Efficacy of Dust Collector for Electric Cast Saw in Reduction of Dust and Noise during Cast Removal Procedure

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Abstract:

Background: Heavy noise and air pollution, both of which are classified as occupational health hazards, were produced during the cast removal procedure.

Objective: The purpose of this article was to design and build a dust collector that could operate with an oscillating saw, to reduce plaster dust and noise during cast removal, protecting healthcare workers and patients from occupational hazards.

Methods: A dust collector was designed and fabricated. The experiment was divided into two groups: five trials for cast saw testing with a vacuum cleaner and five trials for cast saw testing with a vacuum cleaner and a dust collector. Acoustic levels as well as aerosol detection were tested. A dual coil spring could work as a force moderator in this application. When a user applies forces to the cast surface, this spring set returned the cast saw and saw blade to a neutral position, promoting safety.

Results: The traditional cast removal group had higher average acoustic levels in a closed room during every experiment (LAeq), measuring 79.3 dBA, compared with the dust collector group, measuring 77.9 dBA, while the dust collector group had slightly higher 8-hour TWA and LCpeak. Total particle concentration was lower in the dust collector group (-0.0235 mg/m^3) than in the traditional cast removal group (0.005 mg/m^3).

Conclusion: This apparatus may protect patients from overpressure applied to the cast surface. During acoustic tests, the average noise levels differed only slightly between the two groups. In terms of dust containment, a dust collector linked to a vacuum cleaner performed better during the cast removal procedure. In the future, robotic technology and sensor applications may be adapted for this machine.

Keywords: Cast removal; Electric cast saw; Dust collector; Plaster of Paris; Oscillating saw

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Introduction

The human skeleton is made up of living tissues that respond to load and support the rest of the human body's tissues, such as muscles, ligaments, tendons, and so on. However, fractures or injuries to bone tissue can compromise its integrity, necessitating orthopedic surgery and immobilization methods such as intramedullary nails, external fixators, or osteosynthesis plates. There are numerous fixation devices available for fracture immobilization, which can be classified as external or internal fixators, based on their use.[1] Since ancient times, various materials have been used to help immobilize fractures for non-operative management, such as simple wooden splints and rags, plaster of Paris, fiber and soft casts. Plaster of Paris ($2CaSO_4.H_2O$) bandages remain one of the most popular materials, having first been used in the nineteenth century. It is made up of calcium sulphate and water. It is created by partially dehydrating gypsum ($CaSO_4•2H_2O$) at 120°C. When mixed with water, it emits heat and hardens to a porous mass in 5 to 15 minutes. The reason for its popularity is that it is inexpensive, non-irritant, and simple to use.[2] The removal of a circumferential shell of casting material after applying a plaster cast is an important skill for physicians. In this step, physicians will also require a cast saw to remove a plaster cast in certain circumstances, such as removing a cast for reassessment, splitting open a tight cast, removing a wet cast, removing a foreign body underneath the cast, removing a cast to rule out an underlying infection, splitting a cast for airline travel, splitting or removing a cast for suspected compartment syndrome, and removing or trimming an incorrectly applied cast.[3]

The oscillating cast saw was designed to attack any rigid object, but it has the potential to occasionally damage soft tissues. Thermal or abrasive (or both) cast saw injuries may occur during cast removal operations.[4] According to one study, using the safety strip reduced the number of simulated skin touches, when compared to casts removed without the safety strip. Heat transfer was reduced by the safety strips, preventing temperatures at the cast-skin interface from exceeding 50°C. Finally, there was no increase in pressure beneath the casts with the safety strip present after splitting the cast.[5] However, two factors that should be considered when using a cast saw are noise and air pollution. A study found that the mean equivalent continuous noise levels of orthopedic cast clinics were 77.8 dB, the mean noise levels adjusted for an 8-hour day were 76.6 dB, and the mean peak noise levels in adult orthopedic clinics were of the order of 140.0dB. It should be noted that the National Institute of Occupational Safety and Health considers levels above 85 decibels (dB) to be harmful.[6] A study found 2.5-g and 10-g particulate matter (PM2.5 and PM10), also known as coarse particles, with the mean particle concentration in the casting room measured by laser photometer over 5 hours and 50 minutes, being 378.1 g/m^3. When inhaled, this fraction enters the thoracic but not the alveolar parts of the human respiratory system.[7] Exposure to coarse PM was associated with an increase in asthma diagnosis prevalence, hospitalizations, and emergency department visits in children, whereas long-term PM2.5 exposure primarily reduces the vital capacity of lung function in the elderly. Furthermore, PM2.5–10 has a greater negative impact on conductive airway function than PM2.5.[8,9]

As stated above, the purpose of this article was to design and fabricate a dust collector, combined with an oscillating saw, in order to reduce plaster dust and noise during the cast removal procedure, thereby protecting healthcare workers and patients from occupational hazards.

Materials and Methods

The method of design and testing method for a dust collector is shown below.

Machine Design

Normally an electric cast saw is connected to a vacuum cleaner to prevent plaster dust from spreading. However, dust can leak due to a gap between the saw blade and cast. Again, normally nothing is used to absorb noise during the cast removal procedure. Finally, in the absence of a protection mechanism, the control of saw blade depth is solely dependent on the physician's skill, which could result in patient injury. As a result, the authors created a dust collector to aid in improved function of the attached vacuum cleaner. This machine would be designed to be combined with an electric cast saw and a vacuum cleaner without the use of drill holes, screws or bolts. This apparatus's main structure was made of acrylic. To fill the gap between a cast surface and a dust collector, a sheet rubber strip was attached to the lower edge of a dust collector. To protect against mechanical injuries during the cast removal procedure, a dual coil spring was applied. Figure 1 depicts the dust collector drawing.

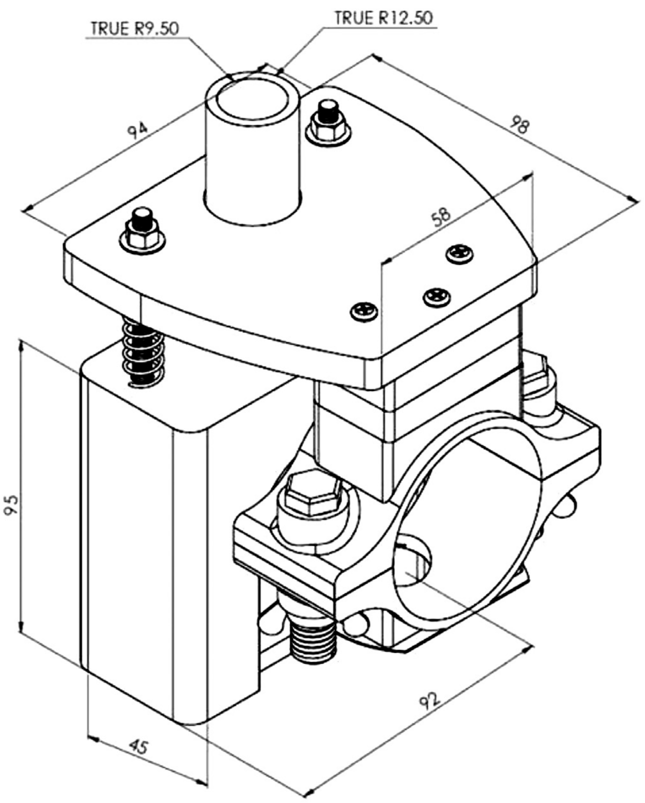

Figure 1 Dust collector's drawing (millimeter)

Experimental Design

The experiment consisted of two groups; five trials for a cast saw with vacuum cleaner testing and five trials for a cast saw with vacuum cleaner and dust collector apparatus. For each experiment, a realistic arm model with plaster cast was placed on the same modified cardboard base within a closed room (Figure 2). The same physician modified all plaster casts, using the same type and amount of undercast padding and plaster of Paris. The same doctor performed all cast cutting operations. Figure 3 illustrates an example of a cast removal operation. There was no cast removal procedure for at least 5 minutes before, during, and after each experiment. Each group's cast cutting procedure was run continuously, followed by a one-hour wait before beginning the next procedure. Each experiment used the Larson Davis LxT2 Sound Level Meter at the same distance as well as the same electric cast saw. To collect larger dust particles, the Universal PCXR8 air sample pump was placed below the operation site.

For all experiments, an oscillating saw 'OSCIMED ERGO SG-OSC-180' 230V 180W speed 12000 to 21000 /min, noise level 65-78 dB and a vacuum cleaner 'OSCIMED ERGO SG-OSC-206-1' 220-240V 50-60Hz 1000W, noise level 60-70 dB, suction 1800 mm water column (40 Litres/sec) were used.

Figure 2 The position of an arm model with plaster cast

Figure 3 The use of a dust collector amalgamated with an oscillating saw and a vacuum cleaner

Acoustic Test[10]

All acoustic trials were carried out with a Larson Davis LxT2 Sound Level Meter. The sound level meter was placed 95 cm away from the center of the plaster cast in horizontal axis and 35 cm above the center of the plaster cast in vertical axis. The equivalent continuous sound level (LAeq) and the C-weighted peak sound pressure level (LC_{peak}) were averaged. The following formula was used to calculate the daily noise dose:

$$D = [C_1/T_1 + C_2/T_2 + C_n T_n] \times 100$$

Where D is the daily dose, C_n is the total time of exposure at a specified noise level, and T_n is the exposure duration for which noise at this level becomes hazardous.

Using the following formula, the daily dose can be converted into an 8-hour TWA (time-weighted average):

$$TWA = 10.0 \times \log(D/100) + 85$$

Aerosol Test[11]

The aerosol particles were detected using a Universal PCXR8 air sample pump during all experiments. The total aerosol mass of all tests was compared before and after particulate testing. A cassette for the sampling filter was placed 95 cm below the center of the plaster cast, while a cassette for the blank filter was placed 65 cm away from the center of the plaster cast on the parallel axis. The following formula was used to calculate the concentration of total particulate in the air volume sampled:

$$C = \frac{(W2 - W1)-(B2 - B1)}{V} \times 10^3$$

Where C is the concentration of total particle (mg/m^3), W1 is the mean tare weight of filter before sampling (mg), W_2 is the mean post-sampling weight of sample-containing filter (mg), B_1 is the mean tare weight of blank filter (mg), and B_2 is the mean post-sampling weight of blank filter (mg).

Results

The same healthcare team carried out all of the experiments. Five plaster casts were cut by the oscillating cast saw with the vacuum cleaner and five by adding the dust collector, making a total of ten. When cutting during the tests, an integrated dual coil spring regulated pressure. When a user applied forces to the cast surface, this spring set then pushed the cast saw and a saw blade back into a neutral position, promoting safety. The following are the sound level and dust particle measurements:

Acoustic Levels

The traditional cast removal group had higher average acoustic levels in a closed room during every experiment, (LAeq), measuring 79.3 dBA, compared with the dust collector group, measuring 77.9 dBA, whereas the dust collector group had slightly higher 8-hour TWA and LCpeak than the traditional cast removal group. Table 1 displays the noise data.

Table 1 The noise exposures during cast cutting in a closed room

Procedure	Average noise levels			
	LAeq (dBA)	8-hr TWA (dBA)	LCpeak (dBC)	Standard Deviation (S.D.)
Traditional cast removal group	79.3	60.9	97.7	18.4
Dust collector group	77.9	61.7	99.0	18.7

Aerosol Levels

Table 2 shows the total aerosol mass of blank filter compared with sampling filter of each group. The dust collector group had a lower total particle concentration (-0.0235 mg/m^3) than the traditional cast removal group (0.005 mg/m^3).

Table 2 The dust concentrations in the dust collector and traditional cast removal groups

		Procedure	
		Traditional cast removal group	Dust collector group
Blank filter	Before	B_1 = 0.0122 g	B_1 = 0.0119 g
	After	B_2 = 0.01225 g	B_2 = 0.0123 g
Sample filter	Before	W_1 = 0.0143 g	W_1 = 0.0136 g
	After	W_2 = 0.01445 g	W_2 = 0.0136 g
Air volume		20 L	17 L
Concentration of total particle		0.005 mg/m^3	-0.0235 mg/m^3

Discussion

Although oscillating cast saws are widely used for cast removal operations, some problems have arisen, as previously stated. A dust collector was created to aid in the operation of a cast saw linked to a vacuum cleaner. This apparatus could protect the patient from overpressure that may be applied to the cast surface. However, at times human error can occur during this procedure. It should be attached, via a secure plate that is inserted beneath the cast to reduce the rate of error. The average noise levels were only slightly different between the two groups during acoustic tests. As a result, this novel technique may not help during cast removal procedures, in reduction of potentially hazardous sound. However, the noise levels in all trials did not exceed the NIOSH recommended exposure limit (REL) for occupational noise exposure (85 dBA as an 8-hr TWA), as recommended by the National Institute for Occupational Safety & Health (NIOSH)[10]. Therefore, if a researcher needs to improve sound absorption efficiency, acoustic absorbing materials, such as nylon fiber, cotton fiber, polypropylene, and rubber should be amalgamated with the newly designed acrylic structure.[11]

Furthermore, the dust concentration measurement results in this article did not deviate from the primary hypothesis. The traditional method revealed a large gap between the saw blade and cast, resulting in marked air born dust production, whereas the dust collector method could confine the plaster dust to a small area. During the dust collector group's test, however, an unusual occurrence occurred. According to Field blanks definition in Quality Assurance Guidance Document 2 - US EPA. (n.d.); If the weight change between pre- and post-field blank weighing exceeds 30 g, contamination may occur during transportation or at the sampling site.[12] In this experiment, the weight difference between pre- and post-field blank weighing in this experiment was - 0.0235 g. The dust collector group's negative total particle concentration was caused by an increase in dust from the mean post-sampling weight of the blank filter in both groups. This phenomenon could be caused by dust particle fluctuation within a closed room.

Another obvious result is an increase in the mean post-sampling weight of the sample-containing filter in the traditional cast removal group, whereas the dust collector group was the same before and after the sampling procedure. To summarize, a dust collector could help the vacuum cleaner work better during the cast removal procedure.

A future study should incorporate a water spray within the acrylic box of a dust collector for absolute dust confinement to improve its capability. Robotic technology is another technique that can be used to reduce human error. For the next dust collector model, the manipulator with actuator motors, a modified gearbox, and a servo motor attached to an oscillating saw could be used.[13] To improve patient safety, sensor technology similar to that used in robot navigation applications should be used to detect the thickness of cast and undercast padding.[14]

Conclusion

A novel dust collector was designed and manufactured in response to the health risk posed to patients and healthcare workers during the cast removal procedure. This device demonstrated how to support the operation of a cast saw and a vacuum cleaner. When compared to the traditional cast removal group, the results showed that it could reduce aerosol spreading while having no discernible difference in acoustic level. Other devices, such as a secure plate, acoustic absorbing materials, and water spray, should be added to improve the safety of patients and medical personnel. Robotic technology and sensor applications can be adapted for this machine in the future. Eventually, the authors hope that this apparatus will inspire anyone to improve their environmental safety workplace in order to reduce risks during biomedical procedures.

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Declaration

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Consent to participate: Not applicable.

Consent for publication: We, the undersigned, give our consent for the publication of identifiable details, which can include photograph(s) and/or videos and/or case history and/or details within the text (“Material”) to be published in the above Journal and Article.

Availability of data and material: Not applicable.

Code availability: Not applicable.

Authors’ contributions: PS designed a machine prototype, fabricated, tested and analyzed data. AJ designed a concept, summarized as well as drafted the manuscript.

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