelegte Meshgraft-Transplantat an den Wundgrund mit leichtem Druck anbringen, um somit auch über markante Unebenheiten hinweg einen vollflächigen Meshgraft-Wundgrundkontakt für die Zeit der Einheilungsphase (5 Tage) zu gewährleisten. Durch die Dauer des Druckes und die Unbeweglichkeit des Schwammes kommt es zu keinem Scherkraftbelastung am Transplantat.

Prinzipiell besteht die Möglichkeit, den Schwamm nicht mittels Faden oder Hautklammern am Hautrand zu fixieren. Beim Sichern der Meshgraft mittels Vakuumtherapie sollte berücksichtigt werden, dass das Anlegen eines Soges mit einer Volumen- und Flächenverminderung des Schwammes einhergeht. Hierdurch wird bei fehlender Fixation des Schwammes am Wundrand dieser schrumpfend dann zurückweichen und damit ein nicht fixiertes Meshgraft – Verschieben und Verwerfungen des vormals vollflächig ausgestrichen Transplantates vermieden.

Um eine Verschiebung des Transplantates unter dem Schwamm zu vermeiden, erscheint somit das Fixieren des Schwammes in diesen 2 Fällen sinnvoll zu sein.

J. Dissemond
A. Körber
S. Grabbe

Verbesserte Einheilrate von Mesh-graft-Transplantaten bei Patienten mit Ulcus cruris durch postoperativen Einsatz von Vakuumversiegelung

Take of Mesh Grafts in Chronic Leg Ulcer Patients Improves by Vacuum-Assisted Closure Device

Zusammenfassung

Die Vakuumversiegelung wird seit einigen Jahren bereits erfolgreich postoperativ zur Fixierung von Spalthaut-Transplantaten eingesetzt. Bislang liegen jedoch kaum wissenschaftlich belegte Daten darüber vor, ob dieser Einsatzbereich die resultierenden Kosten rechtfertigt. Wir berichten über ein Kollektiv von 54 Patienten mit Ulcus cruris und insgesamt 74 konsekutiv durchgeführten Mesh-graft-Transplantationen. Bei 28 Transplantationen erfolgte eine postoperative Vakuumversiegelung, bei 46 Transplantationen wurde eine Therapie mit Silikon-beschichteter Fettgaze durchgeführt. Im Kollektiv mit Vakuumversiegelung zeigte sich 10–14 Tage postoperativ eine Einheilrate von 92,9%. Im Kollektiv ohne postoperative Vakuumversiegelung betrug die Einheilrate 67,4%. In der Analyse der Subpopulationen konnten zudem schlechtere Einheilraten bei Patienten, die älter als 70 Jahre waren, einen Diabetes mellitus hatten oder eine Dermatoliposklerose aufwiesen, objektiviert werden. Unsere retrospektiv ausgewertete vergleichende klinische Studie zeigt erstmals eine signifikant verbesserte Einheilrate von Mesh-graft-Transplantaten bei Patienten mit Ulcus cruris durch den Einsatz einer postoperativen Vakuumversiegelung.

Schlüsselwörter
Vakuumversiegelung · Hauttransplantation · Mesh-graft · Ulcus cruris · chronische Wunde

Abstract

Vacuum-assisted closure (V.A.C.®) is an established therapeutic option in the management of acute and chronic granulating wounds. In recent years, little data has been published concerning skin graft transplantation and postoperative V.A.C.® therapy. We report a consecutive case series of 54 patients with chronic leg ulcer who received a total of 74 mesh grafts. A postoperative V.A.C.® therapy was performed in 28 mesh grafts, and 46 mesh grafts were treated with standard gauze therapy. In the V.A.C.® group, 92.9% grafts showed complete healing. In the treatment group without postoperative V.A.C.® therapy, 67.4% of the mesh grafts had taken. Differential analysis revealed a correlation in patients over 70 years of age or in patients suffering from diabetes mellitus or dermatoliposclerosis. Particularly patients with diabetes mellitus and of greater age exhibited improved take rates in the V.A.C.® group. The results of our study demonstrate for the first time the significant benefit of V.A.C.® therapy after mesh-graft-transplantation in chronic leg ulcer patients as evaluated in a clinical trial with a control group.

Key words
Vacuum-assisted closure · leg ulcer · chronic wound · mesh graft · skin-graft

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Bibliografie
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Einleitung

Durch Patienten mit einem Ulcus cruris resultieren zunehmend volkswirtschaftliche Kosten, die durch stationäre und ambulante Behandlungen, verordnete Therapeutika, krankheitsbedingte Arbeitsunfähigkeit und vorzeitiges Ausscheiden aus dem Erwerbsleben bedingt sind [5]. Trotz optimaler präoperativer Wundgrundkonditionierung belegen verschiedene klinischen Untersuchungen im Rahmen einer abschließenden Hauttransplantation ein Therapieversagen bei 10–67% des sehr heterogenen Patientenklientels [4, 9, 10].

Die Vakuumversiegelung wird seit einigen Jahren bereits erfolgreich postoperativ zur Fixierung von Spalthaut-Transplantaten eingesetzt. Bislang liegen jedoch kaum wissenschaftlich belegte Daten darüber vor, ob dieser Einsatzbereich die resultierenden Kosten rechtfertigt. Im Rahmen der hier vorgestellten klinischen Studie erfolgte der Einsatz der Vakuumversiegelung unter Verwendung eines Polyvinylalkoholschwamms unmittelbar postoperativ nach durchgeführter Mesh-graft-Transplantation. Ziel dieser retrospektiv ausgewerteten Studie war es, den Einfluss der Vakuumversiegelung auf die postoperative Einheilrate im Vergleich zu konventioneller postoperativer Transplantatversorgung mittels Verbänden mit konventioneller Fettgaze zu evaluieren.

Resultate

Wir berichten über ein Kollektiv von 54 Patienten mit Ulcus cruris und insgesamt 74 konsekutiv durchgeführten Mesh-graft-Transplantationen (Abb. **1**). Bei 28 Transplantationen erfolgte eine postoperative Vakuumversiegelung, bei 46 Transplantationen wurde eine Therapie mit Fettgaze durchgeführt. Im Kollektiv mit Vakuumversiegelung (Model Freedom®, Firma KCI), die über 5–7 Tage postoperativ belassen wurde, zeigte sich 10–14 Tage postoperativ eine Einheilrate von 92,9%. Im Kollektiv ohne postoperative Vakuumversiegelung mit postoperativem Einsatz von Mepitel® (Firma Mölnlycke) betrug die Einheilrate 67,4%. In der Analyse der Subpopulationen konnten zudem schlechtere Einheilraten bei Patienten, die älter als 70 Jahre waren, einen Diabetes mellitus hatten oder eine Dermatoliposklerose aufwiesen objektiviert werden. Schwerwiegende Nebenwirkungen wurden nicht beobachtet.

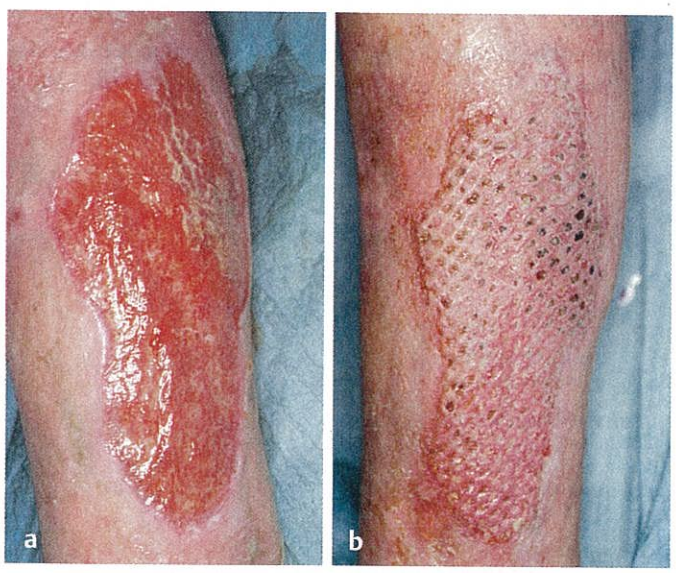

Abb. **1** Ulcus cruris (**a**) vor und (**b**) nach Mesh-graft-Transplantation.

Besprechung

In der von uns durchgeführten Studie konnte erstmals an einem Patientenkollektiv mit Ulcus cruris nachgewiesen werden, dass der postoperative Einsatz der Vakuumversiegelung nach Mesh-graft-Transplantation im Vergleich zu konventioneller Therapie zu einer signifikant verbesserten Einheilrate der Transplantate führt. Nachdem sich die Vakuumversiegelung in der Förderung der Ausbildung von Granulationsgewebe bei Patienten mit einem Ulcus cruris als eine Methode der ersten Wahl hat etablieren können, wird nun auch zunehmend über den erfolgreichen postoperativen Einsatz berichtet. So konnte in mehreren klinischen Untersuchungen gezeigt werden, dass es nach erfolgter Hauttransplantation unter der postoperativen Anlage eines Schwammes in Verbindung mit der Anlage eines Vakuums durch eine Redon-Drainage zu einer Einheilung der Transplantate bei 85–100% der Patienten kam [2, 6]. Der Nachteil der Verwendung einer Redon-Drainage als Sogquelle besteht in dem nicht zu kon-

Tab. **1** Resultate aller untersuchten Patienten

Parameter	*total*	*erfolgreiche Einheilung*	
		absolut	*(%)*
mit VAC	28	26	92,9*
ohne VAC	46	31	67,4
mit Fibrose	31	20	64,5*
ohne Fibrose	43	37	86,0
mit Diabetes	15	9	60,9
ohne Diabetes	59	48	81,4
≥ 70 Jahre	39	33	84,6
> 70 Jahre	35	24	68,6
gesamt	74	57	77,0

* = signifikant (Die statistische Auswertung der untersuchten Patientengruppen erfolgte unter Verwendung des χ^2-Tests. Als signifikant wurde ein $p < 0,05$ gewertet)

Tab. **2** Vorteile und Nachteile der postoperativen Vakuumversiegelung

Vorteile	*Nachteile*
verbesserte Einheilraten	Kosten
kein Sekretstau	hoher Zeitaufwand
Fixation des Transplantates	vereinzelt Schmerzen
hohe Akzeptanz durch Patienten	Geräuschentwicklung
weniger Gram-negative Bakterien	(mehr Gram-positive Bakterien)
erhaltene Mobilität	
physikalische Barriere	
Kosten	

trollierenden System mit hohem Ausgangssog und im Verlauf stetig absteigenden unkontrollierten Druckverhältnissen. Zudem erfolgt keine akustische Warnmeldung, falls das System Druck verlieren sollte. Nach Druckverlust kommt es jedoch zu einem Sekretstau, der als kontraindiziert zu sehen ist. In weiteren kleineren, jedoch nicht standardisierten Fallserien mit teilweise sehr heterogenem Patientenkollektiven wurde über gute Einheilraten unter postoperativer Verwendung einer Vakuumversiegelung bei akuten bzw. chronischen Wunden sowie eine komplikationsfreie postoperative Mobilisation der Patienten berichtet [1, 3, 7, 8]. Zusammenfassend sind die Ergebnisse dieser Untersuchungen bei deutlich heterogenen Patientenkollektiven und überwiegend posttraumatischen Indikationen durchgeführt worden und nur bedingt mit dem von uns beschriebenen Patientenkollektiv vergleichbar. Die herausgearbeiteten Vorteile einer postoperativen Vakuumversiegelung sind jedoch ein hilfreiches Indiz für die Effizienz dieses Verfahrens auch bei anderen Indikationen. Weiterhin erfolgte in keiner dieser Studien ein Vergleich einer konsekutiv untersuchten Population, die in der ersten Phase ohne Vakuumversiegelung und in der zweiten Phase mit Vakuumversiegelung therapiert worden ist. Darüber hinaus waren wir erstmalig in der Lage eine Analyse der Subpopulationen vorzunehmen und zu zeigen, dass die Einheilraten bei Patienten, die älter als 70 Jahre waren, einen Diabetes mellitus hatten oder eine Dermatoliposklerose aufwiesen deutlich, teilweise sogar signifikant, schlechter waren.

Fazit

Unsere retrospektiv ausgewertete vergleichende klinische Studie zeigt erstmals eine signifikant verbesserte Einheilrate von Mesh-graft-Transplantaten bei Patienten mit Ulcus cruris durch den Einsatz einer postoperativen Vakuumversiegelung. Ermutigt durch die Auswertung unserer Resultate möchten wir postulieren, dass sich der postoperative Einsatz einer Vakuumversiegelung nach Mesh-graft-Transplantation trotz der kurzfristig erhöhten Kosten in Zukunft insbesondere bei Patienten mit einem Ulcus cruris zu einer Methode der ersten Wahl entwickeln sollte.

Literatur

[1] Carson SN, Overall K, Lee-Jahshan S, Travis E. Vacuum-assisted closure used for healing chronic wounds and skin grafts in the lower extremities. Ostomy Wound Manage 2004; 50: 52–58
[2] Fleischmann W, Lang E, Kinzl L. Vakuumassistierter Wundverschluss nach Dermatofasziotomie an der unteren Extremität. Unfallchirurg 1996; 9: 488–492
[3] Karl T. Ergebnisse der V.A.C.® Therapie in der Gefäßchirurgie. Vasomed 2005; 5: 172–176
[4] Kirsner RS, Mata SM, Falanga V, Kerdel FA. Split-thickness skin grafting of leg ulcers. The University of Miami Department of Dermatology's experience (1990–1993). Dermatol Surg 1995; 8: 701–703
[5] Körber A, Dissemond J. Aktuelle Therapieoptionen des Ulcus cruris venosum – Teil 1. Wundforum 2005; 3: 8–13
[6] Pfau M, Rennekampff HO, Schaller HE. Skin graft fixation by vacuum assisted topical foam dressing. Akt Traumatol 2001; 31: 232–235
[7] Scherer LA, Shiver S, Chang M, Meredith JW, Owings JT. The vacuum assisted closure device: a method of securing skin grafts and improving graft survival. Arch Surg 2002; 8: 930–934
[8] Sposato G, Molea G, Di Caprio G, Scioli M, La Rusca I, Ziccardi P. Ambulant vacuum-assisted closure of skin-graft dressing in the lower limbs using a portable mini-VAC device. Br J Plast Surg 2001; 3: 235–237
[9] Turczynski R, Tarpila E. Treatment of leg ulcers with split skin grafts: early and late results. Scand J Plast Reconstr Surg Hand Surg 1999; 3: 301–305
[10] Wood MK, Davies DM. Use of split-skin grafting in the treatment of chronic leg ulcers. Ann R Coll Surg Engl 1995; 3: 222–223

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Meshgraftfixation mit V.A.C.® an der unteren Extremität

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Zusammenfassung: Anstelle von Gipsimmobilisationen bei Meshgrafts am Unterschenkel und Fuss wird das Transplantat mit einem V.A.C.® behandelt. Nach 5–7 Tagen wird der V.A.C.® entfernt. Bei 6 Patienten wurde diese Methode angewendet, bei 3 ging der Meshgraft problemlos an, bei 3 Patienten mit zusätzlichem Anpressen des Transplantates mit feuchter Watte kam es zu einem oberflächlichen Infekt und nur partiellem Angehen. Wir folgern, dass die angewandte Methode sich bewährt, zusätzliche Fixationen wie Watte sind kontraproduktiv.

Schlüsselwörter: Mesh-graft, Unterschenkel/Fuss, V.A.C.®, Watte

Fixation of mesh-grafts with V.A.C.® at the lower extremity

Summary: Instead of castimmobilization to guarantee better integration of mesh-grafts at the lower extremity V.A.C.® was applied, that was removed after 5–7 days. 6 patients were treated, 5 as outpatients, 1 patient was hospitalized for social and medical reason for one week. 3 mesh-grafts healed in uneventfully, 3 had problems, they all had in common, that the mesh-graft was further pressed in with wet cotton balls. We conclude that mesh-graft fixation with additional V.A.C.® is a successful method for localisations in the lower extremity. Additional measures e.g. cotton to press the graft further into its bed are contraproductive.

Keywords: Mesh-graft, lower extremity/foot, V.A.C.®, cotton balls

Einleitung: Für das erfolgreiche Angehen von Meshgrafts an der unteren Extremität ist häufig eine temporäre Ruhigstellung mit einem Gips oder einer Orthese je nach Lokalisation erforderlich. Es gilt, unnötige Bewegungen im Wundgebiet zu verhindern. Dies seinerseits bedingt eventuell eine temporäre Thromboseprophylaxe. In Anlehnung an bereits publizierte Erfahrungsberichte mit einer V.A.C.®-Behandlung zur Meshgraftfixation bei pädiatrischen Verbrennungen [1, 2] wurde nach einer Alternative zur konventionellen Ruhigstellung gesucht.

Methodik: Nach Wundkonditionierung mit V.A.C.® wurde im Durchschnitt nach einem Monat ein Meshgraft mit Entnahme des Transplantates vom lateralen, gleichseitigen Oberschenkel mit V.A.C.® fixiert. Die Operation erfolgte unter einer single shot Antibiotikaprophylaxe mit einem Cephalosporin der 2. Generation in Spinalanästhesie mit einer Ausnahme (69-jähriger Patient mit Diabetes mellitus und Dauerantikoagulation bei chronischem Vorhofflimmern) unter tageschirurgischen Massnahmen. Nach Wundreinigung erfolgte die Einnaht des 1:1.5 gemeshten Thierschs mit fortlaufender Prolen 5.0 Naht. Bei 3 Patienten wurde in einer Wundtasche das Transplantat zusätzlich mit feuchter Watte angepresst. Abdecken des gemeshten Bezirkes mit Adaptic, welches allseitig 1 cm über den Hautrand hinausragte. Dann wurde ein schwarzer Schaumgummi mit ebenfalls 1 cm Überlappung des Wundrandes daraufgelegt und die V.A.C.®-Pumpe nach dichter Folienapplikation in Gang gesetzt. Nach 5–7 Tagen wurde ein erster Verbandswechsel vorgenommen und der V.A.C.® entfernt.

Von Juni bis Dezember 2007 wurden 6 Patienten, 5 Männer und eine Frau, mit einem Durchschnittsalter von 56 (17–81) Jahren auf diese Art behandelt. Es handelte sich um 5 Ulzera nach Debridement nach Phlegmone, chronische Hautnekrose, resp. Defektwunde und um einen Hautdefekt nach Verletzung mit einem durchschneidenden Drahtseil an der Fusssohle. Je nach Lokalisation musste der V.A.C.®-Verband mit einer Schaumgummibrücke modifiziert werden. Die ambulante Nachbehandlung wurde zuhause durch einen V.A.C.®-zertifizierten Krankenpfleger vorgenommen.

Ergebnisse: Bei 3 Patienten ohne jegliche Zusatzmassnahme (keine Watte) ging der Meshgraft problemlos an. Nach V.A.C.®-Entfernung wurde das Transplantat mit lokaler Bepanthensalbenapplikation nachbehandelt. Eine Fadenentfernung erfolgte nach 2 Wochen. Bei den 3 Patienten mit zusätzlicher Transplantatanpressung mit feuchter Watte wurde nach V.A.C.®-Abnahme ein oberflächlicher Infekt festgestellt und das Transplantat ging nur unvollständig an. Bei 2 Patienten wurde eine zusätzliche Reverdinläppchenbehandlung angeschlossen, bei einer Patientin mit gutem Erfolg, beim erwähnten Patienten mit Diabetes mellitus und Dauerantikoagulation erneut ohne Angehen der Läppchen. Die Behandlung ist bei diesem Patienten auch heute noch nicht abgeschlossen.

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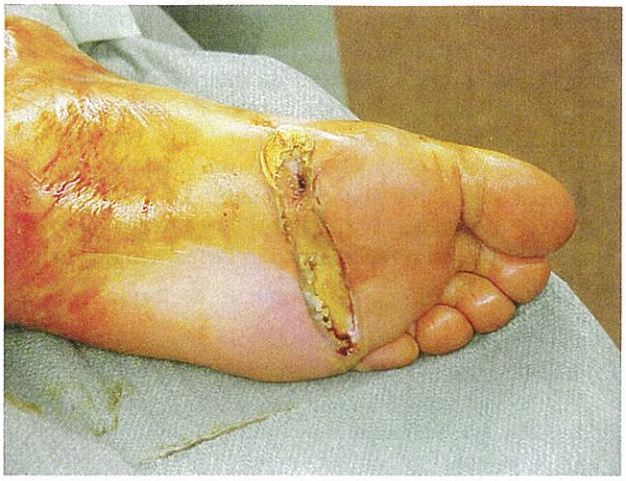

Abb. 1a: R.H., 44 Jahre, männlich. Tiefe Fusssohlenverletzung durch durchscheuerndes Drahtseil (durch den Schuh!)

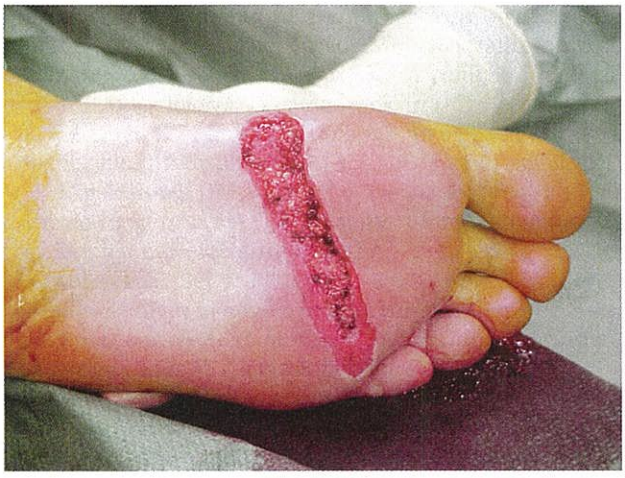

Abb. 1b: Zustand nach initialem Debridement

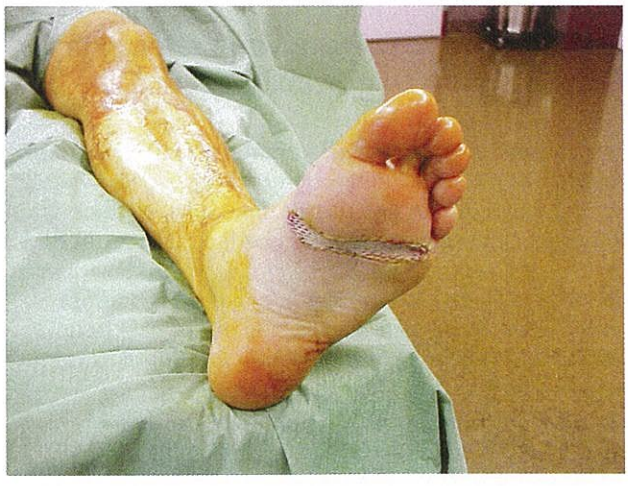

Abb. 1c: Meshgraftdeckung und V.A.C.® nach 3 Wochen

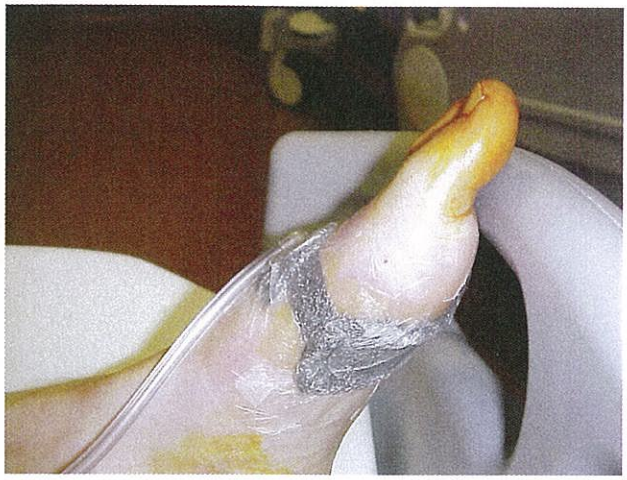

Abb. 1d: V.A.C.®-Technik an Fusssohle mit Umleitung auf den Fussrücken

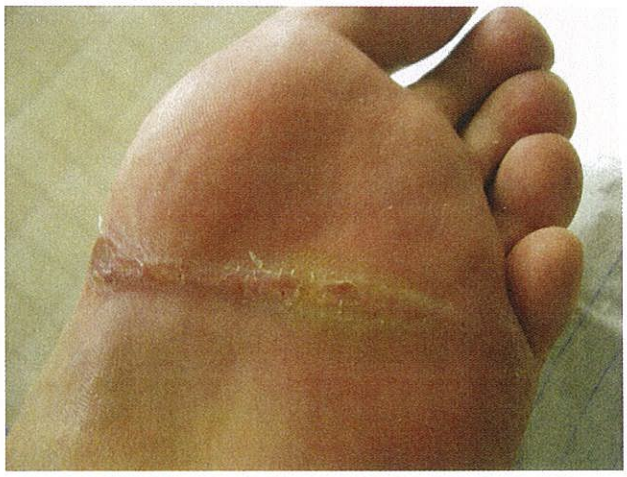

Abb. 1e: Resultat nach 2 Monaten

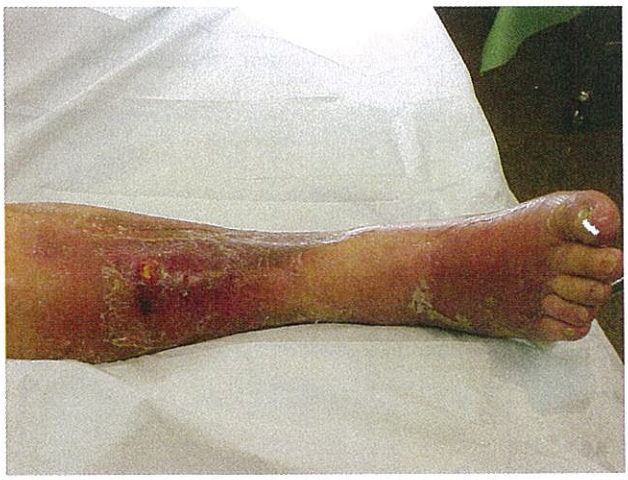

Abb. 2a: N.H., 68 Jahre, männlich, Diabetes mellitus, chronisch venöse Insuffizienz bei insuffizientem tiefen Venensystem. Phlegmone und tiefe Hautnekrose am Unteerschenkel. Indikation zum Debridement und Faszienspaltung. Konditionierung mit V.A.C.®

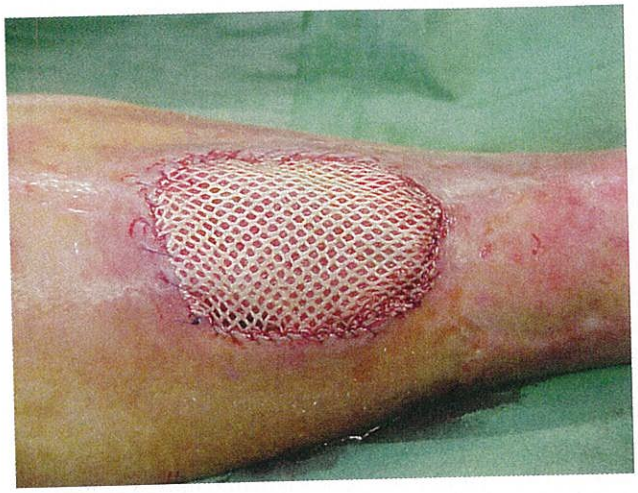

Abb. 2b: Meshgraftdeckung und V.A.C.® und zusätzliches Anpressen mit feuchter Watte nach 3 Wochen

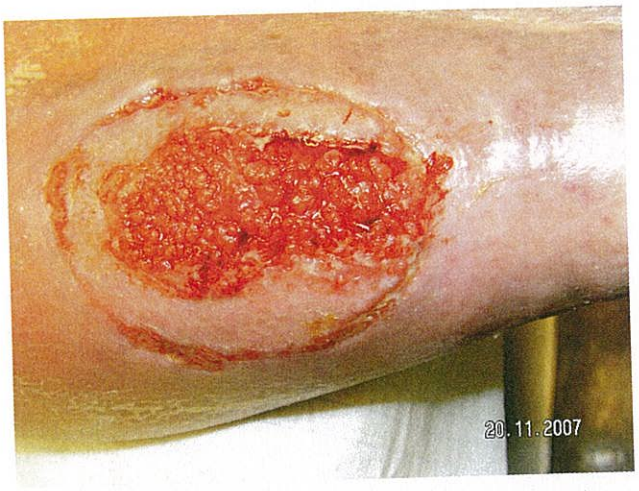

Abb. 2c: Nur partielles Angehen des Grafts, Zustand nach 2 Monaten

Schlussfolgerungen: Die Meshgraftfixation mit einem V.A.C.® an der unteren Extremität bewährt sich. Sie wird vom Patienten gut akzeptiert, da meist schon vorgängig eine Wundkonditionierung damit stattgefunden hat. Zusätzliche Massnahmen wie Applikation von feuchter Watte empfehlen sich nicht. Der Grund ist nicht ganz klar, scheinbar wird damit aber eine feuchte Kammer gebildet, die eine bakterielle Besiedelung begünstigt. Gesunde, junge Patienten mit traumatischen Defektwunden zeigen tendenziell die besseren Resultate.

Literatur

[1] Schintler MV, Schwaiger N, Spendel S, Rappl T, Hellbom B, Pfurtscheller K, Trop Marija, Scharnagl E (2007) Spalthautfixation mit VAC – Erfahrungen bei tief und gazdermalen pädiatrischen Verbrennungen. Direct fmch V.A.C. Therapy. Suppl zum Dreiländerkongress 2007: 50–55.

[2] Roka J, Kamolz LP, Rath T, Frey M (2007) Einsatz der V.A.C. Therapie in der Behandlung Schwerbrandverletzter. Direct fmch V.A.C. Therapy Suppl zum Dreiländerkongress 2007: 49.

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Skin Grafting: The Role of Topical Negative Pressure (TNP) Therapy

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Introduction[1-3]

Skin grafting is an essential component of the reconstructive armamentarium. First described in the Sanskrit manuscripts of India dating back some 3000 years, the application of the technique in modern clinical practice was probably first described by Sir Astley Cooper in 1817, who performed a full thickness skin graft (FTSG) in a hand trauma patient, having obtained the skin from the patient's amputated digit.

The Parisian surgeon Riverdin has been credited with the first significant use of skin grafts in 1869. In the late nineteenth century Ollier (1872) and Thiersch (1874) were first to describe the process of split thickness skin grafting (STSG) as a means of addressing wounds with considerable skin loss. Wolfe is generally considered to have introduced the concept of (and realised the clinical importance of) the FTSG in 1870. Technological advances greatly assisted the process of skin harvest with the guarded skin graft knife (Humby), the drum dermatome (Padgett and Hood, Reese) and the mechanical dermatome (Brown, Davis). A further advance, described by Tanner and colleagues in 1964, was that of the meshed STSG, which allowed a significant expansion of the area that could be grafted for a given area of donor skin.

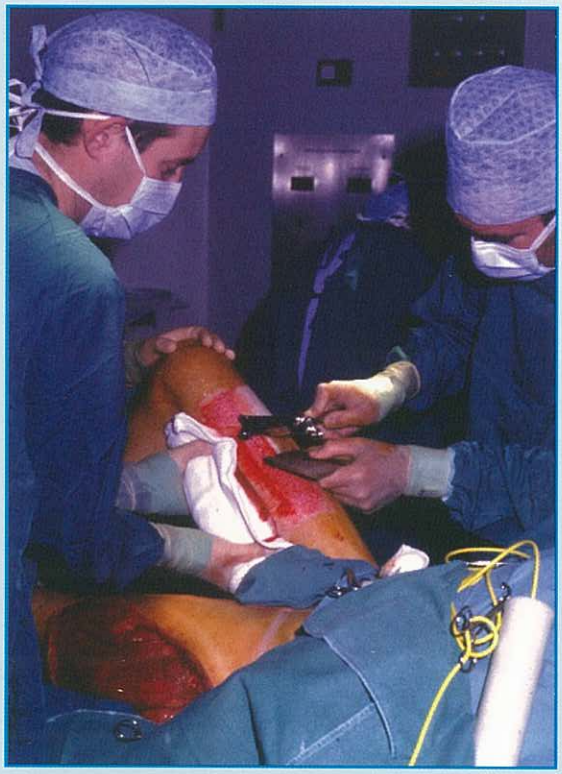


Figure 1: Harvesting of STSG using a free-hand knife. Note the means by which a taut surface is maintained with a 'skin board'

Functional Anatomy[1-3]

The integument, which is of ectodermal origin, covers the entire surface of the body and has a host of roles beyond that of a physical barrier to the environment. It is a homeostatic organ (of temperature, water and salt) and is the principle site of communication with the environment. It also has an essential immunological function, protects against ultraviolet light, and is essential in the synthesis of vitamin D.

5% of the skin is comprised of epidermis – a stratified keratinised squamous epithelium where the predominant cell type is the keratinocyte. The epidermis is the site of origin of the skin appendages (hair follicles, sweat glands, sebaceous glands and the nails). Melanocytes, which are of neuroectodermal origin, reside in the basal cell layer of the epidermis. The epidermis has no blood supply and is nourished from below by simple diffusion.

The dermis, which constitutes 95% of the skin, is composed of a superficial papillary dermis and a deeper reticular dermis. The principal cell is the fibroblast which generates both collagen and elastin fibres. These fibres are supported within a gel-like ground substance, containing glycosaminoglycans and hyaluronic acid. Blood supply is via either fasciocutaneous perforating vessels or musculocutaneous vessels, which connect the deep vessels to the skin. Although numerous vascular plexi exist, functionally the most important are the subdermal plexus, the dermal plexus and the superficial papillary (or subepidermal) plexus just deep to the epidermis.

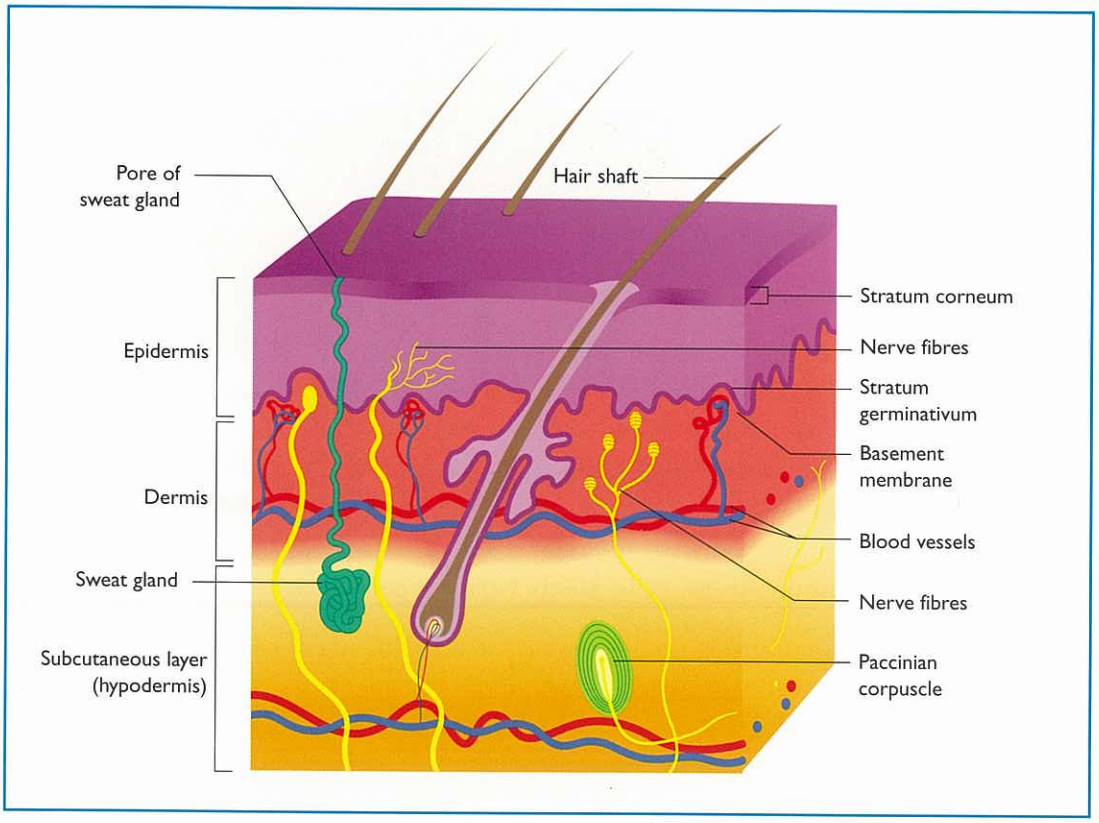


Figure 2: Schematic diagram of the skin

Skin Graft Definitions[1-3]

A graft can be defined as tissue completely removed from one part of the body (referred to as the *donor* site) and transferred to another (the *recipient*) site. It has no blood supply and its survival is wholly dependent on obtaining a vascular supply from the recipient wound bed. A graft could be considered as a 'parasite', which is dead and *may* live – given the correct circumstances.

Whereas an *autograft* is transferred from a donor to the recipient site within the same individual, an *allograft* (or *homograft*) is a graft between genetically different individuals of the same species. A *heterograft* (or *xenograft*) is a tissue graft between different species. All skin grafts contain both epidermis and dermis, however it is the thickness of the latter that determines whether a graft is classified as a *split (STSG)* or *full (FTSG)* thickness skin graft.

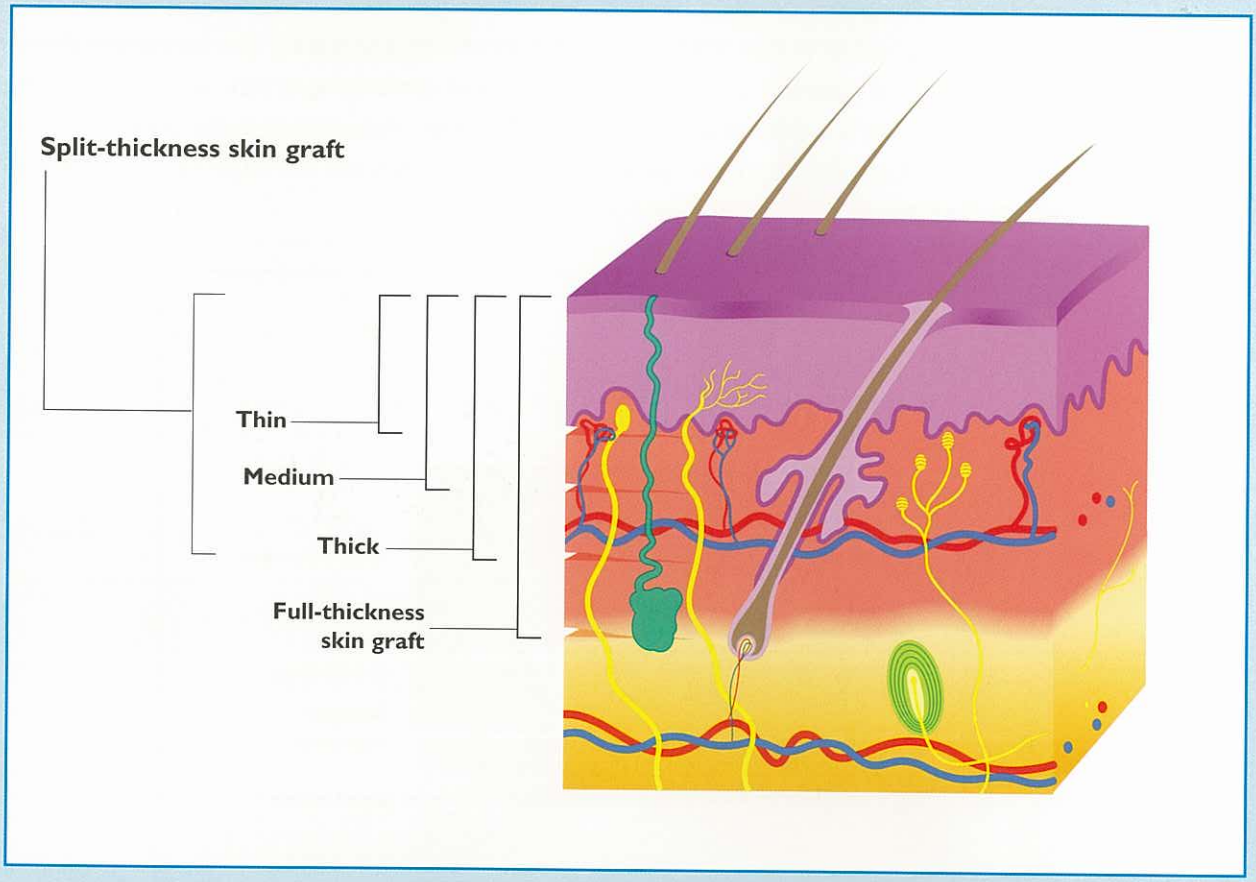


Figure 3: The thickness of various types of skin graft, showing the constituents of each

Skin Graft Selection and Donor Site Considerations

A split thickness skin graft (STSG) contains a variable amount of dermis and is usually harvested from the thigh or buttock (although can be harvested from anywhere on the body including the scalp). The average STSG thickness is approximately 0.012 to 0.018 inches (0.3 to 0.45 mm) thick. The donor site epidermis regenerates from the residual skin adnexal structures, a process which occurs in approximately ten days. If necessary, a donor site may be harvested repeatedly once epithelialisation has occurred (in burns for example), although the residual dermal thickness is the limiting factor.

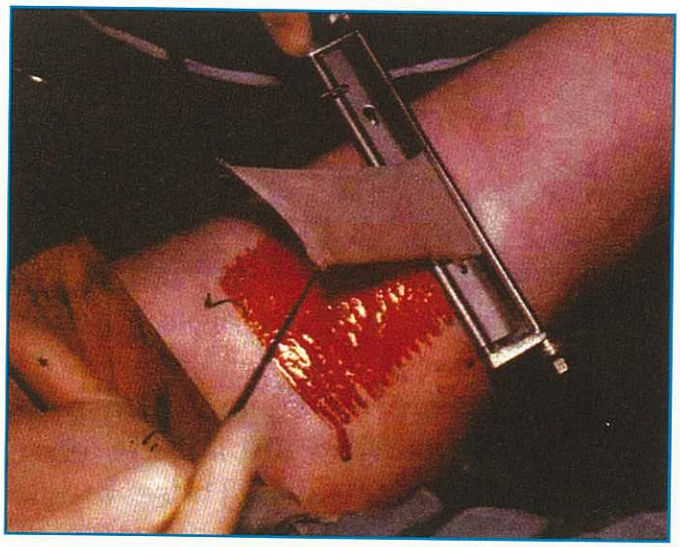


Figure 4a: Harvesting a STSG with a Humby knife

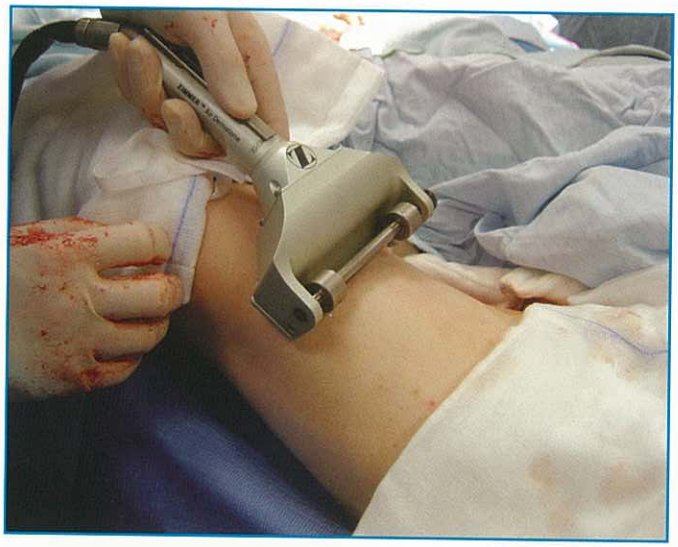


Figure 4b: Harvesting a STSG with a powered dermatome

A full thickness skin graft (FTSG) contains the dermis in its entirety and is usually harvested from a donor site where the skin is thin and has sufficient laxity to allow direct primary closure. This inherently limits the size of FTSG that can be harvested. A pattern of the defect to be grafted is taken (usually with a fragment of sterile paper or foam) in order that, once transferred to the donor site, an accurately shaped donor segment can be marked out for harvest. Suitable FTSG donor sites include retroauricular skin, groin, supraclavicular fossa, flexor aspect of the wrist, or antecubital fossa. FTSGs are always harvested by hand using a scalpel. Unlike STSGs, such grafts have the advantages of resisting contraction, improved durability, reduced pigmentary changes, and an ability to grow in children.

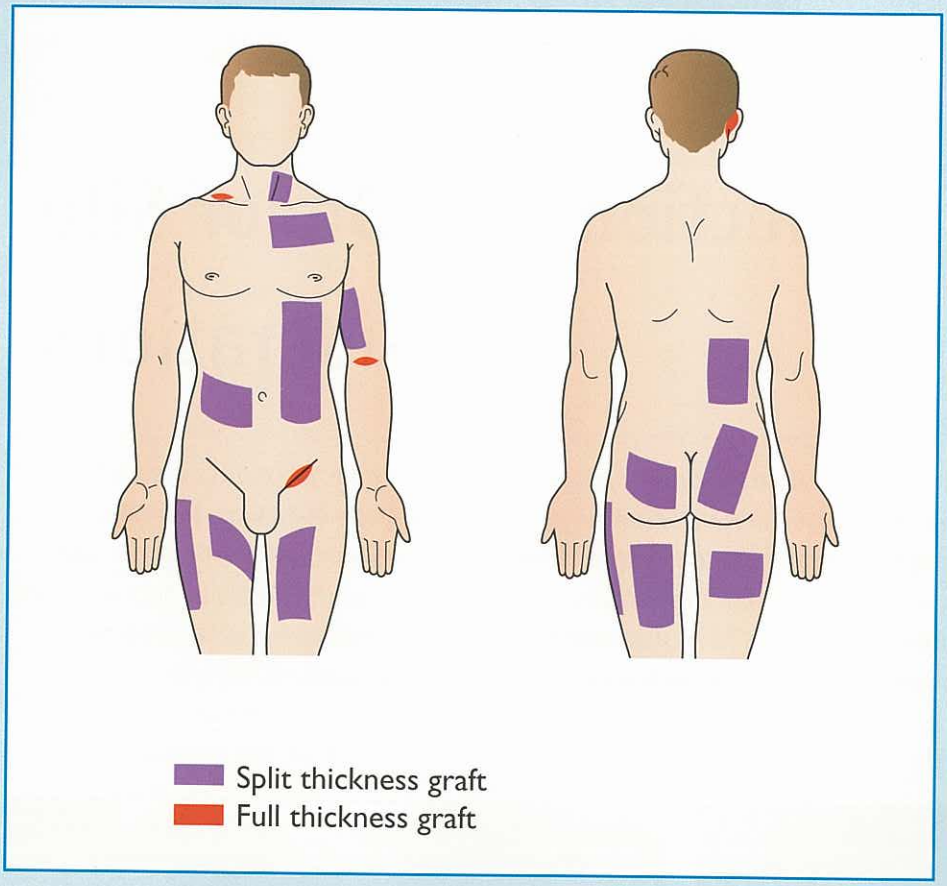


Figure 5: Skin graft donor sites

Clinical Considerations

Patient Factors

Always consider the general medical status of the patient. Is their diabetes mellitus well controlled? Has their cardiac or renal function been optimised pre-operatively? Anaemia and malnutrition should be corrected and patients should be encouraged to stop smoking prior to surgery. Grafting an arterial ulcer is unlikely to be successful if arterial inflow is not first restored by medical, radiological or surgical means. The same approach applies to management of venous or vasculitic ulcers.

Wound Bed Preparation

This is essential to optimise graft take – poor wound bed preparation is a common cause of a failed graft. Skin grafts do not take to exposed cortical bone without periosteum, tendon without paratenon, cartilage without perichondrium, and to heavily irradiated tissue. If a recipient bed is of limited vascularity then other methods must be employed such as burring the outer table of the skull, the use of Topical Negative Pressure Therapy to encourage healthy granulation tissue formation prior to grafting, or the use of an alternative reconstructive technique such as a vascularised flap.

Skin grafts cannot take on necrotic tissue, hence any slough or devitalised tissue must be physically, chemically or biologically debrided prior to grafting.

Pre-operative wound care is essential. The presence of greater than 10^5 microorganisms per gram of tissue is associated with a high risk of graft failure. Beta-haemolytic streptococci and *Pseudomonas* species are particularly associated with an adverse outcome.

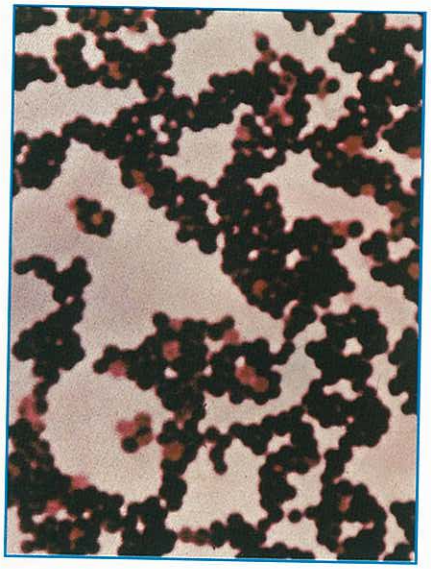


Figure 6: Streptococci are an absolute contra-indication to skin grafting

Intra-operative Wound Bed Preparation

The recipient wound must be thoroughly cleaned (and copiously irrigated with warmed isotonic saline if necessary) and any overgranulations (which can harbour bacteria) should be debrided down to a clean bed. Meticulous haemostasis is essential and can be achieved by direct pressure, diathermy, ligation or adrenaline soaked swabs.

Process of Graft Take

This complex process may be summarized in five stages:

■ Adherence	(Within seconds)
■ Serum (plasmatic) imbibition	(Within 48 hours)
■ Inosculation	(After 48 hours)
■ Revascularisation	(Up to 7 days)
■ Maturation & remodelling	(Months post-operatively)

Maturation involves the processes of contraction, pigmentation and reinnervation. Whereas primary contraction is that resulting immediately after the graft is harvested due to recoil of elastin fibres, secondary contraction is related to the thickness of the graft and is a delayed phenomenon.

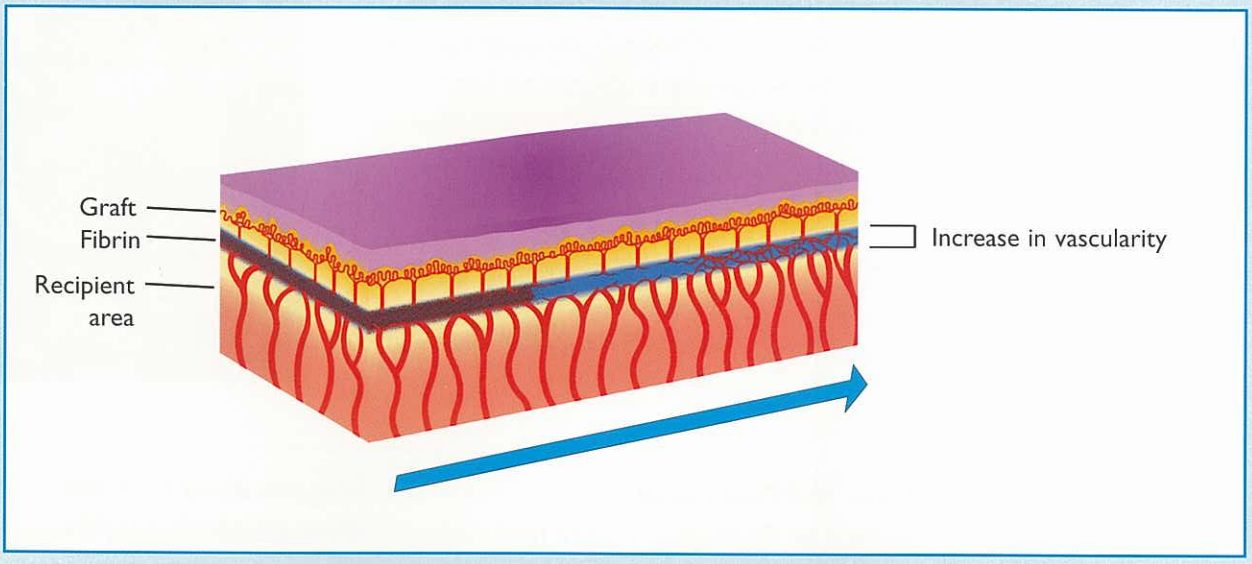


Figure 7: A diagrammatic representation of the process of graft 'take' of a free skin graft

Causes of Graft Failure

A surgeon should expect all skin grafts to adequately 'take' – most would consider a take greater than 95% as both acceptable and desirable. Graft failure (a take of less than 50%) may have been entirely preventable with improved surgical technique (eg. adequate wound bed preparation or attention to meticulous haemostasis) or pre-operative wound care (eg. treatment of streptococcal wound infection). However, it may be related to 'irreversible' factors – such as grafting a traumatic leg ulcer in an elderly diabetic transplant patient taking immunosuppressive therapy. Some authorities might argue that if the patient and wound are fully optimised, and a graft failure is anticipated, then an alternative reconstructive strategy should be adopted.

Recognised causes of skin graft failure include:

Haematoma – the commonest cause of graft failure due to separation of the graft from the recipient bed thereby preventing revascularisation. Meticulous haemostasis is essential.

Inadequate wound bed – either poorly vascularised or due to the presence of excess devitalised tissue or slough.

Infection – particularly *Streptococci*, which are capable of streptokinase-induced breakdown in the adherent fibrin layer.

Seroma – which have a similar mechanism of action as haematoma.

Excessive pressure – pressures in excess of the capillary filling pressure (25–30 mmHg) may cause graft necrosis – a problem over bony prominences such as the sacrum or greater trochanter.

Shear forces – movement resulting from inadequate securing of the graft or proximity to a non-splinted joint.

Technical – covers a host of possibilities from the graft being placed upside down, to harvesting a STSG of inadequate thickness, or not defatting a FTSG sufficiently.

Storage – grafts may be stored in a refrigerator (gently wrapped in moist saline soaked gauze) for up to two weeks. Excessive storage periods, or allowing the graft to desiccate or macerate, will significantly reduce the percentage of graft take.

Patient Factors	Drugs (eg. steroids) Immunosuppresion Chronic disease (eg. diabetes, RhA) Anaemia Malnutrition Local malignancy
Tissue Storage Factors	Prolonged storage Desiccation or maceration
Recipient Site Factors	Inadequate wound bed preparation Infection (especially streptococci) Haematoma or seroma
Technical Factors	Inversion of graft Inadequate STSG thickness Inadequate FTSG defatting
Post-operative Factors	Excessive pressure Shear forces

Table I: Review of causes of skin graft failure

Skin Graft Fixation

Split Skin Graft (STSG)

Immobilisation of the graft is essential in order to allow successful revascularisation. The graft itself may be secured in situ using sutures or staples. In paediatric usage, dissolvable sutures or the use of histoacryl glue may obviate the requirement for a second anaesthetic when performing the dressing change.

A dressing should be applied in order to prevent the generation of shear forces between the graft and the recipient bed and to reduce the risk of haematoma or seroma collection. Traditional methods of securing STSGs include applying foam or saline soaked gauze over the graft (often with an intervening paraffin gauze dressing) and allowing the graft to mould to the natural contours of the recipient site and then apply a circumferential pressure dressing. Splinting of involved joints may reduce the effect of shear forces and reduce the risk of contracture formation. Alternatively a tie-over bolster dressing may be used, a particularly valuable approach where the anatomical location does not facilitate the use of compression bandaging.

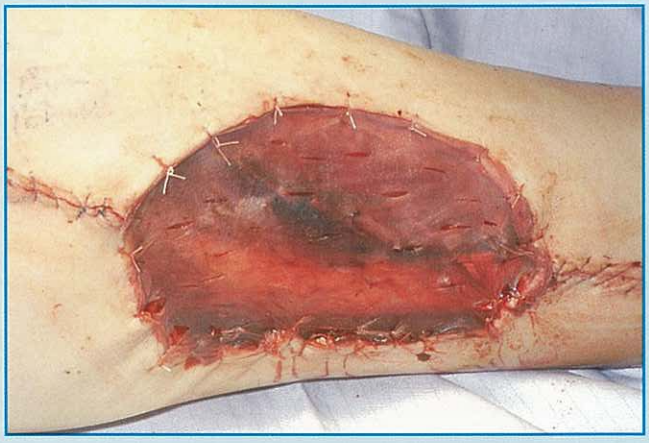


Figure 8a: A fenestrated STSG applied to a radial forearm free flap donor site

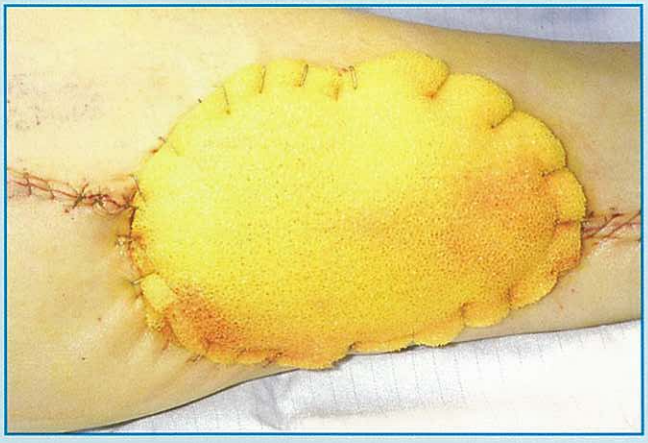


Figure 8b: A foam 'tie-over' dressing is secured with staples

FTSG

These are normally sutured into position, although histoacryl glue may also be used. Staples tend not to be used on account of the small size of the graft and the cosmetic implication (FTSGs frequently being on the face).

A tie-over dressing (using proflavine soaked cotton wool or foam) is traditionally used to ensure that the graft is firmly applied to the recipient site in order to obliterate dead-space. Tie-over dressings (or bolsters) are particularly useful where the contour of the recipient site does not facilitate the application of standard bandaging. Again these are left in situ for up to a week.

The perceived mechanism of tie-over dressings is that the production of positive pressure obliterates dead-space thereby preventing the accumulation of fluid. However, a recent study has demonstrated that such dressings produce no significant positive pressure.[4]

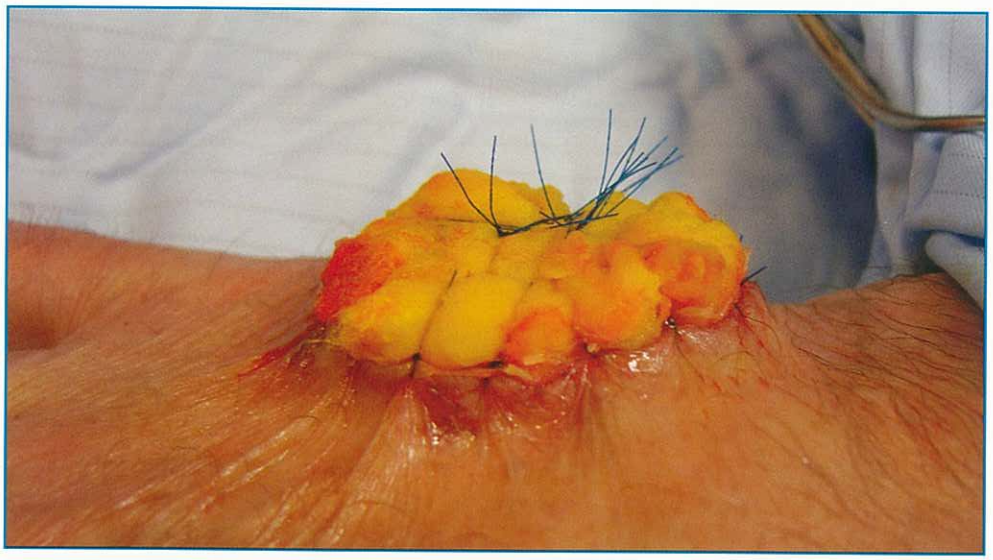


Figure 9: Tie-over Proflavin dressing

Sutures
Glue – Fibrin glue – Histoacryl – Dermabond™
Staples
Gauze pressure dressing
Foam tie-over dressing
Proflavin impregnated cotton wool tie-over dressing

Table II: Methods of skin graft fixation

- Stabilisation/fixation of graft
- Prevention of shearing
- Compressive force
- Removal of subgraft seroma and haematoma
- Prevention of infection
- Comfortable for patient
- Cost effective

Table III: Aims of an ideal skin graft fixation method

Donor Site dressings

The secondary donor site also requires a suitable dressing. FTSG donor wounds can be managed as any primarily closed wound according to the surgeon's preference. Dressings options include:

- Occlusive dressings (Opsite™, Tegaderm™) are comfortable and promote moist wound healing, but do not allow the egress of fluid such as haematoma or seroma.
- Petroleum-impregnated gauze (Jelonet™) – although cheap, has the disadvantage of being adherent and causing significant discomfort on removal. Silicone rubber dressings (Mepitel™) have the advantage of being less adhesive to the wound.
- Biological alginate dressings (Kaltostat™).
- Retention adhesive dressings (Mefix™, Hypafix™ and Fixomull™).
- Hydrocolloid and lipido-colloid dressings (Duoderm™, Urgotul®).

STSG donor sites frequently cause as much, if not more, discomfort to the patient as the recipient site wound. It is recommended that a long acting topical local anaesthetic be applied intra-operatively to provide adequate analgesia in the immediate post-operative period. Re-epithelialisation occurs from the dermal appendages, and care must be taken to avoid secondary infection, which could convert the wound to a full-thickness defect.

A prospective randomized controlled trial has been performed to assess the alginate Kaltostat™ with an adhesive retention tape dressing (Mefix™) in terms of patient comfort and ease of nursing care.[5] The study demonstrated that retention dressings were more comfortable, required less nursing intervention, and allowed greater patient mobility without any compromise in wound healing and at similar cost. The Mefix™ dressing has the additional advantage of minimizing bulk, and they can also get wet, therefore allowing the patient to shower or bathe. Normally the adhesive retention dressing can be left to lift off on its own accord (after 10 days to two weeks), alternatively it may be readily removed by the application of olive oil.

Topical negative pressure (TNP) dressings have also been used for treatment of donor sites. Early results suggest accelerated rates of epithelialisation.[15] (See page 17 – "Specific Applications for TNP".)

Topical Negative Pressure (TNP) Therapy

Topical negative pressure[3,4] (TNP) therapy has now emerged as an important adjunct in surgical practice. It is a novel non-pharmacological, physical wound healing modality which stimulates the wound healing process.[6]

This technique, based upon simple principles but delivering high-tech therapy, involves the application of a vacuum force across the wound surface, using a foam dressing interface. The physical forces generated at the foam-wound interface (via mechanical transduction) lead to a variety of changes in the wound environment, positively enhancing the healing process.

Numerous studies have now reported the successful use of topical negative pressure, known commercially as Vacuum-Assisted Closure™ (KCI, San Antonio, TX), in a clinical setting.[7-14] Primary indications for use have recently been recommended and include the following: upper and lower limb trauma including burn injury, infected wounds, sternal dehiscence, abdominal dehiscence, skin graft fixation, wound bed preparation, pressure ulcers, venous leg ulcers and diabetic ulcers.[6] Furthermore, recent experience has shown useful applications in oral and maxillofacial surgery, gynaecological problems, necrotizing fasciitis, extravasation injuries and reducing donor site morbidity.[15]

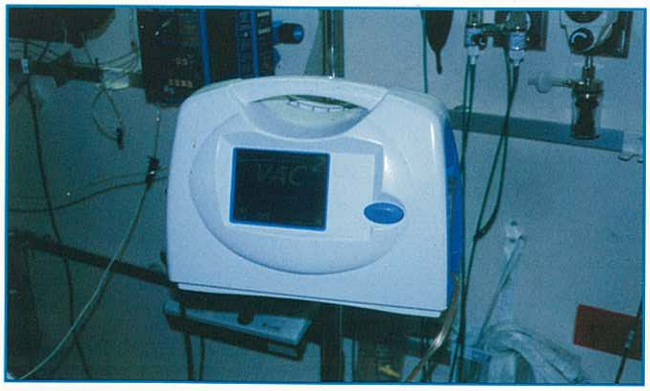


Figure 10. Microprocesor-controlled VAC® ATS™ therapy unit (vacuum pump)

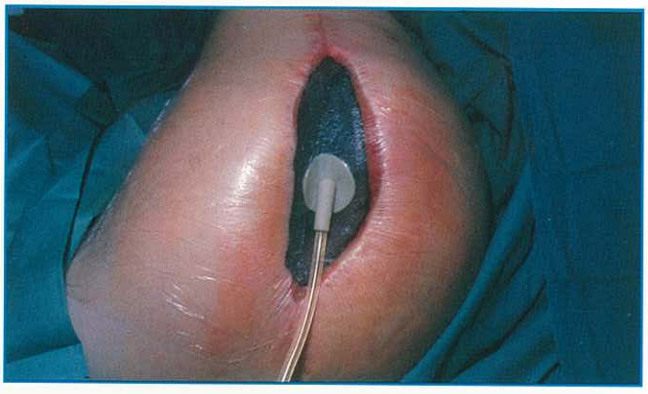


Figure 11. VAC® ATS™ pump and dressing *in situ*

- Traumatic wounds – upper/lower limb, burns
- Infected wounds
- Sternal dehiscence
- Abdominal dehiscence
- Skin graft fixation
- Wound bed preparation & exudates management
- Pressure ulcers – sacral, trochanteric, ischial
- Leg ulcers – venous, diabetic

Table IV: Primary indications for using topical negative pressure therapy in clinical practice

TNP Mechanism of Action

Argenta and Morykwas have postulated that three inter-related factors contribute to the effectiveness of TNP: the removal of excess interstitial fluid, the increase in vascularity and associated decrease of bacterial colonization, and, the response of the tissues in and around the wound to mechanical forces. These concepts have now been expanded and current work is examining the following processes:

Increased local blood flow: By removing excess fluid and restoring blood flow hypoxic conditions are minimised and a "favourable" wound healing environment created. This is corroborated by research showing increased arterial blood flow to extremities subjected to subatmospheric pressure.

Removal of chronic wound fluid: There exists a balance between pro and anti-wound healing molecular factors (eg. growth factors) within the wound environment. Analysis of wound exudates has proven the presence of deleterious constituents to cell proliferation and fibroblast activity. Removal of this fluid by TNP is therefore beneficial to wound healing.

Mechanical stress: As with controlled distraction forces used in bone healing and the Ilizaroff frame, so too TNP induces effects on cellular proliferation and angiogenesis in response to shear forces. This is known as the mechanical transduction effect.

Decreased bacterial colonisation: Removal of contaminated exudate has been proven to decrease bacterial counts after five days treatment with TNP.

Reduction of tissue oedema: It has been postulated that a significant reason for poor healing is due to a zone of stasis (classically incurred in burns) in which interstitial or 3rd space fluid compromised micro-vascular and lymphatic flow by an increased after-load. It is believed that TNP removes fluid thereby decreasing tissue turgor and promoting capillary flow.

Reverse tissue expansion:[34] Gibson coined the term "creep" to the skin's ability to stretch beyond its inherent elasticity. It is this concept that has been exploited in tissue expansion. This stretch not only increases the skin available but at a molecular level increases availability of pro-angiogenic factors. This reversed tissue expansion provides a further theory by which TNP facilitates closue of open wounds.

- **Compressive force on skin graft (splintage effect)**
- **Foam conformability for difficult contours (eg. head & neck, axilla, perineum)**
- **Removal of sub-graft fluid**
- **Enhanced angiogenesis**
- **Improved graft take**
- **Decrease in bacterial colonisation**

Table V: Benefits of TNP in skin graft fixation

Topical Negative Pressure (TNP) Therapy and Skin Graft Fixation

Topical negative pressure has also been utilized for securing skin grafts. In particular, the 'vacuumed' foam (the 'crinkle effect'[34]) acts as an excellent splint in its compressed form. Furthermore, the foam dressing is also able to conform to various contour defects making the therapy extremely useful for difficult anatomical areas. For instance, clinical difficulties commonly arise in contoured areas such as the natal cleft, axillary or inguinal region which are both difficult to dress and prone to shear forces. An additional, yet crucial, benefit is that the suction force is also able to actively remove sub-graft haematoma and tissue fluid. This is facilitated if the graft has been meshed or fenestrated and therefore minimizes complications inherent in more traditional forms of skin grafting fixation.

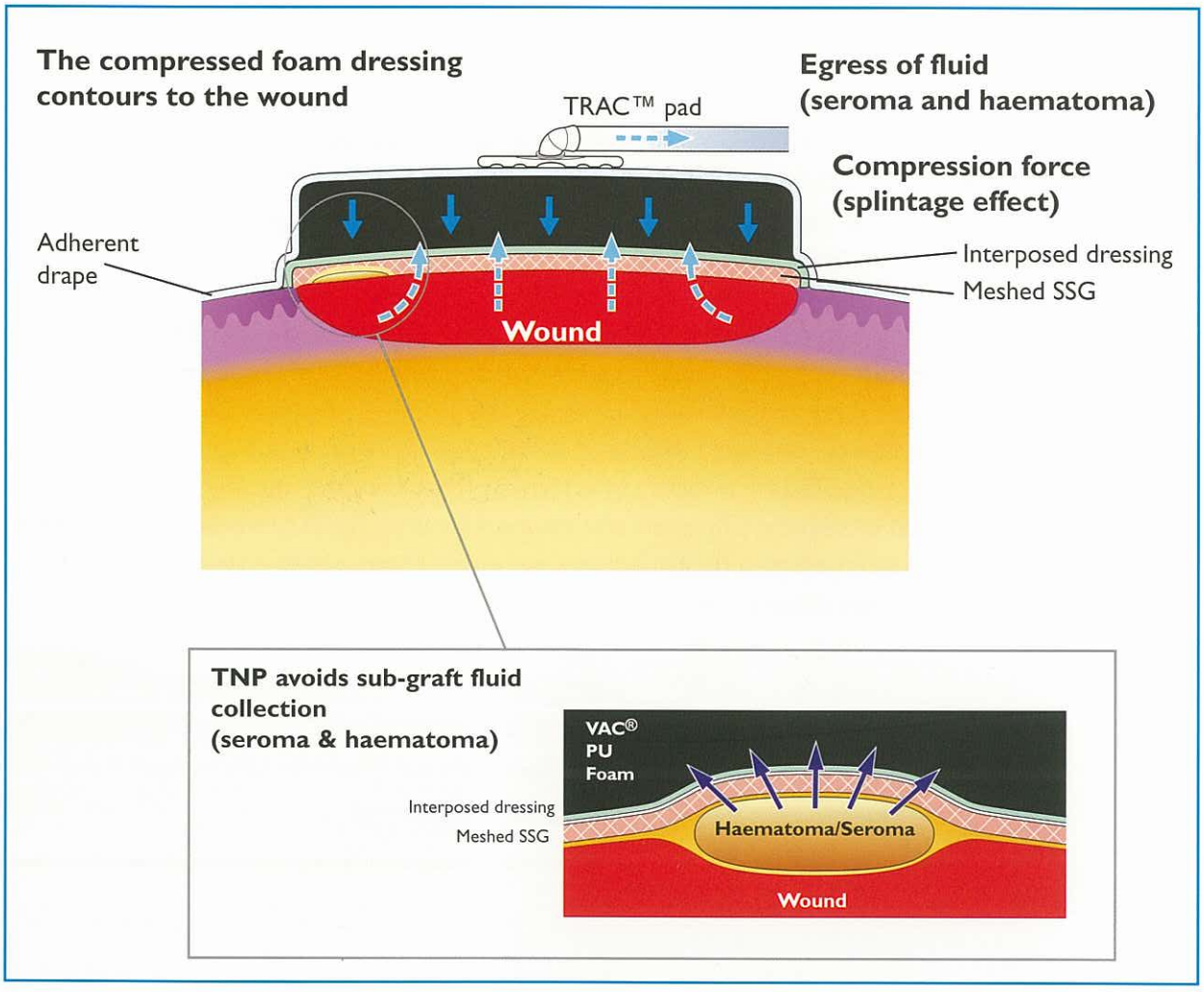


Figure 12. Schematic diagram demonstrating the securing of a STSG with a TNP dressing

Evidence-base for TNP Use in Skin Graft Fixation

Various techniques have been described in the literature detailing the use of TNP for skin graft fixation. Nakayama and associates were one of the first groups to report the use of TNP therapy in dressing skin grafts.[16] The technique adopted by Argenta and Schneider describes the use of meshed STSG tacked to the recipient site with staples or absorbable sutures.[7,17] The use of an interposed porous barrier dressing between the graft and the TNP sponge is advocated in order to prevent adherence. Suitable porous dressings include Mepitel™, TELFA™, Jelonet™ or Urgotul®. TNP is applied continuously (125 mmHg) for a period of up to four days. Over a 100 acute and chronic wounds involving a variety of anatomical sites were grafted using this technique. Graft take was complete in all but two patients (who had heavily contaminated chronic wounds). This study reinforces the advantages of maintaining an immobile graft and the ability to remove accumulated fluid.

Blackburn and colleagues reported the use of a TNP dressing in patients who were grafted with meshed STSG.[18] Graft take was in excess of 95% with a reduced bolstering time of three days. In addition to being able to immobilise grafts on irregular surfaces, the authors propose that one of the additional benefits of the technique includes enhancement of neovascularisation. Furthermore the TNP dressings were easily applied and did not require the use of tie-over sutures. The authors caution against the development of an air-leak in the dressing which if unnoticed, would lead to inevitable graft dessication and subsequent necrosis.

Similarly, Chang and colleagues reported a small series of patients where the STSG was applied to uneven, mobile surfaces such as the axilla, perineum or nuchal area, with an average graft take of 97%.[19]

Scherer and co-workers compared the use of TNP therapy dressings versus standard bolster dressings in 61 patients requiring STSG for a variety of acute soft tissue injuries.[20] The TNP technique was a safe and effective method of securing STSGs and was associated with a significantly reduced requirement for repeat grafts in comparison to the bolster dressing group. There was no difference in length of inpatient stay between the two groups.

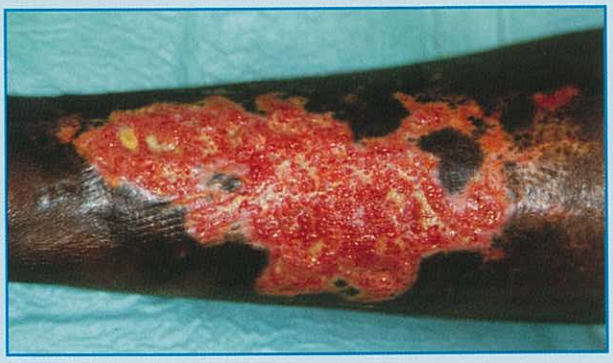


Figure 13a. Leg ulcer before TNP treatment

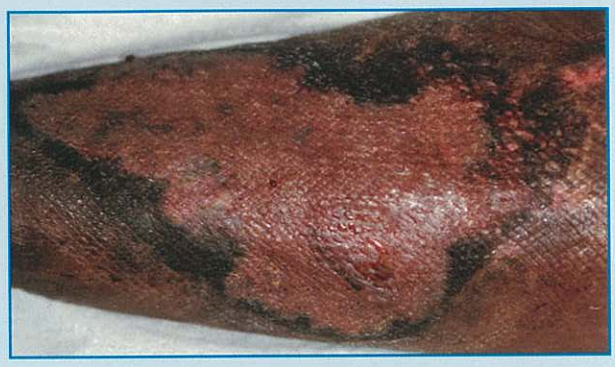


Figure 13b. 100% take after graft fixation with TNP

Specific Applications for TNP

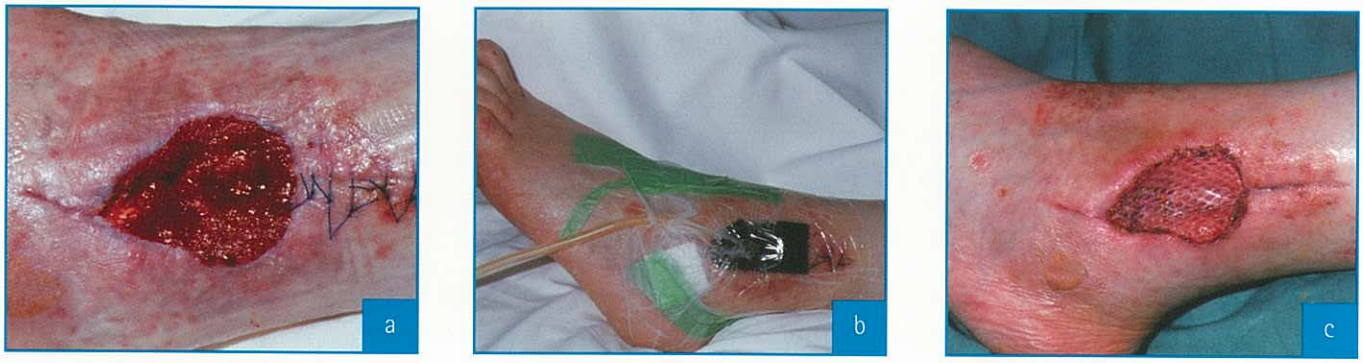


Figure 14. Exposed bone following lower limb trauma. Use for TNP for granulation tissue formation **(a)**. VAC™ dressing placed over SSG **(b)**. 100% skin graft take following use of TNP **(c)**

Scalp Defects

Molnar and co-workers reported a small specialist series of patients with acute full-thickness scalp defects.[21] The outer table of the exposed skull was removed, a STSG applied and augmented with TNP therapy for up to four days. The graft take in patients was approximately 100% without complication.

Degloving Injuries

The application of TNP therapy is not limited to STSGs. TNP therapy may be used in degloving injuries whereby the degloved skin is defatted, fenestrated and re-applied as a FTSG which is secured with a TNP dressing. Meara and colleagues reported the successful use of this technique in patients with degloving injuries with full thickness skin loss.[22] DeFranzo *et al.* reported cases of severe roller degloving injuries affecting the extremities (hand and foot), both of whom were managed by reapplying the defatted full-thickness degloved skin and obtaining fixation with TNP therapy with greater than 95% graft take.[23] Josty and co-workers adopted a similar technique in the case of a significantly degloved foot injury, with a graft take of approximately 95%.[24] Further technical refinements were proposed by Banwell *et al.*, including the use of anatomical foam or 'clam-shell' dressings which would be ideal for either the foot or hand, and the concept of the 'vacuum-bridging' technique, hence obviating the requirement for 'Y' connectors.[25]

Free Flap Donor Sites

Unfortunately STSG breakdown is the most commonly reported complication occurring at the radial forearm donor site, occurring in up to a third of patients. It poses a considerable management dilemma due to the exposure of flexor tendons. Avery and colleagues used TNP therapy to secure STSG to the radial forearm free flap donor site in 15 patients. Graft take was 100% at 5 days.[26]

In a parallel application, Greer *et al.* reported the use of TNP therapy as a salvage procedure with STSG breakdown at the radial forearm free flap donor site.[27] Two cases of donor site STSG breakdown were reported where TNP therapy was applied to encourage the formation of granulation tissue and subsequent epithelialisation. The time to healing was 1 to 2 months faster than would be expected by healing by secondary intention alone. The authors caution against the risks of tendon desiccation and suggest that the direct application of an interposed dressing (beneath the TNP sponge) may be of benefit.

Skin Grafting of Leg Ulcers

Sposato and colleagues have used the Mini-VAC™ as a method of applying TNP therapy to lower extremity ulcers of varying aetiology.[28] A fenestrated STSG was applied to a suitably prepared recipient site and TNP applied for a period of 5 days. It allowed early ambulation in addition to the removal of accumulated secretions. Graft take was 100% in 7 of the 9 cases.

STSG Donor Sites

A study by Genecov and colleagues has determined that TNP therapy increases the rate of skin graft donor site re-epithelialisation in both a porcine model and human subjects compared with a standard occlusive semi-permeable dressing.[15] Wound healing is probably promoted by the active removal of third-space fluid (and hence a concomitant reduction in oedema) and the restoration of local blood flow. The externally applied mechanical forces may have a role in increasing mitosis and angiogenesis.

Complex Wounds

TNP therapy has also been successfully utilised in the management of head and neck wounds,[35,36] burns, perineal problems, necrotizing fasciitis and axillary hidradenitis suppurativa.[29–31] For example, following radical excision of the affected axillary skin in hydradenitis, a meshed STSG can be secured with a TNP dressing for up to seven days, with resulting graft take being in excess of 90% in a report by Elwood and Bolitho.[32] Hynes and colleagues presented a series of five patients with chronic unilateral axillary hidradenitis suppurativa, who were treated in a similar manner with a five-day TNP course following radical excision and meshed STSG application.[33] The result was complete graft take in 80% of patients with excellent preservation of shoulder mobility.

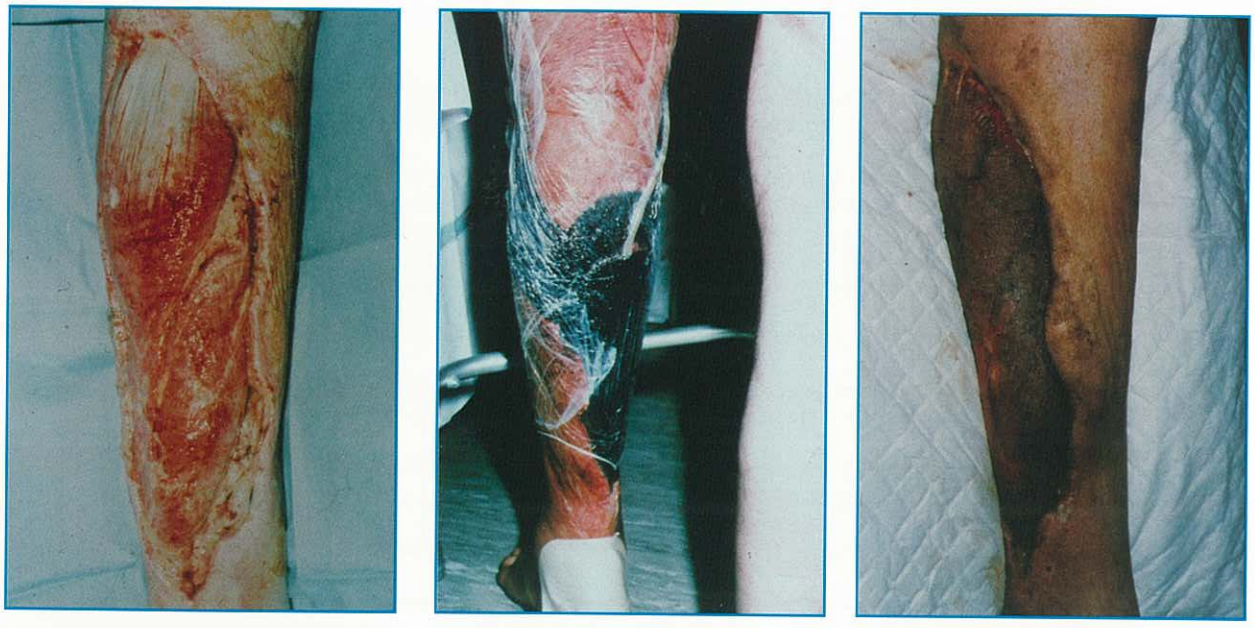
Skin Substitutes

The management strategy of the acutely burned patient has been revolutionised by the introduction of dermal substitutes such as Integra® (Johnson & Johnson). The availability of such products has allowed early burn wound excision and subsequent cover and now forms a critical part of the management of large burn areas. In addition, it has found an important role in burn reconstruction and elective resurfacing. However, one of the common problems involves optimising take rates which traditionally may take up to 3 weeks; furthermore, dermal substitutes are at risk of infection and graft loss and hence require exquisite attention to detail to maximise clinical outcome.

Early reports suggest that utilisation of topical negative pressure (TNP) may enhance dermal substitute take rates and accelerate the process of angiogenesis.[37] However, further experience is required of this exciting symbiosis between two revolutionary wound healing therapies. Trials are currently on-going to confirm the success of this technique.

Conclusion

Existing methods of skin graft fixation are less than ideal. Topical negative pressure may now be considered to be an effective method for fixation of grafts, especially in difficult areas or graft beds. Whilst TNP should not be used for the fixation of all grafts, it appears to have a definite role in the management of complex wounds such as those which are prone to excessive shear forces (adjacent to a joint for example), where use of standard dressings are likely to be difficult due to the anatomical contour of the recipient bed, or where skin graft take is suspected to be sub-optimal. Further important applications include the use of TNP in devastating degloving injuries of the hand or foot, and in the area of augmenting skin-substitute take rates. In particular, this last application has great potential.



Use of TNP to aid graft fixation following necrotising fasciitis

Bibliography

1) Rudolph R, Ballantyne DL. Skin grafts. In McCarthy JG, ed. Plastic Surgery. 1st Edition. Philadelphia: W.B. Saunders Company 1990: 221 - 274.

2) Kelton PL. Skin grafts. Selected Readings in Plastic Surgery. 1995; 8: 1 - 23.

3) Britto JA, Fenton L, Fenton OM. The skin, skin tumours and plastic surgery. In Burnand KG, Young AE, eds. The New Aird's Companion in Surgical Studies. 2nd Edition. London: Churchill Livingstone 1998: 165 - 222.

4) Seymour FK, Giele HP. Tie-overs under pressure. BJPS. 2003; 56: 494 - 497.

5) Hormbrey E, Pandya A, Giele H. Adhesive retention dressings are more comfortable than alginate dressings on split-skin-graft donor sites. BJPS. 2003; 56: 498 - 503.

6) Banwell PE, Teot L. Topical negative pressure (TNP): the evolution of a novel wound therapy. J Wound Care. 2003; 12 (1): 22 - 28.

7) Argenta LC, Morykwas MJ. Vacuum-assisted closure: A new method for wound control and treatment: clinical experience. Ann Plast Surg. 1997; 38 (6): 563 - 576.

8) Morykwas MJ, Argenta LC, Shelton-Brown EI, McGuirt W. Vacuum-assisted closure: A new method for wound control and treatment : animal studies and basic foundation. Ann Plast Surg. 1997; 38 (6): 553 - 562.

9) Fleischmann W, Becker U, Bischoff M, Hoekstra H. Vacuum sealing: indication, technique and results. Eur J Orthop Surg & Trauma. 1995; 5: 37 - 40.

10) Banwell PE, Withey S, Holten IW. The use of negative pressure to promote healing. Br J Plast Surg. 1998; 51 (1): 79.

11) Mullner T, Mrkonjic L, Kwasny O, Vecsei V. The use of negative pressure to promote the healing of tissue defects: a clinical trial using the vacuum sealing technique. Br J Plast Surg. 1997; 50: 194 - 199.

12) Banwell PE. Novel perspectives in wound care: topical negative pressure therapy. European Tissue Repair Society Bulletin. 2002; 9 (2): 49 - 50.

13) Gustafsson R, Johnsson P, Algotsson L, Blomquist S, Ingemansson R. Vacuum assisted closure therapy guided by C-reactive protein level in patients with deep sternal wound infection. J Thorac Cardiovasc Surg. 2002; 123 (5): 895 - 900.

14) Mooney JF3rd, Argenta LC, Marks MW, Morykwas MJ, DeFranzo AJ. Treatmant of soft tissue defects in pediatric patients using the VAC system. Clin Orthop. 2000; 376: 26 - 31.

15) Genecov DG, Schneider AM, Morykwas MJ, Parker D, White WL, Argenta LC. A controlled sub-atmospheric pressure dressing increases the rate of skin graft donor site reepithelialization. Ann Plast Surg. 1998; 40: 219 - 225.

16) Nakayama Y, Iino T, Soeda S. A new method for the dressing of free skin grafts. Plast Reconstr Surg. 1990; 86: 1216 - 1220.

17) Schneider AM, Morykwas MJ, Argenta LC. A new and reliable method of securing grafts to the difficult recipient bed. Plast Reconstr Surg. 1998; 102 (4): 1195 - 1198.

18) Blackburn JH, Boemi L, Hall WW, Jeffords K, Hauck RM, Banducci DR, Graham WP. Negative-pressure dressings as a bolster for skin grafts. Ann Plast Surg. 1998; 40: 453 - 457.

19) Chang KP, Tsai CC, Lin TM, Lai CS, Lin SD. An alternative dressing for skin graft immobilisation: negative pressure dressing. Burns. 2001; 27 (8): 839 - 842.

20) Scherer LA, Shiver S, Chang M, Meredith JW, Owings JT. The vacuum assisted closure device: a method of securing skin grafts and improving graft survival. Arch Surg. 2002; 137 (8): 930 - 933.

21) Molnar JA, DeFranzo AJ, Marks MW. Single-stage approach to skin grafting the exposed skull. Plast Reconstr Surg. 2000; 105: 174 -177.

22) Meara JG, Guo L, Smith JD, Pribaz JJ, Breuing KH, Orgill DP. Vacuum-assisted closure in the treatment of degloving injuries. Ann Plast Surg. 1999; 42: 589.-.594.

23) DeFranzo AJ, Marks MW, Argenta LC, Genecov DG. Vacuum-assisted closure for the treatment of degloving injuries. Plast Reconstr Surg. 1999; 104: 2145 - 2148.

24) Josty IC, Ramaswamy R, Laing JHE. Vacuum-assisted closure: an alternative strategy in the management of degloved injuries of the foot. BJPS. 2001; 54: 363 - 365.

25) Banwell PE, Evison D, Whitworth IM. Vacuum therapy in degloving injuries of the foot: technical refinements. BJPS. 2002; 55 (3); 264 - 266.

26) Avery C, Pereira J, Moody A, Gargiulo M, Whitworth I. Negative pressure wound dressing of the radial forearm donor site. Int J Oral Maxillofac Surg. 2000; 29 (3): 198 - 200.

27) Greer SE, Longaker MT, Margiotta M, Mathews AJ, Kasabian A. The use of subatmospheric pressure dressing for the coverage of radial forearm free flap donor-site exposed tendon complications. Ann Plast Surg. 1999; 43: 551 - 554.

28) Sposato G, Molea G, Di Caprio G, Scioli M, La Rusca I, Ziccardi P. Ambulant vacuum-assisted closure of skin-graft dressing in the lower limbs using a portable mini-VAC device. BJPS. 2001; 54: 235 - 237.

29) Morykwas MJ, David LR, Schneider AM, Whang C, Jennings DA, Canty C, Parker D, White WL, Argenta LC. Use of subatmospheric pressure to prevent progression of partial-thickness burns in a swine model. Journal of Burn Care & Rehabilitation. 1999; 20 (1): 15 - 21.

30) Rosser CJ, Morykwas MJ, Argenta LC, Bare RL. A new technique to manage perineal wounds. Infections in Urology. 2000; 13 (2): 23 - 28.

31) Bonnamy C, Hamel F, Leporrier J, Fouques Y, Viquesnel G, Le Roux Y. Use of the vacuum-assisted closure system for the treatment of perineal gangrene involving the abdominal wall. Ann Chir. 2000; 125 (10): 982 - 984.

32) Elwood ET, Bolitho DG. Negative-pressure dressings in the treatment of hidradenitis suppurative. Ann Plast Surg. 2001; 46: 49 - 51.

33) Hynes PJ, Early MJ, Lawlor D. Split-thickness skin grafts and negative-pressure dressings in the treatment of axillary hidradenitis suppurativa. BJPS. 2002; 55: 507 - 509.

34) Banwell, PE. Topical Negative Pressure therapy. J. Wound Care. 1999; 8(2): 79 - 84.

35) Banwell, PE. Skin graft fixation. Br. J. Oral Maxillo Surg. 1998; 36 (6): 480 - 481.

36) Banwell PE, Gillespie PH, Inglefield C, Holten IW. Use of topical negative pressure and foam dressings for skin graft fixation. Wound Rep. Regen. 1999; 74: A247.

37) Banwell, PE. Advances in topical negative pressure (TNP) therapy. 3rd European Vacuum Therapy Symposium, Salisbury, UK, July 2003.

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A Controlled Subatmospheric Pressure Dressing Increases the Rate of Skin Graft Donor Site Reepithelialization

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The ability to increase the rate of skin graft donor site reepithelialization significantly in a cost-effective manner has important implications for the patient undergoing major reconstructive procedures. In this study the effect of externally applied reduced pressure (the V.A.C.) on the rate of healing of donor site wounds was initially investigated using a porcine model (N = 4), then repeated on humans (N = 10). Split-thickness skin grafts were harvested from the backs of pigs using standard technique. Half of the donor sites were treated with subatmospheric pressure (125 mmHg) and half were treated with an OpSite dressing. Biopsies taken every 48 hours demonstrated that sites exposed to reduced pressure healed at a much faster rate than sites treated with a standard occlusive dressing. Similarly, donor sites in humans reepithelialized faster in 7 of 10 patients, the rate was the same in 2 of 10 patients, and Opsite was faster in 1 of 10 patients. We believe this technology has the potential to be a relatively simple and cost-efficient method for increasing the rate of donor site healing.

Genecov DG, Schneider AM, Morykwas MJ, Parker D, White WL, Argenta LC. A controlled subatmospheric pressure dressing increases the rate of skin graft donor site reepithelialization. Ann Plast Surg 1998;40:219–225

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One of the ironies of modern burn care is that the coverage of excised burns often necessitates the creation of another wound—the skin graft donor site. It is not uncommon for this wound, which can be quite large when the need for unburned skin is great, to be more painful and debilitating than the original burn. Despite a great deal of research and debate, the ideal treatment for the donor site is still unknown.[1] Clearly this wound should be treated in such a manner that both healing and comfort are maximized. In fact, the ability to heal and reharvest a donor site quickly can be life saving when there is little unburned skin to harvest and coverage is urgently needed.

Several growth factors have been shown to speed healing, but the cost-effectiveness of this therapy has not been demonstrated.[2,3] In addition, growth factor therapy is presently only available in select centers. Treatment with cultured epidermal grafts has also been shown to accelerate healing in most studies, but other studies were not able to demonstrate improved results.[4–7] This form of therapy is not only expensive and labor intensive, but also carries the potential risk of disease transmission.

It has been shown previously that acute, chronic, and also burn wounds heal more rapidly and with better infection control when treated with externally applied subatmospheric pressure.[8–10] In this study we investigated whether the application of a simple and relatively inexpensive reduced pressure dressing (the V.A.C.; Kinetic Concepts, Inc., San Antonio, TX) would also significantly affect the healing rate of skin graft donor sites in a pilot study in a pig model, then in human patients.

The V.A.C.® has been cleared by the FDA to promote wound healing in acute wounds, flaps and grafts. Specific claims concerning the treatment of skin graft donor sites have not been cleared by the FDA.

Materials and Methods—Animal Study

Animal protocols were approved by the Institutional Animal Care and Use Committee, and care provided followed the *Guide for the Care and Use of Laboratory Animals*. A swine model was employed, as pig skin is the most similar to that of humans as far as hair density, microarchitecture, etc.[11] Twenty-five-kilogram female pigs

(N = 4) were procured and allowed to acclimate to the research facilities for 1 week. On the day of surgery they were anesthetized with an intramuscular injection of ketamine (60 mg per kilogram), xylaxine (12 mg per kilogram), and acepromazine (0.6 mg per kilogram). Anesthesia was maintained with inhaled halothane (1%). The animals were given one dose of cefazolin (500 mg) intramuscularly before the procedure began. Their backs were shaved and a preparatory solution of Betadine, followed by alcohol, was applied and allowed to dry. An air-driven dermatome (Zimmer, Inc., Warsaw, IN) was used to harvest six 2 × 4-in split-thickness skin grafts from each pig (three per side). (Skin graft thicknesses are conventionally referred to in inches instead of metric measurements.) Three thicknesses of graft were taken from each side: 0.010 in (0.25 mm), 0.012 in (0.3 mm), and 0.014 in (0.35 mm). The skin was discarded, and bleeding from the donor site was controlled with pressure. Six-millimeter-diameter punch biopsies (Baker Cummins Dermatologicals, Miami, FL) were obtained from the donor sites immediately after harvesting.

On one side of each animal, the three donor sites were covered with a large V.A.C. foam dressing, within which there was a fenestrated flexible tube. The dressing was trimmed appropriately to cover all three of the donor sites. A liquid adhesive was applied to the skin around the dressing and allowed to dry. An Ioban adhesive drape (3M, St. Paul, MN) was used to cover the sponge and create an airtight environment over the wound. The V.A.C. tubing was immediately connected to a pump that supplied 125 mmHg of continuous suction. The three control donor sites were covered with a thin-film adhesive dressing (OpSite; Smith and Nephew Inc., Columbia, SC).

Aquaplast (WFR/Aquaplast, Wyckoff, NJ) was molded to the backs of the animals and secured in place with Velcro straps to protect the wounds. A tubular cotton stockinet bandage was placed over the plastic and held in place with circumferential elastic tape. The pigs were allowed to wake in their cages and were given food and water ad libitum when fully recovered. The tubing that supplied the suction to the V.A.C.-treated sites was suspended from the top of the cages in such a manner that the animals could not disrupt it. Approximately 50 ml of serosanguinous fluid was collected each day for the first 3 days from the V.A.C.-treated wounds.

The animals were reanesthetized on postoperative days 2, 4, 7, 9, and 11, at which time all dressings were removed and the wounds were inspected. Six-millimeter-diameter punch biopsies were harvested from all sites and the specimens were immediately placed in a 10% buffered formalin solution. The biopsy sites were closed with a single 4-O nylon suture. The samples were embedded in paraffin after fixation, sectioned, and stained with hematoxylin-eosin stain for histological examination.

The slides were blinded for evaluation. Biopsies of donor sites treated with externally applied subatmospheric pressure were compared with the control sites with the assistance of the Dermatopathology Section of the Department of Pathology. Degree of reepithelialization and healing was assessed in a blinded fashion.

Materials and Methods—Human Study

Fifteen patients who required coverage of denuded surfaces with split-thickness skin grafts were initially enrolled into an Institutional Review Board-approved clinical study. The patients gave informed consent prior to participation in the study. Patient ages ranged from 39 to 81 years of age. Comorbidities included paraplegia (N = 2), insulin-dependent diabetes mellitus (N = 4), systemic infections with positive blood cultures requiring long-term intravenous antibiotics (N = 2), hemodialysis dependence (N = 3), and three traumatic wounds. Wounds were of sufficient size (32–380 cm^2) to require more than one donor site.

Each patient underwent harvesting of the split-thickness skin graft in the operative suite. Grafts were harvested with a dermatome from both thighs in all but 2 patients, in whom the donor sites were located on the same thigh with an area of intact skin between the sites. After the grafts had been harvested, the donor sites were covered with epinephrine-soaked Telfa pads (Kendall Health Care Products, Mansfield, MA). After hemostasis was obtained, 6-mm-diameter punch

biopsies were obtained and placed in 10% buffered formalin. These and subsequent biopsies were fixed and processed in the same manner as the biopsies obtained in the animal portion of the study.

Donor sites on one thigh (or half the sites for the 2 patients with donor sites on the same thigh) were covered with Opsite. A single layer of petroleum-impregnated gauze was placed over the remaining donor sites to minimize disruption of the new, migrating epithelial layer and to prevent ingrowth of capillary buds into the pores of the V.A.C. foam dressing. V.A.C. dressings were cut to the appropriate size and placed over the petroleum gauze. The site was covered and sealed with a sheet of Ioban. A vacuum of 125 mmHg was applied continuously to the donor sites. If significant volumes of fluid had collected in any areas under the Opsite dressing, the fluid was aspirated with needle and syringe, and the puncture site was patched with an additional piece of Opsite.

After 4 days the patients were asked which site, if either, was more painful and the answer was recorded. The Opsite and V.A.C. dressings were then removed. Areas of each donor site were infiltrated with 1% lidocaine with 1:100,000 epinephrine for local anesthesia, and 6-mm-diameter punch biopsies were harvested. The V.A.C. dressing was replaced and the vacuum reapplied. The Opsite was also replaced. At 7 days postgraft, all dressings were again removed and biopsies of the donor sites were taken in the same manner as on day 4. After this time if the V.A.C.-treated site appeared grossly healed, a multiagent antibiotic was placed on the site. If the V.A.C.-treated site appeared not to be healed, a single layer of petroleum-impregnated gauze was placed over the wound. Control wounds had Opsite reapplied to the donor sites.

All biopsies were fixed, sectioned, and mounted, and were stained with hematoxylin-eosin stain. The slides were blinded and evaluated by an independent dermatopathologist who reviewed them for degree of reepithelialization and maturation of the epidermis on a scale of 0 (no evidence of reepithelialization) to 4 (complete, mature-appearing epithelium).

Statistical analysis was performed on the scored data by the Section of Biostatistics of the Department of Public Health Sciences. A paired Student's *t*-test was used to compare degree of reepithelialization between V.A.C.-treated and control donor sites, and significance was accepted at $p \leq 0.05$.

Results—Animal Study

All of the animals tolerated the reduced pressure treatment and Opsite dressings with no adverse effects or visible signs of pain. None of the skin graft donor sites became infected. Biopsies of the donor sites taken immediately after harvesting (Fig 1A) showed removal of the epidermis and part of the dermis, thus confirming that a split-thickness graft had been obtained. All grafts harvested at each thickness were of equal depth for each animal.

On day 2, biopsies from control sites showed no evidence of reepithelialization. There was a large amount of coagulum and debris on the surface of the wounds. Because of this debris it was difficult to make any assessment about the healing process by gross examination. Sites treated with subatmospheric pressure, however, consistently demonstrated a continuous epithelial layer. There was less coagulum and debris on the exposed surface, which was also apparent grossly. All three thicknesses of skin graft donor site revealed a continuous epithelial layer, and in many areas there was a thin layer of cells consistent with a stratum corneum.

By day 4, the Opsite-treated wounds were beginning to reepithelialize (Fig 1B), but in many areas there was separation of the newly formed epithelium from the underlying supporting structures. The epithelium was immature in appearance. V.A.C.-treated sites, however, by day 4 demonstrated a relatively mature-looking epithelium with minimal dermal-epidermal separation (Fig 1C). The wounds were grossly healed and could have been reharvested if needed.

The control wounds were healed at all three thicknesses on day 7, and there was minimal change in the appearance of any of the donor sites, either microscopically or grossly, after that time.

Approximately 50 ml of serosanguinous fluid was collected from each V.A.C.-treated pig per day for the first 3 days, after which there was a

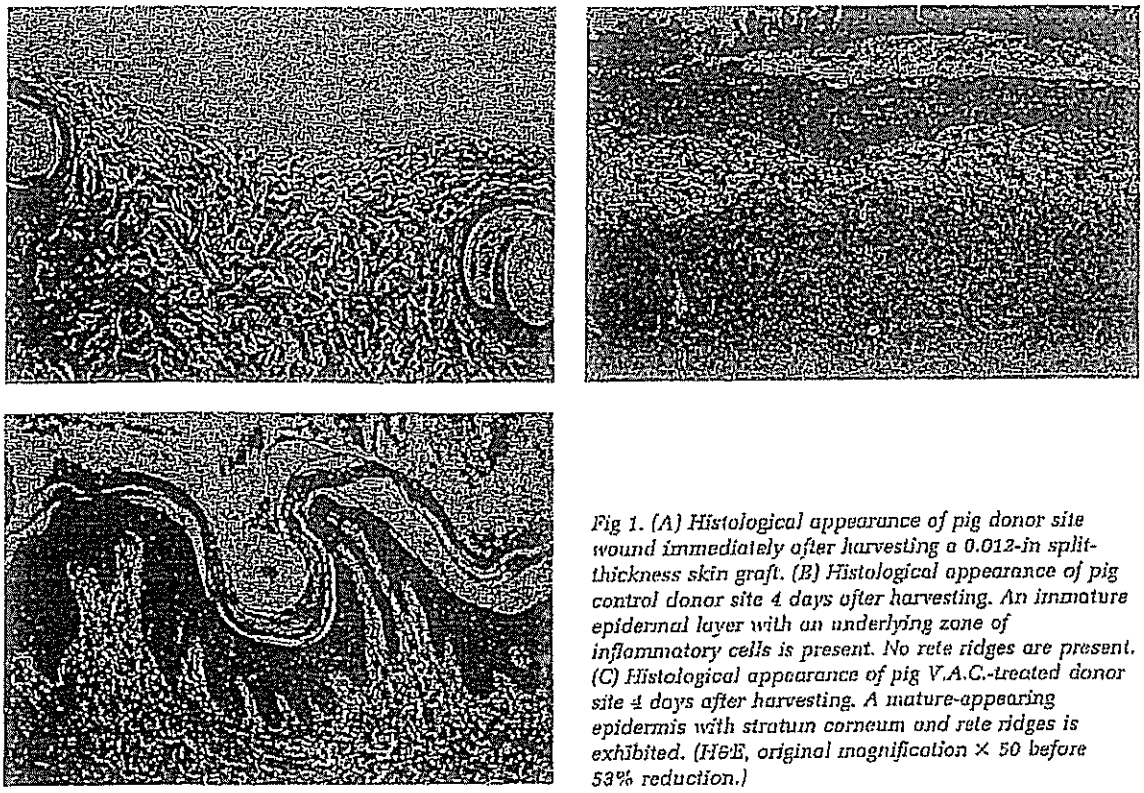

Fig 1. (A) Histological appearance of pig donor site wound immediately after harvesting a 0.012-in split-thickness skin graft. (B) Histological appearance of pig control donor site 4 days after harvesting. An immature epidermal layer with an underlying zone of inflammatory cells is present. No rete ridges are present. (C) Histological appearance of pig V.A.C.-treated donor site 4 days after harvesting. A mature-appearing epidermis with stratum corneum and rete ridges is exhibited. (H&E, original magnification × 50 before 53% reduction.)

minimal amount of fluid obtained. When the sponges were removed, there was no free fluid on the surface of the donor sites.

Results—Human Study

A total of 10 patients completed the study (4 males and 6 females). Of the 5 patients who did not complete the study, 1 patient refused to allow biopsies to be harvested and withdrew, 1 patient left the hospital against medical advice, 1 patient's pump was accidentally disconnected for more than 8 hours, and 2 patients with large control sites had leakage of fluid from under the dressing, which prompted the nursing staff to remove the Opsite and cover the sites with petroleum-impregnated gauze.

Of the 10 patients who completed the study, the V.A.C.-treated donor sites (Fig 2A) of 7 patients were noted to reepithelialize faster than the Opsite-treated control sites (Fig 2B) by day 7. Two patients showed no difference in the rate of reepithelialization of the donor sites by day 7. Wounds in both these patients were slow to heal, and none of the donor sites showed evidence of epithelial maturation. The final patient showed more rapid reepithelialization for the Opsite-treated site. Statistical analysis showed that V.A.C. treatment increased the rate of reepithelialization at $p \leq 0.013$.

None of the patients who completed the study noted any difference in pain associated with either treatment. The 2 patients whose Opsite dressings were removed during the course of the study and were replaced with Xeroform both reported that the Opsite-treated site was more painful. No infections were noted for any of the donor sites treated in the study.

Discussion

The skin serves two main purposes: exclusion of microorganisms from the body and maintenance of fluids and proteins within the body. Disruption of moderate to large areas of skin circumvents these functions with life-threatening consequences. Thus any disruption in the integrity of the skin must be corrected as quickly as possible.

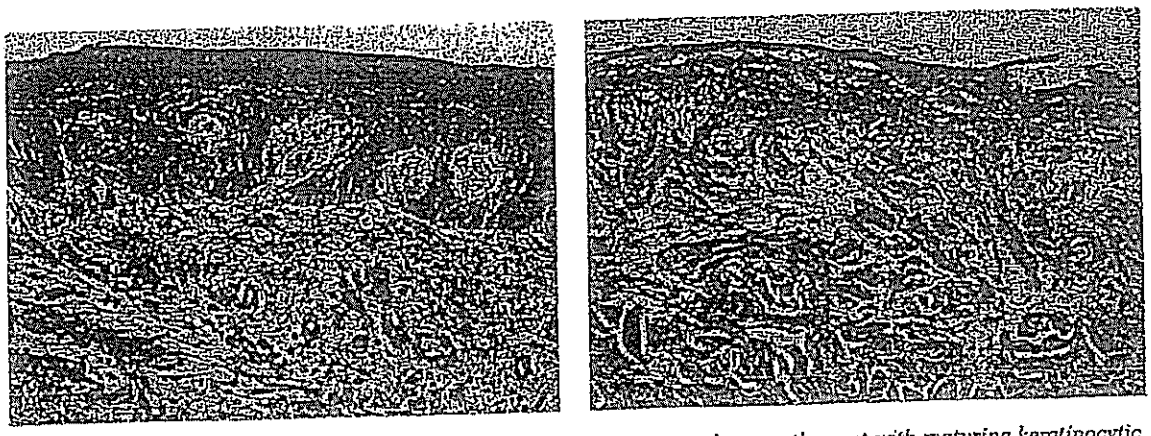

Fig 2. (A) Histological appearance of human V.A.C.-treated donor site 7 days postharvest with maturing keratinocytic layer with stratum corneum. (B) Histological appearance of human Opsite-treated donor site 7 days postgraft with thin, immature keratinocytic layer. (H&E, original magnification × 130 before 49% reduction.)

While there have been significant advances in the development and growth of autologous keratinocytes for grafts, these techniques still have their limitations, including the limited proliferation of cells from older patients, length of time required to grow large volumes, and high costs. Thus the "gold standard" for coverage of denuded areas is still the split-thickness skin graft.

When the surface area of the wound is smaller than that of the available donor sites, there is rarely a problem closing the wound successfully. For small defects, full-thickness skin grafts may be used. These include the entire thickness of the dermis, and though they take longer to revascularize than partial thickness grafts, they contract less than partial-thickness grafts. Most wounds are covered with partial-thickness skin grafts, which include part of the dermis, but leave behind adnexal structures that are the focal points for the spontaneous reepithelialization of the donor site. When the size of the wound is greater than the size of the donor site, multiple split-thickness skin grafts must be harvested serially from the same donor site. In these instances thin grafts are harvested for two reasons. The first is that the dermis does not regenerate following grafting as does the epidermis, and thus a finite amount of dermis is lost with each graft. Hence, with multiple harvests it is possible to remove the entire dermis and create a new full-thickness defect. The second is that thin grafts reepithelialize more rapidly than thicker grafts. Without any intervention, donor sites can be reharvested normally after 14 to 16 days.[12]

A variety of modalities have been used in attempts to increase the rate of healing of skin graft donor sites, including application of growth factors, electromagnetic waves, meshed grafts, cultured keratinocytic grafts, and so forth, which have increased the rate of reepithelialization by 5% to 15%.[2–7,13–19] At least one modality slowed the rate of healing compared with control wounds.[20] Other modalities may have also slowed the rate of healing, but negative results have neither been submitted nor published.

The speed with which the donor sites reepithelialized was the focus of this study. The increases in the rate of reepithelialization of donor sites in both the pig model and humans may be due to two factors. Externally applied mechanical forces have been postulated to increase the rate of mitosis and angiogenesis for decades.[21] More recently, increases in tissue growth secondary to applied forces have formed the basis of soft-tissue expansion and osteogenic distraction (Ilizarov technique).[22–24] Additionally, reduced pressure exposure may promote wound healing by the active removal of third-space fluid reduces edema and restoration of local blood flow, which is clearly important in the complex process of wound healing. The skin graft donor site is a wound, although it is unique in its uniform thickness and its ability to reepithelialize itself.

In the animal study, the application of reduced pressure to the healing skin graft donor site increased the rate of reepithelialization significantly. Treated sites were healed by day 4, whereas control sites did not show complete

healing until day 7. This is a reduction in the time to complete reepithelialization of more than 40%, which is significantly faster than the rates reported for other modalities (5–15%). The control wounds healed at a rate similar to human donor site wounds treated with a semipermeable occlusive dressing (5–12 days).[1] We did not find an appreciable difference between the rates of healing for the three different thicknesses of skin graft, probably because the differences in thickness of the graft were small compared with the depth of the adnexal structures in the skin of the pigs. A fair amount of fluid (50 ml per day) was removed in total from the three donor sites for the first 3 days of treatment. The cessation of fluid output after this time is probably reflective of the restoration of an intact epithelial barrier.

Many researchers have begun to analyze the fluid that accumulates on the surface of donor sites, and they have found varying levels of the well-known cytokines.[25,26] Despite the knowledge of their presence, it is still not clear what roles many of these cellular mediators play. Undoubtedly some are promoters of healing, whereas others are inhibitors of the wound-healing process. By actively removing fluid from the surface of the donor site, the V.A.C. may promote healing by eliminating inhibitors of healing that would be present normally.

A problem common to all investigations of donor site healing involves the inability to monitor the healing process continually. It is necessary to pick time points in such a manner that one can infer what is occurring between them. Too many time points might interfere with the healing and introduce error, and too few does not allow an adequate assessment of when changes are taking place. In the animal model we were able to obtain biopsies at frequent intervals, which allowed for determination of the rate of reepithelialization and maturation of the new epidermis. In many human studies the rate of reepithelialization is estimated by one or two observers who inspect the wounds grossly and decide whether healing is complete.[1–3] Sometimes the wounds are judged to be healed when the dressing falls off. Obviously the advantage of an animal model is the ability to take biopsies frequently and to determine accurately the presence or absence of an epithelial layer and its relative maturity. In humans we were only able to obtain biopsies at 4 and 7 days postgraft, thus the progression of healing could not be monitored as closely as in the porcine study. Additionally, frequent harvesting of biopsies from human donor sites will produce a large number full-thickness injuries that may affect healing or the final appearance of the donor site adversely.

We have found that applying the V.A.C. device to a donor site is relatively simple and requires only that one make sure that an airtight seal is obtained. If a seal is not obtained, the site will not be exposed to reduced pressure because air will be drawn in and over the wound. We left the device in place for the duration of the animal study (11 days), but in clinical use it was left in place for 7 days, at which time there usually was gross evidence of healing. When removing the sponges, it is important to lift them off carefully so that the newly formed epithelium is not damaged.

In the animal portion of the study it was impossible to determine whether the V.A.C. decreased the amount of pain associated with the donor site. The pigs did not show any of the usual signs of discomfort at any point in the project. Patients reported that subatmospheric pressure-treated donor sites did not cause more pain than donor sites treated with occlusive dressings. We have also found that burn patients find the application of subatmospheric pressure to partial-thickness burns to be very comfortable when compared with standard dressings. Because the V.A.C. is an occlusive dressing, we expected it to be at least as comfortable as other occlusive dressings currently in use.

In summary, we found that treatment of split-thickness skin graft donor sites with reduced pressure increased the rate of reepithelialization significantly in both a pig model and in humans compared with donor sites treated with a standard occlusive, semipermeable dressing. Donor sites were healed by day 4 in pigs compared with control wounds, which required 7 days to reepithelialize. In humans, 7 of 10 donor sites reepithelialized significantly faster by day 7 postgraft. Application of subatmospheric pressure to donor sites apparently has the potential to increase the rate of reepithelialization in humans who require extensive grafting. The treatment is simple and

relatively inexpensive. For patients with limited undamaged skin, the technique may be life saving.

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References

1 Smith DJ, Thomson PD, Garner WL, Rodriguez JL. Donor site repair. Am J Surg 1994;167:49S–51S
2 Herndon DN, Hawkins HK, Nguyen TT, et al. Characterization of growth hormone enhanced donor site healing in patients with large cutaneous burns. Ann Surg 1995;221: 649–659
3 Falanga V. Growth factors and chronic wounds: the need to understand the microenvironment. J Dermatol 1992;19: 667–672
4 Teepe RGC, Koch R, Haeseker B. Randomized trial comparing cryopreserved cultured epidermal allografts with tulle-gras in the treatment of split-thickness skin graft donor sites. J Trauma 1993;35:850–854
5 Phillips TJ, Provan A, Colbert D, Easley KW. A randomized single-blind controlled study of cultured epidermal allografts in the treatment of split-thickness skin graft donor sites. Arch Dermatol 1993;129:879–882
6 Fratianne R, Papay F, Housini I, et al. Keratinocyte allografts accelerate healing of split-thickness donor sites: applications for improved treatment of burns. J Burn Care Rehabil 1993;14:148–154
7 Blight A, Fatah MF, Datubo-Brown DD, et al. The treatment of donor sites with cultured epithelial grafts. Br J Plast Surg 1991;44:12–14
8 Argenta LC, Morykwas M. Vacuum-assisted closure: a new method for wound control and treatment: clinical experience. Ann Plast Surg 1997;38:563–577
9 Morykwas M, David L, Schneider AM, et al. Use of the V.A.C. to prevent progression of partial thickness burns in a swine model. J Burn Care Rehabil 1997 (submitted for publication)
10 Morykwas M, Argenta LC, Shelton-Brown E, McGuirt W. Vacuum-assisted closure: a new method for wound control and treatment: animal studies and basic foundation. Ann Plast Surg 1997;38:553–562
11 Meyer W, Schwartz R, Neurand K. The skin of domestic mammals as a model for the human skin, with special reference to the domestic pig. Curr Probl Dermatol 1978; 7:39–52
12 Converse JM, McCarthy JG, Brauer RO, Ballantyne DL. Transplantation of skin: grafts and flaps. In: Converse JM, ed. Reconstructive plastic surgery. 2nd ed, vol. 1. Philadelphia: WB Saunders, 1977:152–239
13 Vanstraelen P. Comparison of calcium sodium alginate (Kaltostat) and porcine xenograft (E-Z Derm) in the healing of split-thickness skin graft donor sites. Burns 1992; 18:145–148
14 Griswold JA, Copina T, Rossi L, et al. A comparison of Xeroform and SkinTemp dressings in the healing of skin graft donor sites. J Burn Care Rehabil 1995;16:136–140
15 Porter JM. A comparative investigation of reepithelialization of split skin graft donor areas after application of hydrocolloid and alginate dressings. Br J Plast Surg 1991; 44:333–337
16 Brown GL, Nanney LB, Griffen J, et al. Enhancement of wound healing by topical treatment with epidermal growth factor. N Engl J Med 1990;321:76–79
17 Ableza VJ, Berlet AC, Manstein ME. An alternative treatment for the split thickness skin-graft donor site. Aesthetic Plast Surg 1997;21:207–209
18 Smith DJ, Thomson PD, Bolton LL, Hutchinson JJ. Microbiology and healing of the occluded skin-graft donor site. Plast Reconstr Surg 1993;91:1094–1097
19 Goldin JH, Broadbent NRG, Nancarrow JD, Marshall T. The effects of diapulse on the healing of wounds: a double blind randomised controlled trial in man. Br J Plast Surg 1981;34:267–270
20 Bettinger DAS, Mast B, Gore D. Hyaluronic acid impedes reepithelialization of skin graft donor sites. J Burn Care Rehabil 1996;17:302–304
21 Thoma R. Ueber die histomechanik des gefasssystems und die pathogenese der angiosklerose. Virchows Arch Pathol Anat 1911;204:1–74
22 Urschel JD, Scott PC, Williams HTG. The effect of mechanical stress on soft and hard tissue repair: a review. Br J Plast Surg 1988;41:182–186
23 Olgins M, Dalsgaard C, Wickman M. Mitotic activity in expanded human skin. Plast Reconstr Surg 1983;91:213–216
24 Ilizarov GA. The tension-stress effect on the genesis and growth of tissues. Part II. The influence of the rate and frequency of distraction. Clin Orthop Rel Res 1989;239: 263–285
25 Grayson LS, Hansbrough JF, Zapata-Sirvent RL, et al. Quantitation of cytokine levels in skin graft donor site wound fluid. Burns 1993;19:401–405
26 Ono I, Gunji H, Suda K, et al. Evaluation of cytokines in donor site wound fluids. Scand J Plast Reconstr Surg Hand Surg 1994;28:269–273

A Prospective, Blinded, Randomized, Controlled Clinical Trial of Topical Negative Pressure Use in Skin Grafting

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Topical negative pressure has been demonstrated to improve graft take in a number of noncomparative studies. This study aimed to assess whether split-thickness skin graft take is improved qualitatively or quantitatively with topical negative pressure therapy compared with standard bolster dressings. A blinded, prospective, randomized trial was conducted of 22 adult inpatients of Liverpool Hospital between July of 2001 and July of 2002 who had wounds requiring skin grafting. After grafting, each wound half was randomized to receive either a standard bolster dressing or a topical negative pressure dressing. Skin graft assessment was performed at 2 weeks by a single observer blinded to the randomization. Two patients were lost to follow-up and were excluded from the study. There were 20 patients (12 men and eight women) in the study group. The median patient age was 64 years (range, 27 to 88 years), and the mean wound size was 128 cm^2 (range, 35 to 450 cm^2). The wound exposed subcutaneous fat in eight patients, muscle in six patients, paratenon in four patients, and deep fascia in two patients. At 2 weeks, wounds that received a topical negative pressure dressing had a greater degree of epithelialization in six cases (30 percent), the same degree of epithelialization in nine cases (45 percent), and less epithelialization in five cases (25 percent) compared with their respective control wounds. Graft quality following topical negative pressure therapy was subjectively determined to be better in 10 cases (50 percent), equivalent in seven cases (35 percent), and worse in three cases (15 percent). Although the quantitative graft take was not significant, the qualitative graft take was found to be significantly better with the use of topical negative pressure therapy ($p < 0.05$). Topical negative pressure significantly improved the qualitative appearance of split-thickness skin grafts as compared with standard bolster dressings. (*Plast. Reconstr. Surg.* 114: 917, 2004.)

Topical negative pressure has been shown to improve wound healing in a number of settings, from acute degloving injuries[1] to chronic, infected, and diabetic wounds.[2–6] In additional, it has been used to prepare wound beds for either grafting of flap closure.[7–9]

Some case series and reports have proposed the use of topical negative pressure as a modality for improving split-thickness skin graft take[10–13] and skin graft donor sites.[14] Advantages cited include improved graft take in lower-limb wounds,[11] application of topical negative pressure over difficult anatomic areas,[15] and early ambulation with portable devices.[11] These studies have cited the advantages of exudate removal, better graft take, and prevention of graft shearing when topical negative pressure is used in combination with skin graft placement.

A recent review of topical negative pressure in wound management[4] concluded that much of the current data on topical negative pressure, especially for chronic wounds, has relied on noncomparative studies. The authors called for the establishment of comparative trials of topical negative pressure to gauge its efficacy and cost-effectiveness. Similarly, despite the increasing use and perceived benefits of topical negative pressure therapy, no prospective randomized trial has investigated its use for skin grafts, particularly in the trauma setting.

We therefore undertook a prospective, blinded, randomized controlled trial to assess whether split-thickness skin graft take is improved with the application of topical negative

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pressure dressings as compared with standard skin graft dressings.

Patients and Methods

We prospectively recruited adult inpatients admitted to Liverpool Hospital from July of 2001 to July of 2002 with wounds 25 cm^2 or larger and judged clinically ready for skin grafting in the operating theater. All patients received a subject information sheet and were informed of the study's aims, anticipated benefits, and potential risks. The ethics committee of the South Western Sydney Area health service approved the study protocol. Pretreatment information was recorded and included patient demographic data, intercurrent medical conditions, and wound parameters, including etiology, size, duration, characteristics, and previous treatment.

At surgery, the wound for grafting was divided into superior and inferior halves. A split-thickness skin graft was harvested using a powered air dermatome (model no. 8801; Zimmer, Dover, Ohio) set to a thickness of 11/1000 inches. The graft was meshed 1:1.5 and used to cover the entire wound (superior and inferior halves) before randomization.

Each wound half was then randomized to receive either a standard pressure bolster dressing or a topical negative pressure dressing. The topical negative pressure dressing consisted of a nonstick Mepitel sheet (Mölnlycke Health Care, Goteborg, Sweden) covered with foam, a suction tube, and an airtight plastic sheet covering, to allow negative pressure to be applied to the wound and drainage of fluid exudate. The tubing was connected to the Vacuum-Assisted Closure Advance Therapy System (Kinetic Concepts International, San Antonio, Texas). The machine was set to deliver 100 mmHg of continuous topical negative pressure.

The standard bolster dressing consisted of Mepitel, Acriflavine wool (Defries Industries, Keysborough, Victoria, Australia), and foam sponge. The wound halves were divided by a narrow bridge of multilayered Comfeel (Coloplast A/S, Humlebaek, Denmark) to prevent the transmission of negative pressure (Figs. 1 and 2).

The dressings were left intact for 5 days. If grafts were placed on lower limbs, patients were immobilized with leg elevation and deep venous thrombosis prophylaxis. Once the dressings were removed, the entire grafted area was treated with daily petroleum gauze (Jelonet; Smith and Nephew, Hull, England), saline-soaked gauze, and crepe. Patients with

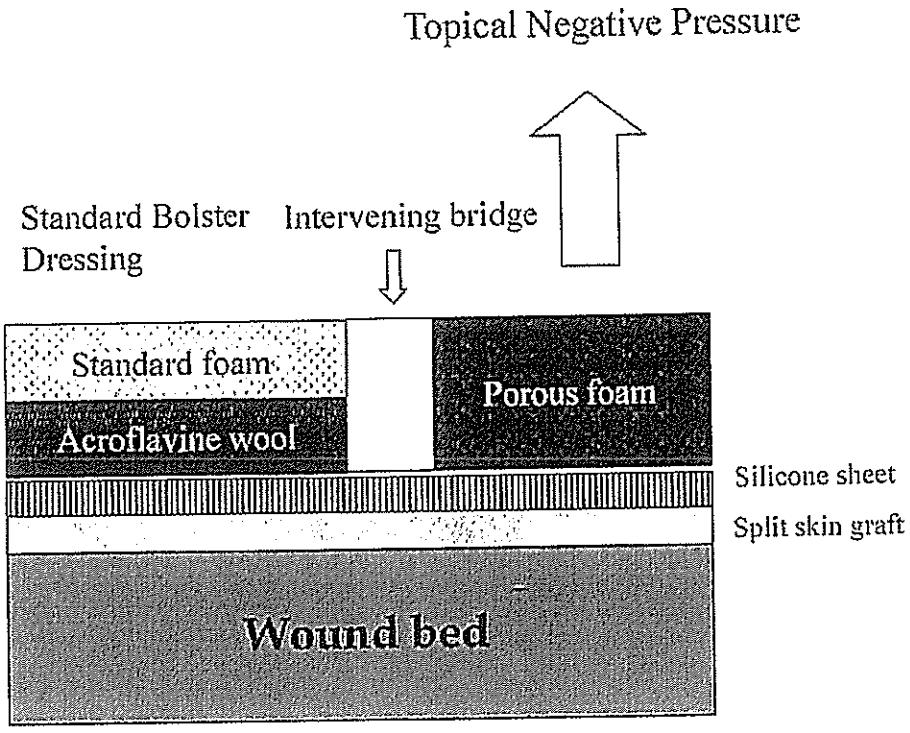

Fig. 1. Schematic representation of dressing of the skin graft with either randomized topical negative pressure dressing or a standard bolster dressing.

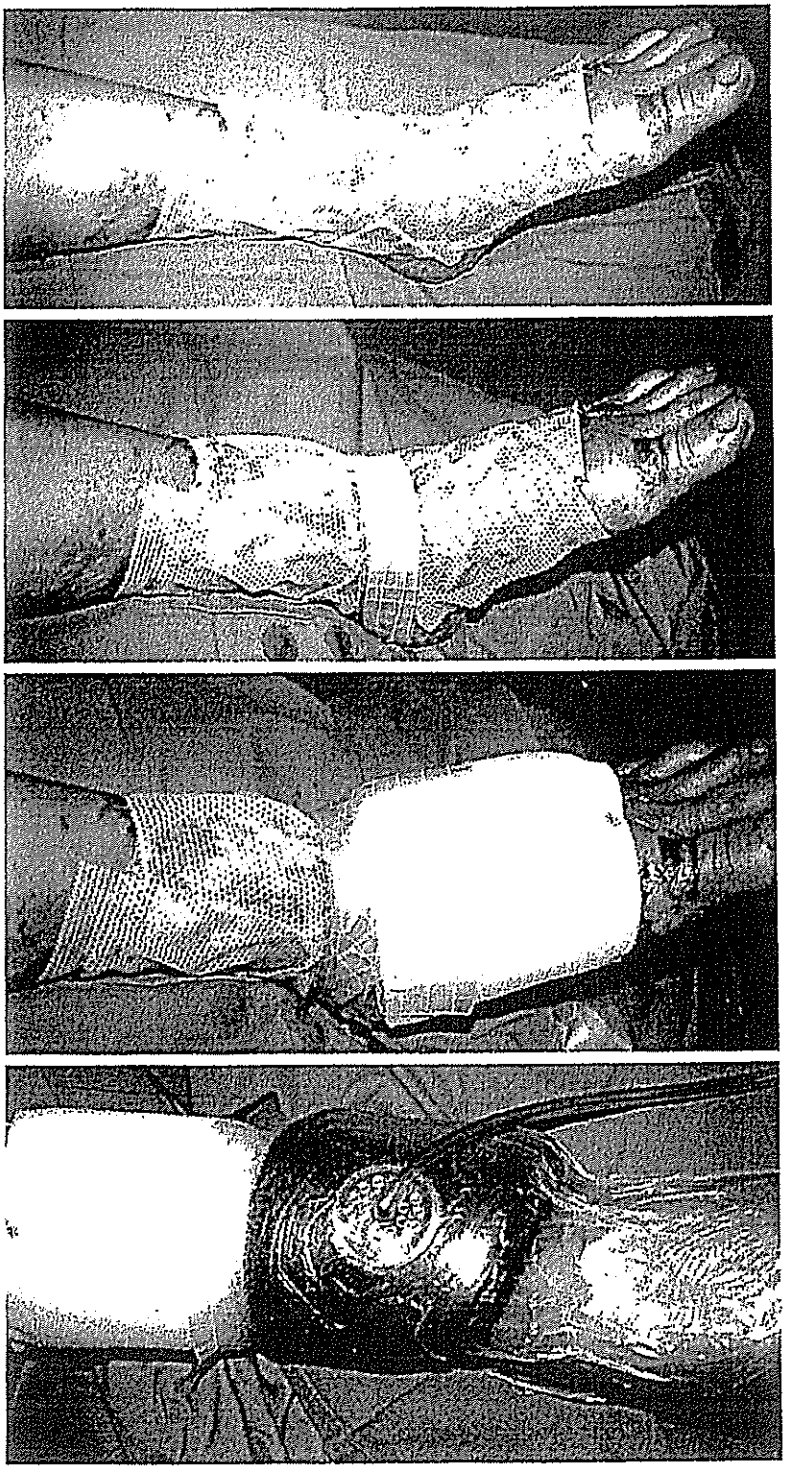

FIG. 2. (*Above*) Silicone sheet dressing over skin graft. (*Second from above*) Construction of a Comfeel dividing bridge and randomization of superior and inferior halves. (*Third from above*) Standard skin graft bolster dressing placed inferiorly. (*Below*) Topical negative pressure dressing applied to superior half of wound.

lower-limb grafts were mobilized using standard protocols, with full ambulation by day 8.

Graft outcome was assessed at 2 weeks by a clinician (Deva) blinded to the randomization of wound halves. Graft take was recorded both quantitatively (expressed as percentage of epithelialization recorded by gross inspection) and qualitatively (rated as poor, satisfactory, good, or excellent). The sign test was used to assess significance between the control and study groups.[16]

Results

Twenty-two patients were recruited into the study. Two patients were lost to follow-up and were thus excluded from the outcome analysis. Of the 20 patients who completed the study, 12 were male; the median patient age was 64 years (range, 27 to 88 years).

The average wound size was 128 cm^2 (range, 35 to 450 cm^2), with a mean duration of 18 days (range, 0 to 90 days). Ten wounds were acute and the remaining 10 were subacute or chronic (>5 days' duration). The structures exposed at the base of the wound were fat in eight patients, muscle in six patients, paratenon in four patients, and fascia in two patients.

Three patients had experienced prior graft failure before being entered into the study. Topical negative pressure was randomized to the superior half of the wound in 10 patients and the inferior half in the remaining 10.

All wounds healed without the need for further débridement or regrafting. The dressings were well tolerated by the patients. In three patients, there was some difficulty in maintaining topical negative pressure during therapy. This did not affect delivery of topical negative pressure to the graft area for significant periods of time.

At 2 weeks, wounds receiving topical negative pressure had a greater degree of epithelialization in six cases (30 percent), the same degree of epithelialization in nine cases (45 percent), and less epithelialization in five cases (25 percent), compared with their respective control wounds. In the qualitative assessment, graft take following topical negative pressure therapy was subjectively determined to be better in 10 cases (50 percent), equivalent in seven cases (35 percent), and worse in three cases (15 percent) (Fig. 3). The quantitative graft take was not significantly different between the groups. The qualitative graft take, however, was found to be significantly better with the use of topical negative pressure ($p < 0.05$).

Table I summarizes the clinical outcomes.

Discussion

The use of topical negative pressure has led to an increase in initial treatment costs for wound management. While these costs may be offset be shorter treatment times and better clinical outcomes, no randomized controlled trials exist to clearly establish the therapeutic and economic benefits of topical negative pressure. Innovative treatments should be tested to the highest possible level in this environment of evidence-based medicine if the limited financial resources of the health care system are to provide the optimum standard of care.

Noncomparative studies have reported that topical negative pressure is effective in treating

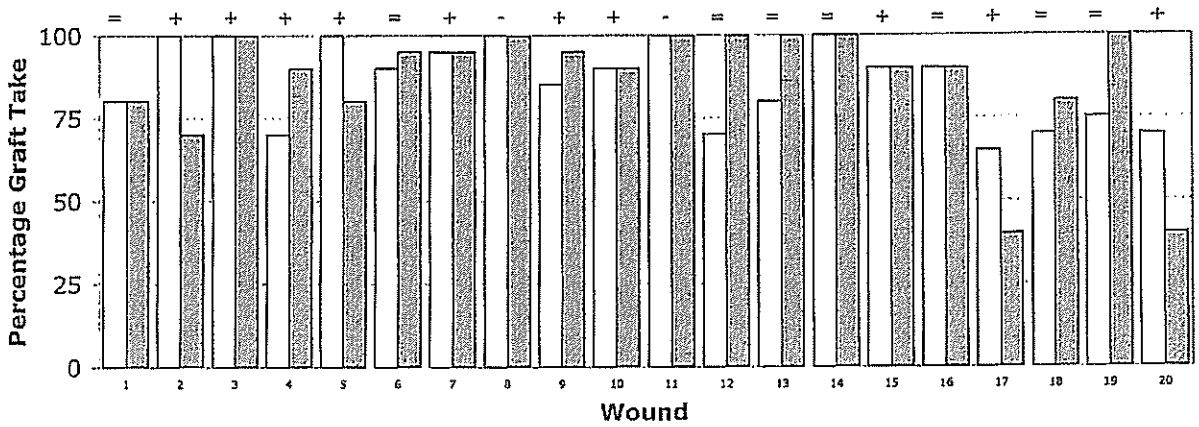

Fig. 3. Quantitative and qualitative outcomes following topical negative pressure therapy versus standard bolster dressings for skin grafts. Quantitative take: □, topical negative pressure; ▩, standard bolster dressing; qualitative take: +, better; =, equivalent; −, worse.

TABLE I
Summary of Treatment and Outcome Data for Each Study Subject

Age (years)/Sex	Site	Mechanism	Wound Area (cm^2)	Wound Base	% Graft Take with TNP	% Graft Take with Bolster	Qualitative Take of TNP vs. Bolster
44/M	Right iliac fossa	MRSA wound infection	40	Fat	80	80	Equivalent
62/M	Right lateral malleolus	Wound infection ORIF	50	Paratenon	100	70	Better
88/F	Right dorsal forearm	Extravasation injury	50	Fat	100	100	Better
66/F	Left anteromedial thigh	Necrotizing fasciitis	336	Muscle	70	90	Better
44/M	Left lateral thigh	Contact burn	150	Fat	100	80	Better
52/M	Sacrum and right buttock	Trauma	120	Muscle	90	95	Equivalent
79/F	Left ankle and foot dorsum	Hot oil burn	170	Fat	95	95	Better
60/F	Medial leg	Pressure ulcer	60	Fat	100	100	Worse
48/M	Right anteromedial thigh	Degloving injury	450	Muscle	85	95	Better
48/M	Right lower leg	Degloving injury	50	Muscle	90	90	Better
27/M	Left knee	Chemical burn	56	Fat	100	100	Worse
72/M	Sternum	Sternal dehiscence	90	Muscle	70	100	Equivalent
44/M	Right foot	Contact burn	36	Paratenon	80	100	Worse
88/F	Left lower leg	Trauma	420	Fat	100	100	Equivalent
74/M	Left lower leg	Cellulitis	140	Muscle	90	90	Better
40/F	Right lower leg	Trauma	90	Paratenon	90	90	Equivalent
75/M	Left lateral leg	Trauma	105	Paratenon	65	40	Better
34/F	Right lateral arm	Contact burn	44	Fat	70	80	Equivalent
78/M	Right lower leg	Trauma and venous disease	35	Fascia	75	100	Equivalent
72/F	Right lower leg	Trauma	77	Fascia	70	40	Better

TNP, topical negative pressure; MRSA, methicillin-resistant *Staphylococcus aureus*; ORIF, open reduction, internal fixation.

large, difficult, and traumatic wounds.[2–6] Clinical and experimental studies have shown that it creates an environment that promotes wound healing by increasing blood flow, improving oxygenation, increasing granulation tissue formation, and removing excess interstitial fluid.[2,3] A reduction in bacterial contamination has also been reported.[2,3] Application of topical negative pressure also provides a means for graft immobilization and apposition to the wound bed.[10–13]

Our randomized controlled trial showed that use of topical negative pressure therapy on split-thickness skin grafts significantly improved the quality of the skin graft's appearance postoperatively. Skin grafts receiving topical negative pressure displayed epithelialization rates equal to or better than those in control grafts in 75 percent of cases. Skin grafts receiving topical negative pressure were qualitatively equal to or better than control grafts in 85 percent of cases. These comparative data showed a significantly better quality of skin graft take following the use of topical negative pressure. It is postulated that the removal of exudate and bacteria together with the improvement in oxygenation observed in previous experimental studies[2,3] may also work to improve the quality of skin graft take.

These findings, however, have to be considered in the context of the high rates of graft take in clinical practice and our relatively small sample size. In addition, we did not assess long-term skin graft stability following topical negative pressure therapy. Further randomized studies combining topical negative pressure and skin grafts with early mobilization, earlier takedown of graft dressings, and/or early discharge with community treatment are planned.

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REFERENCES

1. Meara, J. G., Guo, L., Smith, J. D., Pribaz, J. J., Beuning, K. H., and Orgill, D. P. Vacuum-assisted closure in the treatment of degloving injuries. *Ann. Plast. Surg.* 42: 589, 1999.
2. Morykwas, M. J., Argenta, L. C., Shelton-Brown, E. I., and McGuirt, W. Vacuum-assisted closure: A new method for wound control and treatment: Animal studies and basic foundation. *Ann. Plast. Surg.* 38: 553, 1997.
3. Argenta, L. C., and Morykwas, M. J. Vacuum-assisted closure: A new method for wound control and treatment: Clinical experience. *Ann. Plast. Surg.* 38: 563, 1997.
4. Evans, D., and Land, L. Topical negative pressure for treating chronic wounds: A systematic review. *Br. J. Plast. Surg.* 54: 238, 2001.
5. Greer, S. E., Longaker, M. T., Margiotta, M., Mathews, A. J., and Kasabian, A. The use of subatmospheric pressure dressings for the coverage of radial forearm free flap donor site exposed tendon complications. *Ann. Plast. Surg.* 43: 551, 1999.

6. Deva, A. K., Buckland, G. H., Fisher, E., et al. Topical negative pressure in wound management. *Med. J. Aust.* 173: 128, 2000.
7. Fenn, C. H., and Butler, P. E. M. Abdominoplasty wound-healing complications: Assisted closure using foam suction dressing. *Br. J. Plast. Surg.* 54: 348, 2001.
8. Wu, S. H., Zecha, P. J., Feitz, R., and Hovius, S. E. R. Vacuum therapy as an intermediate phase in wound closure: A clinical experience. *Eur. J. Plast. Surg.* 23: 174, 2000.
9. Song, D. H., Wu, L. C., Lohman, R. F., Gottlieb, L. J., and Franczyk, M. Vacuum-assisted closure for the treatment of sternal wounds: The bridge between débridement and definitive closure. *Plast. Reconstr. Surg.* 111: 92, 2003.
10. Blackburn, J. H., Boemi, L., Hall, W. W., et al. Negative pressure dressings as a bolster for skin grafts. *Ann. Plast. Surg.* 40: 453, 1997.
11. Sposato, G., Molea, G., Di Caprio, G., Scioli, M., La Rusca, I., and Ziccardi, P. Ambulant vacuum-assisted closure of skin graft dressing in the lower limbs using a portable mini-VAC device. *Br. J. Plast. Surg.* 54: 235, 2001.
12. Molnar, J. A., De Franzo, A. J., and Marks, M. W. Single-stage approach to skin grafting the exposed skull. *Plast. Reconstr. Surg.* 105: 174, 2000.
13. Scherer, L. A., Shiver, S., Chang, M., Meredith, W. J., and Owings, J. T. The vacuum assisted closure device: A method of securing skin grafts and improving graft survival. *Arch. Surg.* 137: 930, 2002.
14. Genecov, D. G., Schneider, A. M., Morykwas, M. J., Parker, D., White, W. L., and Argenta, L. C. A controlled sub-atmospheric dressing increases the rate of skin graft donor site re-epithelialisation. *Ann. Plast. Surg.* 40: 219, 1998.
15. Greer, S. E., Duthie, E., Cartolano, B., Koehler, K. M., Maydick-Younberg, D., and Longaker, M. T. Techniques for applying subatmospheric pressure dressing to wounds in difficult regions of anatomy. *J. Wound Ostomy Continence Nurs.* 26: 250, 1999.
16. Altman, D. G. *Practical Statistics for Medical Research.* London: Chapman and Hall, 1991.