A simple technique to prolong molding time during application of a fiberglass cast: An *in vitro* study

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Abstract

Casting is routinely used for acute and post-operative immobilization and remains a cornerstone in the non-operative management of fractures and deformities. The application of a properly fitted and well-molded cast, especially for a trainee, can be challenging. We present a simple method of prolonging cure time of fiberglass cast — placing ice in the dip water. Eight-ply, five-inch fiberglass cast was circumferentially applied to an aluminum-wrapped cardboard cylinder. An electronic, 2-channel temperature sensor (TR-71wf Temp Logger, T&D Corporation, Matsumoto, Japan), accurate to 0.1ºC and accurate to ±0.3ºC, was placed between the fourth and fifth layers of fiberglass. Thirty total casts were tested using 9±1ºC (cold), 22±1ºC (ambient), and 36±1ºC (warm) dip water. Room temperature was maintained at 24±1ºC. Cast temperatures were measured during the exothermic reaction generated by the cast curing. Peak temperatures and cure times were recorded. Cure time was defined as the point of downward deflection on the time-temperature curve immediately after peak. Cure and peak temperatures were compared among groups using analysis of variance. Mean cure time was 3.5±0.1 minutes for warm water, 5.0±0.4 minutes for ambient water and 7.0±0.5 minutes for cold water. Peak temperature, measured between layers 4 and 5 of the cast material, was 36.6±0.8ºC for warm water, 31.1±1.4ºC for ambient water and 25.2±0.5ºC for cold water. Cold afforded, on average, an additional 2 minutes (40% increase) in cure time compared to ambient water and an additional 3.5 minutes (100% increase) compared to warm water. Cure time differences were significant (P<0.001) for all groups, as were peak temperature differences (P<0.001). Temperatures concerning for development of burns were never reached. Utilizing iced dip water when casting is a simple and effective method to prolong the time available for cast application. Orthopedic residents and trainees may find this useful in learning to fabricate a high quality cast. For the experienced orthopedic surgeon, this method eliminates the need to bridge long-limb casts and facilitates the application of complex casts.

Introduction

Over the decades, orthopedic practices have evolved from casting as the mainstay of treatment for many fractures. Despite this, casting remains a mainstay in the correction of deformity, non-operative fracture management, postoperative immobilization and temporization of acute fractures until the time of surgery. The application of a cast, especially for an inexperienced operator, can be a challenging task. Even for the seasoned orthopedic surgeon, a complex cast requiring multiple molds can present difficulty. In the setting of an acute fracture, a properly fitted, well-molded and often long-limb cast is of critical importance. In this scenario, it is common for a short distal cast to be applied and later bridged to a long-arm or long-leg cast. This method of staging is done in order to allow adequate time to mold the cast before it cures; however, the transition area results in a potential point of weakness at which the cast may fail. We present a simple method of prolonging cure time of fiberglass cast – placing ice in the dip water to significantly lower its temperature during placement of the cast. We demonstrate the magnitude of difference in cure time of a fiberglass cast when utilizing iced, room temperature or warm dip water options. The authors of this manuscript have no potential conflicts of interest to report.

Materials and Methods

A hollow cardboard cylinder open to air on both sides was wrapped in aluminum foil and secured to a laboratory bench. Eight-ply, five-inch synthetic fiberglass cast (Delta-Lite Plus, BSN Medical, Luxembourg) was circumferentially applied to this cylinder with an electronic, 2-channel temperature sensor (TR-71wf Temp Logger, T&D Corporation, Matsumoto, Japan), accurate to 0.1ºC and accurate to ±0.3ºC, was sandwiched between the fourth and fifth layers of cast material (Figure 1). Of note, the cast manufacturer does not have a recommendation as to the number of layers of cast to use during application. A standard mercury thermometer was also sandwiched between the fourth and fifth cast layers opposite to the side with the electronic sensor to ensure consistent and accurate measurements. A total of thirty casts were applied, with the aluminum foil changed between each application. Ten casts were tested under three groups: dip water temperature maintained at 9±1ºC (cold group), dip water temperature of 22±1ºC (ambient group), and dip water temperature 36±1ºC (warm group). Room temperature was maintained at 24±1ºC throughout testing. It should be noted that the cast manufacturer recommends a maximum temperature of dip water to be 25ºC. Cold water for testing was obtained by placing two cups of ice into a standard half-filled 7-quart basin of water. Ambient and warm water was obtained from the tap. Water temperature was continuously measured throughout testing with an electronic sensor with temperature readings every 1 second. Each cast roll was submerged in water for 10 seconds prior to application of the cast. Cast temperatures were measured electronically at 1-second intervals during the exothermic reaction generated by the cast curing. Peak temperatures, measured between layers 4 and 5 of the cast material, and times to cure were recorded. In order to standardize measurement, time to cure was defined as the exact point of downward deflection of the time-temperature curve immediately after the peak. Differences among the three groups with respect to time to cure as well as peak temperatures were compared using analysis of variance (ANOVA). Gaussian distribution of the data

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Key words: casting; technique; cast; exothermic; prolonging; cure; time.

Contributions: the authors contributed equally.

Conflict of interest: the authors declare no potential conflict of interest.

Funding: none.

Received for publication: 15 July 2017.
Revision received: 18 December 2017.
Accepted for publication: 24 December 2017.

Orthopedic Reviews 2018;10:7314
doi:10.4081/or.2018.7314

was evaluated using the Kolmogorov and Smirnov Test.

Results

Table 1 summarizes the results of the study. Mean time to cure for the warm water group was 3.5±0.1 minutes, with a peak temperature of 36.6±0.8ºC. Mean time to cure for the ambient water group was 5.0±0.4 minutes, with a peak temperature of 31.1±1.4ºC. Mean time to cure for the cold water group was 7.0±0.5 minutes, with a peak temperature of 25.2±0.5ºC. The cold water group afforded, on average, an additional 2 minutes or 40% increase in curing time compared with the room temperature group and an additional 3.5 minutes or 100% increase in curing time compared with the warm water group. The differences in time required to cure were significant ($P<0.001$) for all groups. While peak temperature differences were also significant ($P<0.001$) for all groups, no single test ever reached a temperature concerning for development of cutaneous burns. Each group followed a Gaussian distribution.

Discussion

In this study, we demonstrate that cast cure time is significantly prolonged by placing ice in the dip water to lower its temperature to 9±1ºC. In order to standardize measurements, we considered a cast cured immediately after the temperature peak, at the point of downward deflection of the time-temperature curve. The manufacturer reports a working time of 0-3 minutes, a set time of 3-5 minutes and the allowance of weight bearing at 20 minutes. Thus, while these times vary with environmental factors, they suggest that even after the peak temperature, the process continues to further strengthen the cast. Despite this, it was noted that at our defined cure point, the cast was palpably hard and would be impossible to mold further. For our cold water group, we maintained a temperature of 9±1ºC. An ice bath will maintain a temperature closer to 4ºC once fully equilibrated. However, in the setting of clinical practice, it is unnecessary to wait for this equilibration. Two cups of ice placed in a standard half-filled wash basin of room temperature water will suffice for the purposes of extending working time with the cast.

Casting material cures with an exothermic reaction and has been known to rarely result in cutaneous thermal injury.[1-4] In order to better understand the cause of these burns, prior studies have investigated the time-temperature profile of setting casts and evaluated the environmental variables affecting this relationship.[2-8] Increasing dip water temperature and cast thickness, as well as the use of extra fast setting material has been shown to increase risk of burns. Allowing casted extremities to dry on a pillow, overwrapping plaster casts immediately with synthetic cast and even the pressure molds on the cast have also been demonstrate to correlate with increased peak and duration of cure temperatures.[5] In these studies, dip water temperature was of the most significant factors affecting risk of burn. In the setting of application of a simple minimally molded cast, such as postoperatively, it is often tempting to use warmer dip water in order to speed the process. Cast manufacturers as well as several authors caution against this and recommend that water temperature under 24ºC or, *slightly cool to touch* be used to minimize the risk of thermal injury.[4,8,9] Furthermore, under normal conditions, synthetic casts have been demonstrated to have a relatively low risk of thermal injury.[2,10]

Williamson and Scholtz studied the relationship between the temperature of a thermal insult and the time of exposure necessary to result in burns in normal volar forearms.[11] Despite some individual differences in susceptibility to burns, they found a predictable, inverse relationship between temperature and the duration of thermal insult resulting in burns. The lowest temperature they tested that resulted in cutaneous

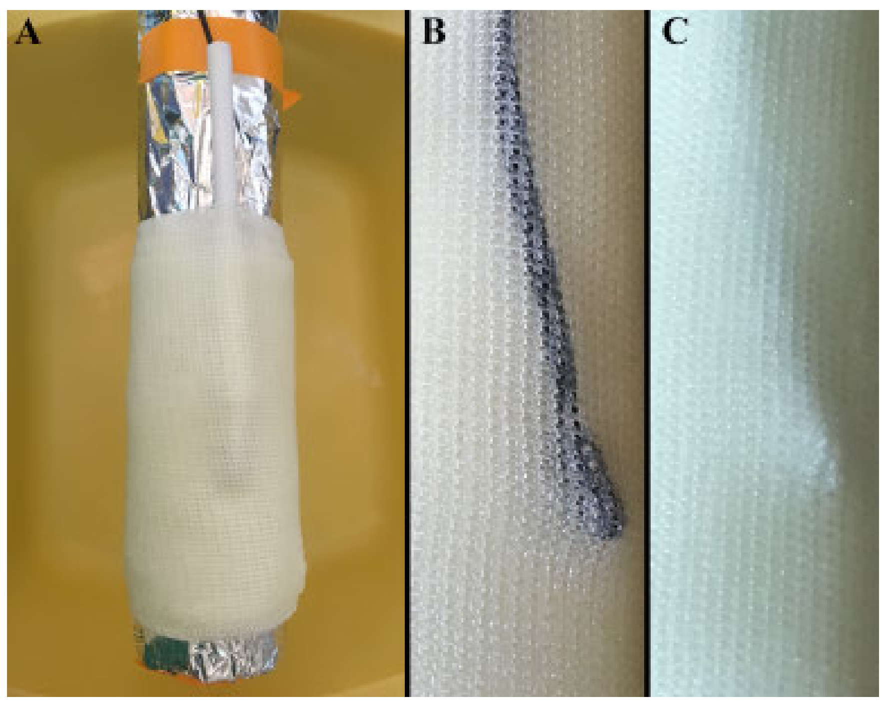

Figure 1. A) the aluminum-wrapped cardboard cylinder is pictured, around which 5 inch fiberglass casting was wrapped and centered over the temperature sensor (A). B) the temperature sensor is pictured, with one layer of fiberglass cast overlaying the sensor. C) four layers of fiberglass cast completely cover the temperature sensor.

Table 1. Study results.

Water	Mean cure time (min) ± SD	Peak temperature (ºC) ± SD	P-value	Sample Size, N.
Cold	7.0 ± 0.5	25.2 ± 0.5	P<0.005	10
Ambient	5.1 ± 0.4	31.1 ± 1.4	P<0.005	10
Warm	3.5 ± 0.1	36.6 ± 0.8	P<0.005	10

manifestations of injury was 47.8ºC, which resulted in an erythematous macule at 20 minutes of exposure. The lowest temperature that caused a blistering reaction was 50ºC at 12 minutes of exposure. Hutchinson and Hutchinson discussed the potential for injured extremities to have a lower threshold of time and temperature necessary to sustain burns.[7] Since most casts are applied post-operatively or to extremities with soft tissue injury or fracture, they defined a threshold of 40ºC as at risk for thermal insult.

The use of ice water for dipping likely makes the risk of burns nearly negligible. Given existing data on factors affecting risk of thermal injury, our study primarily investigated how dip water temperature affects cure time. This was not a focus of previous studies, and none have recorded time to cure with the use of iced water. Some of the reports evaluating the risk of cast burns utilized a heated carbon element or a glass tube filled with circulating water to more accurately represent the temperature of a human extremity.[3,4] In contrast to these studies, we did not attempt to measure simulated skin surface temperature, but rather the temperature within the setting fiberglass itself. For this measurement, we placed our temperature sensors within the cast rather than securing them at the surface of the simulated limb. Thus, we were able to use a simplified limb model consisting of a cardboard cylinder most similar to the PVC pipe model used by Hutchinson and Hutchinson.[7] It should be noted that the temperatures we report are not intended to be interpreted as potential skin surface temperatures and were used principally to assess cure time.

While extra fast setting cast material is available in order to expedite the placement of a simple cast, such as is often the case post-operatively, there are minimal options available to slow down the curing process. To our knowledge, there has only been one paper demonstrating a technique for prolonging cast set time.[12] In that report, the authors described applying the fiberglass cast without dipping it in water. Between each layer of fiberglass, they applied water-based lubricant to the cast, which they report initiates the curing process more slowly. The authors of that study did not, however, demonstrate any data regarding the increase in time afforded with this method. Furthermore, it is unknown if the use of a lubricant negatively alters the integrity of the cast, since manufacturers recommend the use of water. Finally, the lubricant technique adds time as well as cost to the process.

Conclusions

Casting is routinely used for acute and post-operative immobilization and remains a cornerstone in the non-operative management of fractures as well as limb and spine deformities. Utilizing iced water to dip fiberglass cast is a simple and effective method to significantly prolong the time available to apply and mold a well-fitting cast. The technique allows for the standard method of cast application, with the only difference being the requirement of ice in the dip water. Orthopedic residents and technicians early in training may find this useful in learning to fabricate a high quality cast. For the experienced orthopedic surgeon, this method eliminates the need to bridge long-limb casts and facilitates the application of a complex cast requiring multiple molds.

References

1. Read JA, Ferguson N, Ricketts DM. Plaster cast burns: the reality. Emerg Med J 2008;25:827-8.
2. DeMaio M, McHale K, Lenhart M, et al. Plaster: our orthopaedic heritage: AAOS exhibit selection. J Bone Joint Surg Am 2012;94:e152.
3. Halanski MA, Halanski AD, Oza A, et al. Thermal injury with contemporary cast-application techniques and methods to circumvent morbidity. J Bone Joint Surg Am 2007;89:2369-77.
4. Burghardt RD, Anderson JG, Reed RA, Herzenberg JE. Exothermic properties of plaster-synthetic composite casts. J Child Orthop 2014;8:193-201.
5. Lindeque BGP, Shuler FD, Bates CM. Skin temperatures generated following plaster splint application. Orthopedics 2013;36:364-7.
6. Deignan BJ, Iaquinto JM, Eskildsen SM, et al. Effect of pressure applied during casting on temperatures beneath casts. J Pediatr Orthop 2011;31:791-7.
7. Hutchinson MJ, Hutchinson MR. Factors contributing to the temperature beneath plaster or fiberglass cast material. J Orthop Surg Res 2008;3:10.
8. Ahmed SS, Carmichael KD. Plaster and synthetic cast temperatures in a clinical setting: an in vivo study. Orthopedics 2011;34:99.
9. Lavalette R, Pope MH, Dickstein H. Setting temperatures of plaster casts. The influence of technical variables. J Bone Joint Surg Am 1982;64:907-11.
10. Pope MH, Callahan G, Lavalette R. Setting temperatures of synthetic casts. J Bone Joint Surg Am 1985;67:262-4.
11. Williamson C, Scholtz JR. Time-temperature relationships in thermal blister formation. J Invest Dermatol 1949; 12:41-7.
12. Smith GD, Hart RG, Tsai T-M. Fiberglass cast application. Am J Emerg Med 2005;23:347-50.