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Cast-Saw Burns: Evaluation of Skin, Cast, and Blade Temperatures Generated During Cast Removal

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Background: The use of an oscillating saw for cast removal creates a potential for iatrogenic injury and patient discomfort. Burns and abrasions can occur from the heat created by frictional forces and direct blade contact. With use of a cadaver model system, skin temperature measurements were recorded during cast removal with an oscillating saw.

Methods: Casts of uniform thickness were applied to cadavers equilibrated to body temperature. The casts were removed by a single individual while simultaneously measuring temperatures at the skin-padding interface, cast-padding interface, and the blade. Variables tested include two removal techniques, two casting materials (fiberglass and plaster), and two cast-padding thicknesses.

Results: A poor removal technique (the cast saw blade never leaving the cast material during cutting), fiberglass casting material, and thinner cast padding resulted in significantly higher skin temperatures. The poor technique increased skin temperatures by an average of 5.0°C ($p < 0.05$). Fiberglass casting materials increased skin temperatures by an average of 7.4°C ($p < 0.05$). Four layers of cast padding compared with two layers decreased skin temperatures by 8.0°C ($p < 0.05$).

Conclusions: The highest skin temperatures were recorded for fiberglass casts with two layers of padding. The lowest skin temperatures were recorded for plaster casts with four layers of padding. Four layers of cast padding compared with two layers significantly reduced skin temperatures for both plaster and fiberglass casts.

Clinical Relevance: A routine assessment of the layers of padding and the type of cast material prior to splitting casts with an oscillating saw can help clinicians to identify cast removal conditions with a higher risk for causing patient discomfort, abrasions, or burns.

Cast removal with use of an oscillating saw is not a completely benign procedure. Cast saws can produce thermal injury or abrasions during cast removal, which compromises patient care and can result in litigation. Although this is a defined risk in an orthopaedic practice, surveys have demonstrated that less than one hour of formal training in cast application and removal is given to resident physicians[1]. Two identified causes of injury during cast removal have been described: (1) an inexperienced, ill-trained user and (2) a blunt saw blade[2].

Heat generated at the saw blade during cast removal has been reported in a polyvinyl chloride pipe model system[1]. For all treatment groups, lower blade temperatures were generated with use of newer blades and the Stryker CastVac saw[1]. While plaster and fiberglass casts are being split, saw blade temperatures can be elevated to a range that would increase the risk of second or third-degree burns[1]. Although the previous study is helpful for the selection of appropriate equipment for cast removal, we know of no study that has evaluated variables that alter the temperatures generated at the skin during cast removal. In addition, to our knowledge, no study has evaluated the well-accepted up-and-down technique of cast-splitting with use of an oscillation saw.

We conducted a cadaver study that simultaneously measured temperatures at the skin-padding interface and the cast-padding interface during cast removal. Variables assessed included the technique of removal (defined as poor compared with good), cast material (fiberglass compared with plaster), and layers of cast padding (two compared with four). We hypothesized that higher skin temperatures are generated during

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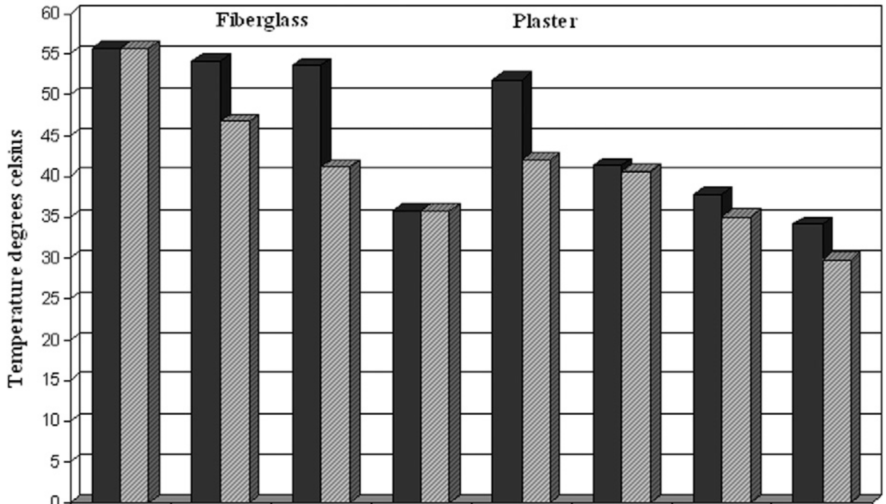

	Blade	Cast	Skin/2 layers	Skin/4 layers	Blade	Cast	Skin/2 layers	Skin/4 layers
■ Poor technique	55.7	54.1	53.6	35.8	51.9	41.3	37.8	34.2
▨ Good technique	55.7	46.7	41.1	35.8	42.0	40.6	35.1	29.8

Fig. 1

The average temperatures measured at the saw blade, the cast, and the skin with two and four layers of cast padding for each removal condition. The averages are from duplicate experiments.

cast removal with use of a poor technique, fiberglass material, and thinner cast padding.

Materials and Methods

Plaster (Specialist fast-setting plaster; BSN Medical, Charlotte, North Carolina) and fiberglass (Delta-Lite conformable casting tape; BSN Medical) short leg casts were applied by one author (F.D.S.) at a uniform thickness (2 mm) to cadaver lower extremities equilibrated to body temperature with use of a circulating water-heating blanket. A total of four cadavers (eight cadaver legs) were used. The 2-mm cast thickness was derived by measuring the sidewall thickness of twenty casts (plaster and fiberglass) that had been removed from patients and still retained mechanical stability. Extremities were padded with either two or four layers of cast padding (WEBRIL; Kendall, Mansfield, Massachusetts). Although additional padding is frequently used for splinting traumatic injuries, evaluation of twenty casts that had been applied for closed fracture management and later were removed in our clinic demonstrated between two and four layers of padding for upper and lower-extremity casts.

During cast application, two sets of chromel-alumel (K-type) thermocouples (OMK-TDA8 data acquisition system; Omega Engineering, Stamford, Connecticut) were placed on the skin surface and at the cast-padding interface located medially and laterally at the distal one-third of the leg. Thermocouples were selected to provide appropriate sensitivity (41 μV/°C) for the temperatures generated during testing. The locations of the thermocouples were marked on the external surface of the cast. Temperature measurements obtained during each pass of the cast saw included skin temperature, cast-padding interface temperature, and direct blade temperature. Cadaver temperature measurement from the skin thermocouples confirmed equilibration to normal body temperature. The casts were dried for one week in a room regulated at 20°C with uniform relative humidity.

The Stryker 940 cast cutter saw with 986 CastVac (Stryker Instruments, Kalamazoo, Michigan) was used for cast removal. This equipment has been shown to produce lower blade and cast temperatures[1]. Casts were removed by one author (F.D.S.), with equal distance traveled at uniform speed, using two techniques: the cast saw blade never leaving the cast material during removal (the poor technique) and the cast saw blade removed from the cast material after each cut to allow for cooling (the good technique). Cast removal began with the insertion of the blade at the proximal extent of the short leg cast with preliminary

TABLE I Comparison of Mean Temperatures for Each Variable

	Mean Temperature (°C)	P Value
Technique		
Poor	40.4	<0.05
Good	35.4	
Material		
Fiberglass	41.6	<0.05
Plaster	34.2	
Cast padding		
Two layers	41.9	<0.05
Four layers	33.9	

TABLE II Comparison of Mean Temperatures for Material and Layers of Cast Padding

	Mean Temperature (*C°*)	P Value
Two layers of cast padding		
Fiberglass	47.4	<0.05
Plaster	36.4	
Four layers of cast padding		
Fiberglass	35.8	<0.05
Plaster	32.0	

testing revealing maximal blade temperatures prior to thermocouple contact. Temperature measurements were obtained at 200-ms intervals from the thermocouples located on the distal one-third of the leg. Maximum temperatures at the skin and cast-padding interface were recorded. Blade temperatures were measured at the end of cast material removal by placing a thermocouple on the blade. Because variations in cast thickness would be expected to alter heat generation during removal, a vernier caliper was used to ensure that the cast thickness was a uniform 2 mm over the thermocouple. Cast saw blades were changed following removal of four casts[1]. For the eight possible cast removal conditions, two temperature measurements were obtained at the skin-padding interface, cast-padding interface, and saw blade.

Statistical Methods

Analysis of variance was used to calculate the mean skin temperature for each variable and to determine significant skin temperature differences in the following groups: (1) a poor technique compared with a good technique, (2) fiberglass compared with plaster, and (3) two layers compared with four layers of cast padding. Factorial analysis of variance was used to calculate the mean skin temperatures and to determine significant differences in skin temperature for the combined variables of materials and layers. The level of significance was set at a p value of <0.05. All skin temperature differences reported are significant.

Results

Average temperature measurements are shown in Figure 1. Saw-blade temperatures generated the highest temperature readings obtained for all variables tested. Regardless of the technique used for removal, the highest blade temperatures (average, 55.7°C) were recorded during the removal of fiberglass casts. The lowest skin temperatures (average, 29.8°C) were recorded when the good technique was used in the removal of plaster casts with four layers of cast padding. Using analysis of variance, one can assess the differences in temperatures generated at the skin surface for each of the variables tested (Table I). The poor technique increased skin temperatures by an average of 5.0°C ($p < 0.05$). Fiberglass casting materials increased skin temperatures by an average of 7.4°C ($p < 0.05$). The use of four layers of cast padding compared with two layers decreased skin temperatures by 8.0°C ($p < 0.05$).

In the clinical setting, removal techniques vary. A factorial analysis of variance was used to compare the skin temperature data combining both removal techniques (Table II). The highest skin temperatures were recorded for fiberglass casts with two layers of padding. The lowest skin temperatures were recorded for plaster casts with four layers of padding. Four layers of cast padding compared with two layers significantly reduced skin temperatures for both plaster and fiberglass casts ($p < 0.05$) (Table II and Fig. 2). Altering the thickness of cast padding had a greater effect on reducing the skin temperature for fiberglass casts (Fig. 2).

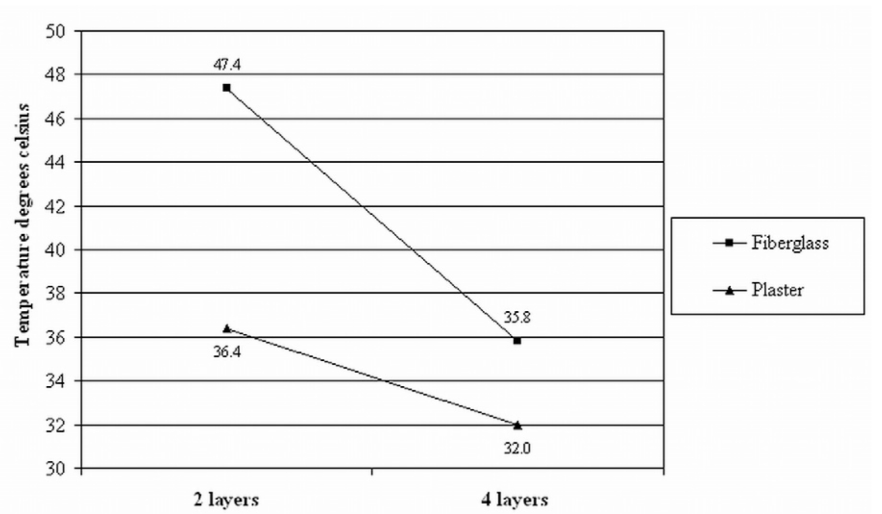

Fig. 2

A plot showing the decrease in skin temperature achieved with the addition of two layers of cast padding. A greater reduction in skin temperature is noted during removal when two layers of padding are added to fiberglass casts (11.6°C) versus plaster (4.4°C).

Discussion

There is a paucity of data evaluating factors that may predispose patients to injury during cast removal. A review of the literature revealed two studies that addressed cast-saw injuries. In one study, the authors stated that "inadvertent cast-saw burns are attributable to inadequately padded casts, improper technique, or uncooperative patients."[1] Support for this statement was provided by Ansari et al., who attributed skin abrasions or burns to two factors: inexperienced users and blunt saw blades[2]. They reported abrasions or burns in twenty-eight (0.72%) of 3875 patients who had a plaster cast removed over a one-year period. The injuries were reported to have cost the hospital approximately £8000 (US$15,898 at the current exchange rate) per patient for a cumulative total of $445,144.

While splitting 3/8 in (9.5-mm)-thick plaster and fiberglass casts, Killian et al. generated saw-blade temperatures that would increase the risk of second or third-degree burns[1]. Lower blade temperatures were generated with use of the Stryker cast saw (temperatures at least 10°C cooler compared with other commercial brands). In order to minimize the temperatures generated in our research protocol, this cast saw was used in addition to fresh saw blades and thin casts (2 mm). We analyzed factors that could affect the generation of heat during cast removal, with use of a model of skin-temperature measurement in cadavers equilibrated to body temperature.

Data analysis showed increased skin temperatures when a poor technique was used, when two layers of cast padding were used, and when removing fiberglass casts (Table I). The relationship between contact time and temperature for the production of skin burns has been established for normal skin[3-5]. According to Williamson and Scholtz[4], a temperature of 57.8°C in contact with healthy skin for five seconds can cause an erythematous macule; 60°C, for five seconds can cause an edematous fat papule; and 60°C, for ten seconds can cause a skin blister. A number of studies have evaluated the setting temperatures of casting materials with use of these historical controls to predict thermal injury[6-10]. The relationship between skin thermal insult and discomfort has also been established. Lawrence and Bull found that, when subjects grasped a heated copper pipe handle, most reported discomfort when the skin-handle interface reached 43°C[5].

With use of these historical controls, two groups in this study approached the threshold to produce thermal injury: (1) fiberglass casts with two layers of cast padding removed with use of the poor technique (53.6°C) and (2) direct contact with the blade (55.7°C). These temperatures are not high enough to cause burns in normal tissues, but they would be expected to cause patient discomfort. The authors of previous studies have suggested that skin changes following skeletal trauma (edema, subdermal fat loss, and ischemia) can theoretically lower the threshold for thermal injury[7]. It is worth commenting that patient injury can also occur because of the additive effects of temperature and abrasion from close contact with the blade. The data presented should be used to develop protocols aimed at avoiding conditions that increase the chance of thermal injury while improving patient comfort.

Significant differences in skin temperatures were noted when the removal technique was altered, the layers of cast padding were altered, and the casting material was altered. A poor removal technique increased skin temperatures by an average of 5.0°C ($p < 0.05$). Fiberglass casting materials increased skin temperatures by an average of 7.4°C ($p < 0.05$). Four layers of cast padding compared with two layers decreased skin temperatures by 8.0°C ($p < 0.05$). A review of the skin temperature data shows that one should be able to safely remove plaster casts with two or four layers of padding when the good, or even the poor, technique is used; fiberglass casts with four layers of padding when the good or poor technique is used; and fiberglass casts with two layers of padding when the good technique is used. We certainly do not recommend the use of the poor technique; however, the data help to demonstrate safer cast-removal conditions when an oscillating saw is used.

Killian et al. demonstrated the most favorable equipment for reducing cast-saw blade temperatures[1]. This equipment was used in this research protocol. Except for uncooperative patients, variables affecting the amount of heat generated at the skin surface during cast removal are clinician-dependent. Physicians and technicians applying casts should keep these variables in mind. The data show that appropriately padded casts of fiberglass or plaster can be removed safely. There are several factors that determine the choice of casting material[11]. Both plaster and fiberglass have advantages and disadvantages. Plaster is commonly used when a well-molded cast is required to immobilize an acute fracture after closed reduction. Fiberglass is lighter, more comfortable, and has waterproof options. It does not mold as well and thus is often used for nondisplaced fractures or for protected immobilization in healing fractures. The need for the addition of cast padding depends on fracture stabilization requirements.

The addition of more cast padding provided increased thermal protection, which was significant in all groups ($p < 0.05$). We suggest maximizing the amount of cast padding when possible while balancing the risk of losing reduction or having inadequate immobilization. When a thinly padded cast requires removal, an experienced individual with well-maintained equipment should be able to remove it without injury. If there is increased concern or if the patient is at high risk for complications[11] (i.e., one who is obtunded or comatose, under anesthesia, very young, or developmentally delayed or spastic), one may consider soaking off a plaster cast following the recommendations by Sadruddin et al.[12]. Alternatively, one can use heavy shears or commercially available plastic strips that are placed between the skin and cast and act as a barrier of protection from cast-saw blades.

We agree with the recommendation that saw blades should be changed frequently, with previous research protocols demonstrating a 20° to 40°C increase in blade temperature when the blade was used three to five times[1,2]. We urge routine assessment of saw-blade dullness or consideration of keeping a log book attached to cast saws to record the number of casts removed per blade.

Lastly, we provide data supporting the superiority of the up-and-down technique compared with running the cast-saw blade through a cast. We recommend that resident training programs adequately reinforce the use of this technique.

The limitations of our study should be discussed. While we did not generate temperatures that exceeded the threshold for thermal injury, we did exceed the normal pain threshold. This may have been due to the use of casts at a thickness of 2 mm while Killian et al. used casts that were 3/8 in (9.5 mm) in thickness. The effect of cast thickness was not evaluated in this study, but it is surmised that increased thickness would correlate with higher temperatures. Killian et al. reported observed clinical temperatures of >99°C when splitting casts with a thickness of ≥1/2 in (12.7 mm)[1]. In addition, we know of no study evaluating the thermal production characteristics when a "composite cast" (plaster overwrapped with fiberglass) is removed. This method adds rigidity while minimizing bulk and has become popular in our observation and as evidenced in the recent study by Halanski et al. that included experiments studying its thermal production during the setting process[10].

Additional trials with more cast padding (six or more layers) would have been interesting but would have strayed from the tenets suggested by Charnley for closed fracture management[13]. Also, there are several types of cast padding utilized in clinical practice; however, we tested only WEBRIL, which is a cotton-based product. We could have improved our study by evaluating the differential insulating properties of other types of cast padding.

Lastly, although we were able to measure temperatures at the skin, our model does not exactly mimic the circulatory dynamics in a living limb. Obviously, performing the study on human subjects would be ideal; however, the potential to cause injury and discomfort would not meet institutional review board approval.

In conclusion, we delineated factors that result in increased skin temperature during cast removal. We demonstrated cast removal conditions that resulted in temperatures below the threshold for thermal injury and discomfort. The results of this study suggest that one who is experienced in cast-cutting and uses well-maintained equipment and a good technique can remove most casts with minimal risk of thermal injury. Prior studies have outlined the importance of the use of the appropriate cast saw and the avoidance of the use of dull blades[1,2]. Institutions and residency training programs should ensure adequate training to all those involved in removing casts[1,2]. Knowledge of the factors that increase skin temperatures and the identification of high-risk patients can help clinicians to minimize the risk of cast-saw injuries. ■

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