Ease of Application and Removal of Common Total-Contact Cast Systems Used in the Podiatric Medical Community

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Background: Although total-contact cast (TCC) systems are considered the gold standard for off-loading plantar ulcers, less than 6% of patients with diabetic foot ulcers receive them due to negative perceptions of special technique requirements and time investment in their application and removal. We compared the ease of use and casting time of four TCC systems.

Methods: Four novice casters applied each of the four TCC systems three times using the manufacturer's written instructions for cast application and removal of each cast type. For each TCC system, casters also provided ratings of quality and effectiveness, their level of confidence in applying each system, and overall ease of use.

Results: The time to complete the first application of each cast type was not different among TCC systems. However, by the third application, TCC-EZ had a significantly faster application time than the other three TCC systems. In addition, TCC-EZ was considered better overall in packaging and instructions, quality of cast components, and casting method than the other TCC systems. Half of the casters rated TCC-EZ and MedE-Kast as the easiest to apply after the third and final trial, and TCC-EZ and MedE-Kast were rated as being the cast chosen to use in the casters' clinical practices.

Conclusions: One of the obstacles to use of TCC systems, despite being recognized as the gold standard of off-loading, is the perception of a prolonged learning curve on application. This study demonstrated that TCC-EZ can be applied by novice casters in less than 14 minutes after their third application experience. (J Am Podiatr Med Assoc 109(6): 445-450, 2019)

Diabetes is the seventh leading cause of death in the United States, with 69,071 death certificates listing diabetes as the underlying cause of death.[1] The total estimated costs of diagnosed diabetes have increased 41%, from $174 billion in 2007 to $245 billion in 2012. Diabetic foot ulcers occur in approximately 15% of patients with diabetes, and of those who develop a foot ulcer, 6% will be hospitalized due to infection or other ulcer-related complications.[2] Ulcers form due to a combination of factors, including diabetic neuropathy, poor circulation, and structural changes as well as friction and repetitive trauma.[3]

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During weightbearing activities, feet are exposed to significant forces, particularly during dynamic activities such as walking. The pressure under the plantar surface during walking varies depending on the area of the foot due to the normal rollover motion of the foot. Pressure modulation, commonly referred to as off-loading, is used to mitigate pressure at an area of high vertical and shear stress on the diabetic foot.[4] Common methods to off-load the foot include bedrest, wheelchair, crutch-assisted walking, total-contact casts (TCCs), half shoes, therapeutic shoes, and removable cast walkers.[5] Removable walkers and TCC systems have been found to be very effective in reducing plantar pressure in midfoot and forefoot regions[5] and significantly superior to half shoes or therapeutic shoes.[6,7]

Total-contact cast systems are considered the gold standard for off-loading forefoot ulcers.[6,8,9] They help redistribute weight from the plantar surface of the foot to reduce pressure from a

particular area. Also, TCC systems are considered cost-effective treatment. The average cost of treatment per patient is $11,946 compared with $22,494 when TCC is not used.[10] Fife et al,[11] using real-world data from a large wound care registry, found that only 6% of patients with diabetic foot ulcer received TCCs. Furthermore, in a 5-year retrospective analysis of more than 25,000 patients with diabetes, they found that only 3.7% of eligible ulcers received TCCs[11] and that the most frequently used method, the postoperative shoe, was the least effective. Underuse of the TCC represents lost opportunities for healing wounds, improving patients' quality of life, and maximizing the efficiency of health-care systems.

There is much resistance to the use of TCCs. Some of the many reasons why TCC systems are not used include time-consuming to apply, lack of skill or confidence in the application of TCCs, and lack of availability of a specialist/cast technician with adequate training or experience to safely apply a TCC.[12] The purpose of this study was to compare the ease of use and casting time, as applied by inexperienced professionals, of four different TCC systems: TCC-EZ (Integra LifeSciences Corp, Plainsboro, New Jersey), MedE-Kast (Integra), BSN Cutimed Off-Loader (BSN Medical Inc, Charlotte, North Carolina), and a standardized homemade casting system (a traditional TCC with a plaster first layer and a fiberglass second layer, followed by posterior splints and a final fiberglass layer).

Materials and Methods

Four casting-naive, first-year podiatric physicians were chosen to serve as casters. They were chosen because they had knowledge of foot and lower-leg anatomy and off-loading principles but had limited knowledge of TCC application or removal. Casts were applied to volunteers who consented to have three TCC applications and met the following criteria: adults weighing less than 250 lb, intact sensation of the foot, a palpable pedal pulse, no wounds or fractures on the casted leg, no sensitivity to casting materials, and able to lie prone or sit still for 30 minutes at a time. A casting specialist was present during all TCC applications to observe the applications and ensure the safety of both caster and volunteer cast recipient. In addition, all casters attended a 2-hour training of safe cast-saw techniques during the week before the start of the study. Casters were cleared to begin the study only when both the caster and the training instructor indicated readiness for safe cast removal. The casters and the volunteers gave informed consent, and the Barry University institutional review board approved the study protocol.

Measured casting time included the preparation and application of each TCC system through the fitting and application of a boot or shoe, when applicable. Cast application and removal was timed using a standard stopwatch. Casters applied and removed TCCs as per the written instructions provided by the manufacturer of each cast type. For the homemade cast, the researchers created step-by-step application and removal instructions. Casters were prohibited from viewing application and removal videos available for the various TCCs. Investigators assigned, at random, three volunteers to work with each caster. Casters consecutively applied and removed each cast three times to the lower legs of the volunteers. The casters first applied all three casts, then, after casts were dry, removed all three. To prevent bias, the brand of each cast was blinded and the order of the casts given to each caster was randomized. Timekeepers recorded the time taken to apply and remove each cast. Application and removal were carefully monitored by casting specialists.

Casters were surveyed after their first and last application and removal of each cast type. Casting quality and effectiveness was assessed using several surveys to evaluate the quality and effectiveness of the packaging and instructions, cast components, and casting method. Caster ratings of their level of confidence applying each TCC system were also collected. This rating included the confidence in their ability to begin the application process, ability to apply the TCCs, and that their application was error free. Finally, casters were asked to rate the overall ease of use after they finished all of the trials of all of the casts. Casters were asked to reply to seven questions to assess overall ease of use. They were asked to indicate which cast was the easiest to apply and remove correctly the first time and the final time. They were also asked to indicate which cast left the least room for application and removal error. Finally, they were asked to indicate which cast they would choose to use in their clinical practice taking into account ease of use, efficacy, patient comfort, and patient welfare.

A 2-way analysis of variance (ANOVA) (cast type $\times$ trial) was used to compare casting times. Kruskal-Wallis ANOVAs were used to compare casters' ratings of the quality and effectiveness of the packaging and instructions, cast components, and casting method for each cast and to compare rankings of caster ratings of their confidence level

in applying each cast. Finally, a qualitative description of the casters' rankings of overall ease of use was completed.

Results

The purpose of this study was to compare the ease of use and casting time of four different TCC systems as applied by inexperienced professionals. Casting times for each cast type across the 3 trials are found in Table 1. A 2-way ANOVA (cast type × trial) was run to compare the total casting times, and there was a significant interaction between cast and trial ($F_{6,11} = 2.44$; $P = .44$). Follow-up tests revealed that although the homemade cast had the shortest cast application time in trial 1, the TCC-EZ cast was the fastest in trials 2 and 3 (Fig. 1).

Caster assessment of the packaging and instructions, cast components, casting method, and overall ranking were determined using a 4-point Likert scale with a maximum score of 12 (1 = not at all effective, 2 = somewhat effective, 3 = effective, and 4 = very effective). Assessments of packaging and instructions were analyzed with a Kruskal-Wallis comparison. No significant differences were found among TCC systems in the packaging and instructions ($\chi^2_3 = 0.991$; $P > .05$). However, the TCC-EZ cast was ranked the highest (Table 2).

Caster rankings of the quality and effectiveness in the casting components were compared using a Kruskal-Wallis test. There were no significant differences in rankings between casts ($\chi^2_3 = 0.375$; $P > .05$). However, the TCC-EZ and the MedE-Kast were ranked the highest for the quality and effectiveness of casting components (Table 2). Caster rankings of the preferred TCC system were compared with a Kruskal-Wallis test. There were no significant differences in rankings between casts ($\chi^2_3 = 0.499$; $P > .05$). However, once again, the TCC-EZ was ranked the highest for cast application (Table 2). Caster rankings of the overall quality and effectiveness for each cast were compared using a Kruskal-Wallis test. There were no significant differences in rankings between casts ($\chi^2_3 = 1.43$; $P > .05$). However, once again, the TCC-EZ was ranked the highest for cast application (Table 2).

A Kruskal-Wallis ANOVA was run to compare the ranking of caster ratings of their confidence level in applying each cast type. There were no significant

Table 1. Total Casting Times by Trial

TCC System	Trial 1	Trial 2	Trial 3
TCC-EZ	39.5 ± 7.4	19.5 ± 3.1	13.8 ± 3.2[a]
MedE-Kast	42.5 ± 10.9	24.8 ± 4.2	25.5 ± 5.0[b]
BSN Cutimed Offloader	35.8 ± 9.0	23.5 ± 6.8	18.8 ± 3.9[c]
Homemade	25.8 ± 10.1	24.3 ± 4.6	22.0 ± 4.7[b]

Note: Data are given as mean ± SD minutes (n = 4 per TCC system and trial).

Abbreviation: TCC, total-contact cast.

[a]Statistically significantly different, $P = .000$, one-way analysis of variance (2 *df*), compared with trial 1 and significantly different, $P = .013$, one-way analysis of variance (3 *df*), compared with all other TCCs.

[b]MedE-Kast ($P = .74$) and homemade ($P = .27$) were not different across the three trials.

[c]Statistically significantly different, $P = .018$, one-way analysis of variance (2 *df*), compared with trial 1.

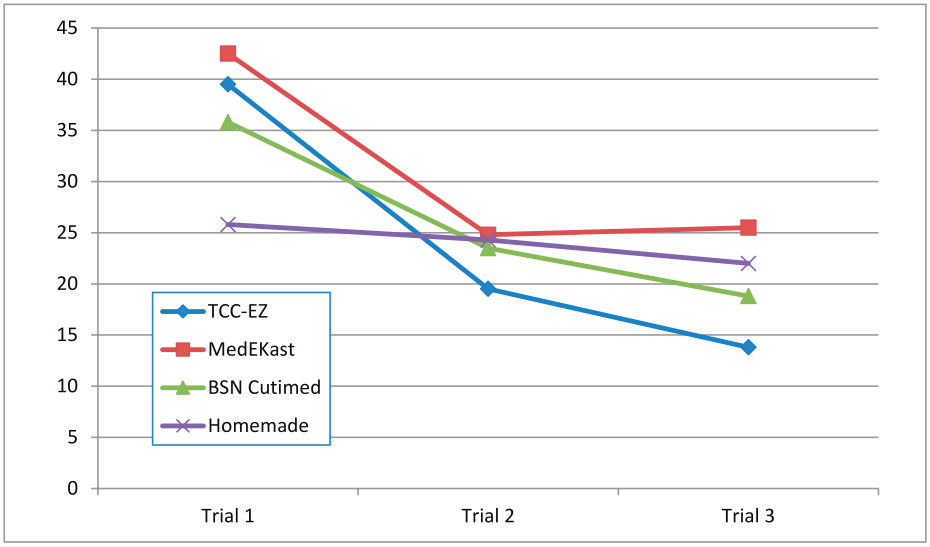


Figure 1. Total casting times by trial.

Table 2. Mean Total Rankings of the Quality and Effectiveness of TCCs

TCC System	Packaging and Instructions	Cast Components	Cast Method	Overall
TCC-EZ	10	10.36	9.8	10.8
MedE-Kast	8.3	10.3	8.1	8.4
BSN Cutimed Offloader	8.8	6.8	7.8	7.8
Homemade	7.0	6.8	8.1	7.1

Note: Casters rated these areas on a 4-point Likert scale (1 = not at all effective, 2 = somewhat effective, 3 = effective, and 4 = very effective). Maximum score was 12.

Abbreviation: TCC, total-contact cast.

differences in the caster ratings of confidence ($\chi^2_3 = 3.35$; $P > .05$) (Fig 2).

Casters were asked seven questions to rate overall ease of use (Table 3). They were asked to indicate which cast was the easiest to apply and remove correctly the first time and the final time. They were also asked which cast left the least room for error during application and removal. Finally, they were asked which cast they would choose to use in clinical practice taking into account ease of use, efficacy, patient comfort, and patient welfare. Two casters rated the TCC-EZ and the MedE-Kast as the easiest to apply after the third and final trial. The TCC-EZ was rated as the TCC with the least room for application error by three of the four casters. Again, the TCC-EZ and the MedE-Kast were rated as being the casts chosen to use in the casters' clinical practice.

Anecdotally, the casting specialists remarked that the novice casters had difficulty securing the footplate and walking heel in both the homemade and MedE-Kast applications. Casters would often cover the entire walking heel, including the treads, which resulted in an unsatisfactory and unsafe cast application. Most casters corrected this application error by the third application.

Discussion

Results of the casting time analysis indicated that the TCC-EZ cast was the quickest for the novice casters to apply in the second and third trials. This supports the findings of Bohn[13] and Jensen et al,[14] who studied experienced casters. In the present study of novice casters, the TCC-EZ cast was applied in an average of 13.8 minutes at the third application. This time is very similar to the 10 minutes reported by Bohn for experienced casters. The TCC-EZ cast also had the fastest decline in time from trial 1 to trial 2, indicating the quickest

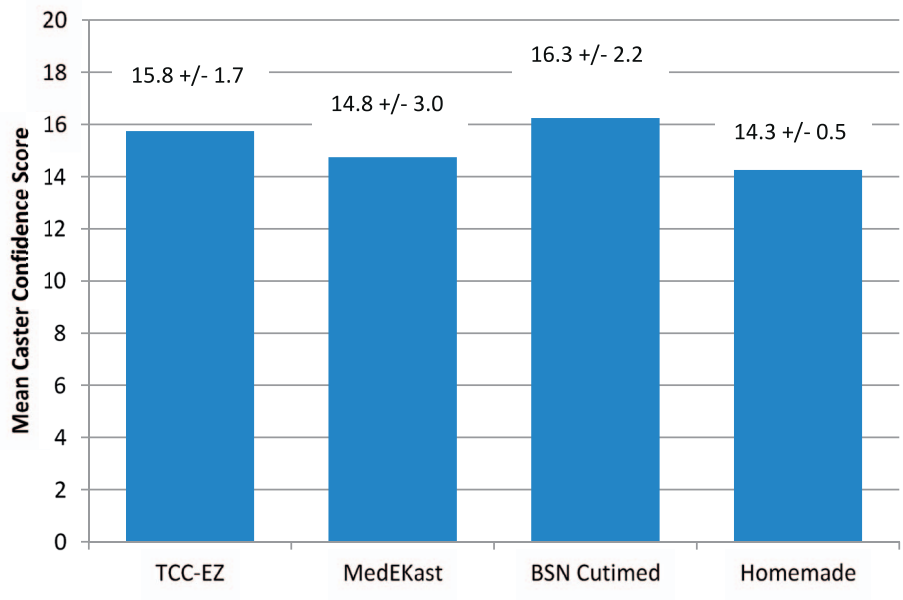


Figure 2. Total caster confidence ratings. Note that confidence ratings could range from 5 to 20. TCC, total-contact cast.

Table 3. Assessment of Overall Ease of Use

Caster No.	Q1: Easiest to Apply Correctly the First Time	Q2: Easiest to Apply Correctly the Third Time	Q3: Easiest to Remove Correctly the First Time	Q4: Easiest to Remove Correctly the Third Time	Q5: Least Room for Application Error	Q6: Least Room for Removal Error	Q7: Use in Clinical Practice
1	B	A	A	C	A	D	B
2	D	A	C	C	D	C	A
3	A	B	A	A	A	A	A
4	B	B	C	B	A	C	B

Note: A = TCC-EZ, B = MedE-Kast, C = BSN Cutimed, and D = homemade cast.

learning curve. The homemade cast was the quickest to apply on the first trial. One reason for this could be the specific nature of the instructions for the homemade cast. Because this type of cast does not come with instructions, the researchers wrote the instructions. It is possible that these instructions were somewhat clearer for a novice to follow. Also, casters were not allowed to view videos of the casting techniques (as recommended by the TCC-EZ system) to control the level of instruction given for each cast. These factors could have combined to contribute to why the homemade cast was the quickest in the first trial. However, once the casters became familiar with the other casting techniques after the first trial, the TCC-EZ and the BSN Cutimed casts outperformed the homemade cast. For novice casters, after only three casting trials, the TCC-EZ cast had the fastest total casting time compared with the BSN Cutimed, homemade, and Medi-Kast TCC systems.

In the analysis of caster ratings of quality of casting instructions, materials, and casting method between the TCC systems, although not significantly different, the TCC-EZ was rated the highest compared with all of the other casts. It is possible that a larger study with more casters could have resulted in statistical significance. Clinically, however, the trend is toward the novice casters rating the TCC-EZ cast as the highest in quality.

In the comparison of ease of use, qualitative data indicated that the TCC-EZ and the MedE-Kast were rated as the easiest to apply after the third trial and the preferred casting method for clinical practice. The TCC-EZ and the BSN Cutimed casts were chosen as the easiest to remove at the first trial, but the BSN Cutimed was chosen by two of the four casters as the easiest after the third trial. The homemade cast was selected by only one caster as the easiest to apply the first time and least room for error in removal. These results are consistent with those of Jensen et al.[14] Although not the fastest to apply in the first trial, the TCC-EZ was the fastest for the novice casters to apply by the third trial ($P <$ .013). It was also the top-rated cast for ease of application and quality of instructions, materials, and casting method.

Conclusions

In this study of novice casters applying four different TCC systems, the time to apply the first cast was no different among TCC systems, but the TCC-EZ had a significantly faster application time than the other three TCC systems by the third application. In addition, the TCC-EZ was considered better overall in packaging and instructions, quality of cast components, and casting method than the other TCC systems. One of the obstacles to use of TCC systems, despite being recognized as the gold standard for off-loading, is the perception of a prolonged learning curve on application. This study demonstrated that the TCC-EZ can be applied by novice casters in less than 14 minutes after their third application experience.

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Conflict of Interest: Dr. Jensen is the inventor of the TCC-EZ cast and worked as a consultant to Derma Sciences.

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