



Figure 1: Total Contact Cast

What Is the “Essential” TCC?

Here’s an update on the gold standard of off-loading devices.

BY JAMES MCGUIRE DPM AND TIMOTHY GREENE

The Total Contact Cast (TCC) for decades has been praised as the “gold standard” for treatment of neuropathic plantar ulceration (Figure 1).¹⁻⁶ The success of the TCC is attributed to its ability to both “unload” the plantar foot and maintain immobilization through the use of a non-removable cast. Reducing or eliminating plantar pressures associated with the formation and chronicity of neuropathic ulcers will maximize wound healing potential and help prevent recurrence of plantar wounds. Relying on the principles of off-loading and forced immobilization, a properly applied TCC provides the best environment to aid in healing of these often-difficult wounds.

The use of a total contact molded insole to achieve a redistribution of forces from areas of high pressure to those of relatively low pressure for plantar unloading has also been studied extensively, and countless devices, techniques, and modifications have been developed for this purpose.⁷⁻¹³ These have included the actual foot bed of the TCC, pixilated off-loading walkers, diabetic healing shoes, and even depth footwear for

everyday use (Figure 2). The TCC and more recently, TCC “kit” systems have continuously proven to be the most effective modalities for treating and healing neuropathic foot ulcerations. TCC “kits” have been devel-

of these kits and design changes incorporated by the companies to individualize their products have caused us to reevaluate the original concept of the TCC and to try to determine the “essential” off-loading features of

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oped by several companies to streamline the application of the modality and increase its use by practitioners who have been slow to embrace the TCC despite convincing research to validate its use. The various features

the contact cast (Figures 3-5).

What makes it work? Does it have to be applied exactly as originally described? Are there essential components of a “total contact cast” that are a must and others that allow for creative modification?

Despite its proven track record, the TCC is often under-utilized in daily practice.^{14,15} Fife, et al. found that of all the sites surveyed, only 6% of patients received treatment with a TCC.¹⁵ Similarly, after surveying 895 clinics that treat diabetic foot ulcerations, Wu, et al. concluded that only 1.7% of centers routinely use



Figure 2: Diabetic Healing Shoe with Pixelated Insole

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Figure 3: Cutimed Off Loader Select



Figure 4: Derma Sciences TCC-EZ System



Figure 5: MedE-Kast Ultra Total Contact Cast System

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TCC's, and that 58.1% of centers did not consider the TCC as the gold standard for treating a non-infected diabetic foot ulceration.¹⁴

While most practitioners understand the need for pressure reduction in the healing of these wounds, up to 41.2% of respondents utilize much less successful and often ineffective shoe modification techniques instead of more robust off-loading techniques provided by the various non-removable devices we will discuss.

Their survey found that the reasons for this lack of support for non-removable off-loading devices, including TCCs, can be attributed to patient tolerance (55.3%), the time needed to apply the cast (54.3%), cost of materials (31.6%), reimburse-

ment issues (27.5%), familiarity with method of application (25%), customizing parts (20.9%), staffing/ordering supplies (15.2%), and clinician coverage (10.6%).¹⁴

can be traced back to the work of Dr. Paul Brand who helped pioneer the method of total contact plaster casting while working with leprosy patients (Hansen's disease) in India during the 1950s and later in Carville Louisiana.¹⁷⁻²⁰ He studied the etiology and development of neuropathic ulceration, and postulated that there were four main predisposing factors that led to tissue breakdown.¹⁸

1) Direct mechanical disruption of tissue

2) Sustained pressure over a long period of time, leading to localized tissue ischemia

3) Repetitious low stress over a long period of time, leading to tissue inflammation

4) Infection via an ulceration formed from the aforementioned mechanisms of injury.

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Also of significance is a high, perceived complication rate during treatment with a TCC.¹⁶ Respondents also mentioned concern over the need for frequent changes and or close monitoring of the patient; however, this is not unique to casting modalities, as the same can be said of most any wound care modality in general practice today. The TCC continues to remain the "gold standard" of treatment for neuropathic foot ulcerations but its status as a treatment modality is tarnished by its lack of acceptance by medical professionals worldwide.

History of TCC

The history of the TCC in the management of diabetic neuropathic ulcerations in the United States

Reduction in size of the wounds, time to wound healing, and decreased recurrence of complications were all improved by removing the pressures associated with the formation of these wounds. It was upon these principles that the technique of total contact casting was born. Since that time, it is generally agreed that neuropathic sensory loss plays a vital role, if not the leading role, in the onset of ulceration.²¹

This was confirmed by a prospective study performed by Young, et al. in 1994, where he demonstrated a seven-fold increased risk of ulceration in the neuropathic patient population.²² When sensory input is lost, the effects of the repeated stresses to the foot are compounded and ulceration commonly results. This was just one of many studies that helped shape the understanding that pressure and stress lead to the break-

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down of healthy tissue.^{21,23-25}

In his original work, Dr. Brand used a “close fitting” plaster cast with minimal padding on the foot and leg, a plywood board attached to the plantar surface, and a rubber, peg-style walker base attached to the cast to allow for ambulation.^(2,20) This method of total contact casting spread slowly in the medical community, with eventual acceptance based on the superior wound healing noted with its use.⁶

The original technique of application called for the patient to be placed in a prone position with the knee and ankle 90 degrees to the leg. The wound was dressed with a light dressing and the toes were protected with interdigital padding. A stockinette was applied to cover the foot and leg and the only padding used were pieces of 1/4 inch adhesive felt, applied to the essential bony prominences of the tibial crest and the malleoli. This was done to prevent friction injury from the cast and allow for removal with a cast saw. The toes were then covered with an adhesive foam so the cast could be closed over the neuropathic digits to prevent injury from trauma or debris getting into the cast. A moldable creamy plaster called Gypsona™ was applied and molded into the arch and

with the cast. This has been referred to as a “wound isolation TCC”.^{29,30}

Authors Burns and Begg noted that a modified TCC with 12mm of polyurethane foam gave the additional benefit of providing more

applications, or no felt padding using instead a thick protective sock. The rigid external shell has even been replaced with a slightly flexible, roll-on fiberglass sock that is relatively stiff with light patients but must be rein-

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off-loading than a traditional TCC. They found that a cast modified with 6mm of slow-rebound cellular urethane and 6mm of soft cellular urethane can provide an increase in the plantar unloading properties of the cast. The variables for measurement were peak pressure at the ulcer site, mean pressure, and pressure-time integral. They found the addition of foam inside the cast improved the peak pressure reduction at the ulcer site when compared to a cast shoe by 70% (44% in the TCC alone), the mean pressure compared to a cast shoe improved by 60% (47% in the TCC alone), and the pressure time integral compared to a cast shoe improved by 69% (37% in the TCC alone).

While this study was designed primarily to map the pressure reduc-

forced when patients are too heavy.³¹

Despite the variations made to the original design, the studies with the various forms of the TCC have continued to demonstrate improved off-loading and superior healing when compared to other methods commonly utilized.³² It was originally thought that the TCC was effective because it disburbed the vertical or “ground reactive” forces to the entire plantar aspect of the foot by virtue of its total contact with the plantar surface of the foot. Instead of having one or two “focal” points of pressure at the site of tissue breakdown, the close molding of the cast against the foot would allow the forces to be spread to the entire plantar surface.¹⁷

Additionally, it was thought that by conforming the cast to the contours of the foot, one could prevent “shear” forces from occurring on or around the delicate wound bed. It was believed that this shear force contributed to occlusion of delicate blood vessels as well as cause the new, healing epithelial layers to slough off under this horizontal pressure, impeding the healing potential of the wound.³³⁻³⁶

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around the ankle to ensure a tight fit that would not allow for any motion that might induce shearing. The plywood and walking base were then applied to complete the cast.

Modern TCC

The modern TCC has been modified in many ways. Plaster has been replaced with fiberglass casting tape either in whole or as the final outer layer.⁽²⁶⁻²⁸⁾ The plantar surface has been padded in part or totally to address areas of common irritation seen

tion achieved using polyurethane foam inside the TCC, and no direct measure of effectiveness on ulcer healing was given, the authors nevertheless felt confident recommending the utilization of polyurethane foam in TCCs to further improve healing based on the dramatic pressure reduction they saw in the study.

TCC systems or kits have been manufactured that have utilized several modifications on the original design including: increased leg and foot padding, and either expanded felt

Shear Forces

Shear forces have been described as the causative factor for the development of hyperkeratotic wound edges which also impede healing.³⁷ This phenomenon has been described as the “edge effect,” and methods of reducing these forces on wound margins have been shown to be beneficial to the healing of the wound through migration of healthy epithelial layers from the edges to the

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Figure 6: Zero G Brace with Offloading Insole Removed



Figure 7: Patellar Tendon Bearing PTB AFO with Rocker Soled Depth Shoe



Figure 8: Torch Limb Load Custom Molded Boot

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center of the wound³³

It is indeed true that the presence of focal points of increased pressure are a significant risk for tissue breakdown and formation of neuropathic ulcerations.^{21,22} Additionally, it has been demonstrated that by reducing the forces on these focal points of increased pressure, as well as reducing shear forces on the edges of wounds, clinicians can reduce the incidence of ulcerations and can heal ulcers that are already present.³⁸ The question to be asked then is, “Is the immobilization and shear reduction of the cast the essential off-loading component of the TCC?”

Pressure Mapping Techniques

With the advent of new pressure mapping techniques, it has been demonstrated that the leg or “shank” portion of a tight fitting TCC is the single most important component of the cast when it comes to off-loading

leg that is “suspended” in the rigid conical cast, transferring up to 40% of its force to the rigid external walls, thereby “hanging” the leg in the air.

The cast conforms closely to the calf and provides total contact circumferential “wall pressure” against the leg, preventing its plantar-ward excursion. We refer to this as the “limb-load concept”, a principle utilized by several removable ankle foot orthoses that attempt to suspend the foot off the ground with either Velcro straps or custom molded intimate contact leg sections with or without a patellar tendon bearing feature (Figures 6,7). There is also a “limb load” custom molded boot that has attempted to use this principle to increase the effectiveness of the off-loading of the device (Figure 8).

The essential nature of loading the limb to off-load the foot was illustrated in a study performed by Leibner, et al., where they compared the reduction in plantar pressures between a traditional TCC and a

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the plantar foot.^{9,39,40} In a study by Shaw, et al., the authors demonstrated that the majority of the weight borne by a TCC could be attributed to the tight fitting, conically shaped leg section that accepted upwards of 30 + % of the weight applied to the limb, thereby preventing weight transfer to the foot.⁹

Subsequent studies using a thin pressure mapping device applied directly to the leg confirmed that off-loading is indeed due to the “conical” shape of the leg, with the cast wall receiving 36-41% of the weight transfer.^{39,40} This hypothesis states that the support occurs as the wider proximal portion of the leg tries to slip down into the narrower distal portion of the cast which is attached to a rigid foot and ankle section. Ground reactive forces are applied to the cast. Weight stress from the patient enters the cast through the

TCC that had the conical leg portion removed, effectively making it a well-conforming foot cast.⁴⁰ By measuring the peak plantar pressures during both stance and walking phases, they demonstrated a greater reduction in plantar pressures from the baseline while wearing the traditional TCC. This also helps to explain why repeated studies show that a well-constructed TCC has consistently been demonstrated to be more effective than a shoe-type off-loading device.

The BOOT™ study

In an attempt to apply this to a TCC and quantify the design’s ability to offload the foot, we conducted the BOOT™ study (Body mass and Obesity Off-loading Trials) at the Temple University School of Podiatric Medicine. Meyr, Pirrozzini, and

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McGuire compared two different TCC designs to evaluate their efficacy with increasing body mass. The primary outcome measure was mean peak plantar pressure in the heel, midfoot, forefoot, and first metatarsal, and the two variables were modification of patient weight (from “normal” BMI to “overweight”, “obese” and “morbidly obese”) and the two TCC constructs.

A “standard” TCC as described above was compared to an alternate TCC that was designed to utilize the essential off-loading component of the “total contact leg section”. In order to achieve this, we used a rigid fiberglass leg section to support the limb and applied it over a urethane roll-foam padding to eliminate the slippage commonly seen with polyester or cotton padding (Figure 9). A well-padded foot and ankle section, that can be either open or closed toe, is then applied using a total contact footbed consisting of open cell polyurethane foam and polyester cast padding (Figure 10). The foot was essentially “suspended” within a fiberglass walking cast relying completely on the total contact leg section for off-loading (Figure 11).

As we postulated, we were unable to observe statistically significant differences between the two TCC designs with regard to mean peak plantar pressures in any plantar foot anatomic area with any weight class.⁴¹



Figure 9: Fiberglass Cast Tape over Urethane Roll Foam

Previously, it had been described that TCCs do provide off-loading to the rearfoot, but to a lesser degree than the forefoot, making them less effective for heel ulcerations, and ne-

finding to those previously discussed, in that by increasing the off-loading properties of the proximal shank portion of the cast, the plantar pressures under the rearfoot ulcerations were

The essential components needed for maximum off-loading of any device are inability to remove the device, a total contact foot bed (padded or rigid), and a limb-load upper cast.

cessitating the need for further modifications.⁴² Tamir, et al. looked at the healing rates in rearfoot ulcerations, comparing the efficacy of a traditional TCC vs. a cast that had been modified to provide more transfer of weight to the leg using lateral “stirrups” for greater off-loading.²⁶ Their results demonstrated a similar

minimized to almost zero and healing rates increased significantly.

Extending the off-loading more proximally by using a patellar tendon-bearing (PTB) design might be expected to provide additional off-loading. According to Tanaka, however, the use of a PTB cast does not seem to provide greater off-loading than a similarly constructed total contact cast.⁴³ This study demonstrated that the foot is best offloaded by the “limb load” of a TCC, and not by the “hanging” type off-loading that a more proximal patellar tendon cast provides.

The combined results of these studies demonstrate that the “essential” off-loading component of a TCC in terms of reduction of plantar pressures involves a closely molded total contact leg section that effectively “suspends” the foot, which does not have to be rigidly immobilized to achieve plantar foot off-loading. In regard to forefoot ulcerations, the greatest reduction in plantar pressures would occur if the leg section was able to completely remove all weight from the foot. This is impossible given the inability



Figure 10: Applying the Padded Foot Section



Figure 11: Completing the Limb Load TCC

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to ever achieve total patient compliance, the anatomical variability of the leg, and the ever-present fluctuating edema in the injured limb.

By modifying the TCC to allow for a highly padded, well protected, but still total contact foot bed within a rigid cast, the device can reduce shearing within the cast and provide the necessary off-loading to reduce plantar pressures under pressure-sensitive areas to the point where wounds will heal. Given the success of other non-removable methods that rely essentially on forced compliance and a total contact footbed³² with no off-loading by way of the limb-load concept such as the “iTCC”,⁴⁴ the “Rader football dressing”,⁴⁵ and the “Felted Foam” off-loading technique,⁴⁶ one might postulate that the essential components needed for maximum off-loading of any device are inability to remove the device, a total contact foot bed (padded or rigid), and a limb-load upper cast (Figures 12-14). **PM**

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Figure 13: The Rader Football Dressing with Toes Exposed



Figure 12: The iTCC using a Cable Tie to Prevent Removal of the Walker

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Figure 14: The Felted Foam Dressing

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Dr. McGuire is Chairperson at the Temple University School of Podiatric Medicine, Department of Podiatric Medicine and Orthopedics; Director, Leonard S. Abrams Center for Advanced Wound Healing, and

has been a member of the faculty since 1992. He has extensive experience in wound management and biomechanics of the foot and ankle. Dr. McGuire is a founding fellow of the American Professional Wound Care Association, and a member of the planning committee for the annual Advances in Skin and Wound Care meeting.



Timothy Greene is a third-year student at the Temple University School of Podiatric Medicine.