



■ GENERAL ORTHOPAEDICS

Drill splatter in orthopaedic procedures and its importance during the COVID-19 pandemic

AN EXPERIMENTAL STUDY

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Aims

During the COVID-19 pandemic, drilling has been classified as an aerosol-generating procedure. However, there is limited evidence on the effects of bone drilling on splatter generation. Our aim was to quantify the effect of drilling on splatter generation within the orthopaedic operative setting.

Methods

This study was performed using a Stryker System 7 dual rotating drill at full speed. Two fluid mediums (Videne (Solution 1) and Fluorescein (Solution 2)) were used to simulate drill splatter conditions. Drilling occurred at saw bone level (0 cm) and at different heights (20 cm, 50 cm, and 100 cm) above the target to simulate the surgeon 'working arm length', with and without using a drill guide. The furthest droplets were marked and the droplet displacement was measured in cm. A surgical microscope was used to detect microscopic droplets.

Results

Bone drilling produced 5 cm and 7 cm droplet displacement using Solutions 1 and 2, respectively. Drilling at 100 cm above the target produced the greatest splatter generation with a 95 cm macroscopic droplet displacement using Solution 2. Microscopic droplet generation was noticed at further distances than what can be macroscopically seen using Solution 1 (98 cm). Using the drill guide, there was negligible drill splatter generation.

Conclusion

Our study has shown lower than anticipated drill splatter generation. The use of a drill guide acted as a protective measure and significantly reduced drill splatter. We therefore recommend using a drill guide at all times to reduce the risk of viral transmission in the operative setting.

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Introduction

Electric drills are routinely used in orthopaedic surgical procedures to create a linear route through bone and facilitate the passage of a screw or a wire. There are, however, concerns about the production of suspended liquid particles, otherwise known as aerosols, when operating the drill. Material from the operative site may become aerosolized by the action of the electric drill's rotatory instrument, vibrations, or a combination of both on the

bone's blood, generating drill splatter.¹ Drill splatter is the proportion of the aerosol that is most visible to the naked eye. Within an aerosol, hazardous infectious agents such as viral nuclei can be embedded and remain in the air for long periods of time.² Aerosols from the drill splatter can therefore be dispersed to the operating theatre surroundings, possibly reaching the upper respiratory tract for those who are in close proximity to the infected tissues for lengthy periods of time, which includes the

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operating surgeon and their assistants.^{3,4} Nevertheless, for an effective viral transmission to occur, having the viral nuclei solely in the droplet is insufficient—the virus must remain viable.³ Whether or not the SARS-COV-2 remains viable in aerosols and for how long is still being investigated;^{3,5} however, the current evidence suggests that *Betacoronaviridae* group, such as the 2003 SARS-COV-1, are viable in aerosols.^{2,3,5}

During the early stages of the COVID-19 pandemic, trauma and orthopaedic procedures involving the use of high-speed electric drills had been classified as aerosol-generating and specific personal protective equipment (PPE) as well as several suggestions were recommended for all healthcare personnel involved in such procedures to reduce the risk of viral transmission.⁶⁻⁹ There is growing evidence to suggest dental mechanical instruments including handpieces, ultrasonic scalers, air polishers, and air-abrasions produce a significant amount of splatter.¹ This is also evident in surgical equipment such as diagnostic nasopharyngoscopy, skin dermabrasion, and oscillating saws used by otolaryngology, plastics, and forensic specialities, respectively.^{2,10,11} However, there is currently limited evidence in the literature on drill splatter generation by electric drills used in trauma and orthopaedic procedures. The aim of our study was to quantify the effect of drilling on splatter generation within the orthopaedic operative setting. Our hypothesis was that high-speed electric drilling will produce significant drill splatter that extends beyond the surgeon's working arm's length. We also hypothesize that using a drill guide will reduce drill splatter distance.

Methods

Experimental set-up. A custom set-up was used for this experiment for ease of use and repetition. Floor sheets were used as the base of this experimental set-up. A central marker (X) was drawn in the middle of the floor, the point at which drilling ensued. Two fluid mediums were used to simulate drill splatter conditions: Fluorescein (Fluorescein Drain Tracing Dye; Monument Tools, UK) and Videne (Povidone-Iodine, 10% cutaneous solution; Ecolab, UK). Solution 1 was created using 100 ml of Videne diluted in 900 ml of water. Solution 2 was created using 22.3 g of Fluorescein diluted in 900 ml of water, as per the manufacturer's recommendations. A standard femur-shaped saw bone model was used with a solid outer cortical bone, which uses a mixture of short glass fibre and epoxy resin pressure injected around a rigid polyurethane cancellous foam core material. The mid-shaft area had a hollow intramedullary canal. A Stryker System 7 high-speed dual rotating drill (Stryker, USA) was used throughout the experiment at full speed.

Experimental protocol and measurements. Drilling ensued at four different heights above X: 0 cm, 20 cm, 50 cm, and 100 cm. For each height, the drill was dipped

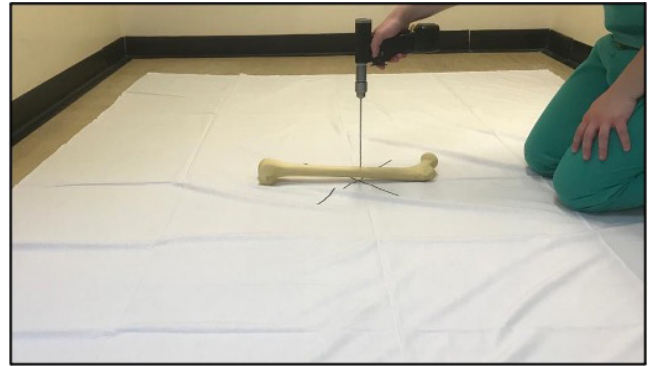


Fig. 1

At 0 cm height, the drill was aimed directly onto the saw bone which was placed at X.

fully into Solution 1 and then used at full speed for five seconds. This was repeated three consecutive times before measurements were taken and recorded. Following the completion of each run, the measurements were taken, and the floor sheets were labelled with a black marker pen which were then stored in a safe and clean area, and new floor sheets were placed. At 0 cm height, the drill was aimed directly onto the saw bone, which was placed at X, as shown in Figure 1. This was repeated without the presence of the saw bone to simulate the surgeon's different working arm's length or "testing the drill" at 20 cm, 50 cm, and 100 cm heights.

The same heights and protocol were repeated with the presence of a drill guide which acted as a sheath that covers the drill tip fully. Following the completion of each run, the floor sheets were again labelled, stored in a safe and clean area, and new floor sheets were placed. Measurements were taken and recorded. The same protocol and heights were repeated with Solution 2 with and without the drill guide, changing the floor sheets following each run. An ultraviolet (UV) light was used to detect macroscopic droplets arising from the drill splatter of Solution 2 at each height.

Following each run with and without the drill guide, two independent orthopaedic surgeons (RK, NG) labelled the furthest macroscopic droplet seen, arising from the splatter. The distance between X and the droplet displacement was measured in cm. To detect microscopic droplet propagation, a Carl Zeiss surgical microscope (Prescott's Surgical Microscopes, UK) with a focal distance range of 200 mm to 500 mm and a $\times 10$ magnification, was used to examine each sheet. The surgeons then, under microscopic vision, labelled and measured microscopic droplet displacement from X in cm. All measurements were recorded to the nearest 1 integer. As an experimental study with neither patient nor cadaveric contact, formal ethical approval was deemed not to be required.



Fig. 2

Microscopic drill splatter using Solution 1 at 20 cm height, with more than 98 cm microscopic droplet displacement on the floor sheet using the Carl Zeiss surgical microscope at $\times 10$ magnification.

Results

Solution 1 without drill guide. Drilling directly onto the saw bone at 0 cm height produced drill splatter with a 5 cm macroscopic droplet displacement. At 20 cm height, the drill splatter had a 17 cm macroscopic droplet displacement. At 50 cm and 100 cm heights, the drill splatter had a 24 cm and 48 cm macroscopic droplet displacement, respectively. Using the surgical microscope, microscopic droplets were noted farther than macroscopically seen, with a droplet displacement of more than 98 cm when drilling at a 20 cm height, as shown in Figure 2.

Solution 2 without drill guide. Drilling directly onto the saw bone at 0 cm height produced drill splatter with a 7 cm macroscopic droplet displacement as shown in Figure 3a. At 20 cm height, the drill splatter had a 23 cm macroscopic droplet displacement. At 50 cm and 100 cm heights, the drill splatter had a 67 cm and 95 cm (Figure 3b) macroscopic droplet displacement respectively. Using the surgical microscope, no microscopic droplets were noted beyond what was seen macroscopically.

Solution 1 and 2 with a drill guide. With Solution 1, drilling directly onto the saw bone at 0 cm height produced negligible drill splatter with < 1 cm macroscopic droplet displacement. This was also the case at 20 cm and 50 cm heights. At 100 cm height, drilling produced a 7 cm macroscopic droplet displacement respectively. Using the

surgical microscope, no microscopic droplets were noted other than what was seen macroscopically.

With Solution 2, drilling directly onto the saw bone at 0 cm height produced negligible drill splatter with < 1 cm macroscopic droplet displacement. At 50 cm and 100 cm heights, drilling produced drill splatter with a 29 cm macroscopic droplet displacement. Using the surgical microscope, no microscopic droplets were noted farther than what was seen macroscopically. A summary of our results for both macroscopic and microscopic droplet displacement using either of the solutions is shown in Table I.

Discussion

In the initial phase of the COVID-19 pandemic, high-speed electric drilling in trauma and orthopaedic procedures was classified as an aerosol-generating procedure,^{6,7} despite limited evidence within the literature to quantify the effect of drill splatter and aerosol generation. In our study, droplet displacement was seen at 98 cm while using an electric drill if held a distance above the bone. However, both drilling with a guide and drilling at bone level significantly reduced splatter generation. We would therefore recommend using a drill guide at all times and avoid operating the drill away from the bone surface

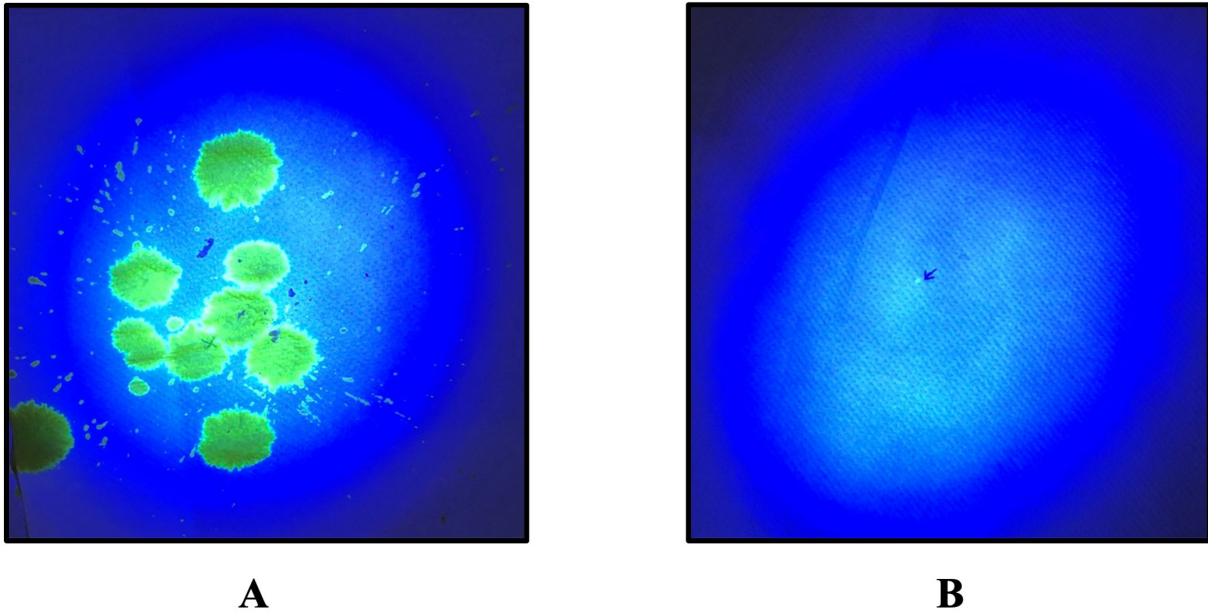


Fig. 3

a) Macroscopic drill splatter using Solution 2 at 0 cm height with a 7 cm macroscopic droplet displacement on the floor sheet. The saw bone was removed for better demonstration. b) Labelled macroscopic drill splatter using Solution 2 at 100 cm height with a 95 cm macroscopic droplet displacement on the floor sheet.

Table 1. Summary of drill splatter generation.

| Height | Solution 1 | | Solution 2 | |
|----------------------------------|-------------------------|------------------|---------------------|------------------|
| | Without drill guide | With drill guide | Without drill guide | With drill guide |
| 0 cm | 5 | < 1 | 7 | < 1 |
| 20 cm | 17 | < 1 | 23 | < 1 |
| 50 cm | 24 | < 1 | 67 | 29 |
| 100 cm | 48 | 7 | 95 | 29 |
| Microscopic droplet displacement | 98 seen at 20 cm height | None seen | None seen | None seen |

to reduce the risk of viral transmission in the operative setting.

Splash injury to the face as a result of drill splatter remains a serious safety concern for the operating theatre staff including orthopaedic surgeons. It is estimated that 81% of the blood particles greater than 10 mm will reach the operator airways with 1.5% reaching the tracheo-bronchial region and 1.9% ending in the alveoli.³ This could be higher in situations where splatter generation is greater, such as the use of high-speed rotatory devices and longer operating times.^{10,12} As a result, during the COVID-19 pandemic, along with the recommended PPE, efforts have been made to reduce the risk of viral transmission during aerosol-generating procedures.^{4,7-9,12-15} One study by Sharma et al¹⁵ has shown drill splatter to extend beyond 182 cm away from the surgical site during temporal bone preparation in mastoidectomies. In their cadaveric study, they found staff within a 30 cm to 90 cm radius were at increased risk of splash injury during the operation when high-speed drills are used in otolaryngological procedures. Accordingly, they recommended

all steps to be taken to reduce the number of personnel within a 180 cm radius from the surgical site.¹⁵ In our study, we have found that the splatter arising from high speed-drilling without a drill guide could result in droplet displacement up to 98 cm away from the primary site. This splatter was shown to be reduced considerably to < 1 cm at 0 cm height with the use of a drill guide. Even when drilling with a guide at 100 cm above the bone, the maximum droplet displacement was 29 cm away from the primary target as compared to 98 cm without the guide. The drill guide, in this case, acts as an additional protective layer around the drill, suppressing the amount of splatter generated by the rotatory drill tip. We would therefore recommend avoiding operating the drill away from the bone surface and encourage use of a drill guide at all times to reduce the amount of drill splatter. This would aim to reduce the risk of viral transmission in the operative setting during the COVID-19 pandemic and beyond.

Limitations to our study include the difference in viscosity and density of Fluorescein and Videne to

human blood. The differences in splatter generation and subsequent droplet displacement both macro- and microscopically may be related to the differences in solution viscosity and density. These two solutions were used given their densities are similar to that of blood, as well as for ease of detection in this experiment.¹⁶ Furthermore, in this experimental study, there was no assessment of aerosolization from drilling. Micik et al¹⁷ defined the term “aerosol” as particles less than 50 µm in diameter and the term “splatter” as airborne particles larger than 50 µm in diameter.¹⁷ In this experiment, efforts were made to detect microscopic droplets using the Carl Zeiss surgical microscope with × 10 magnification. Despite the lack of aerosol measurements in this study, we believe it is still essential to determine and understand the quantity of splatter generation and the distance such droplets can move to reduce the risk of viral transmission within the operating theatre. The last limitation is that this experiment was done in vitro conditions. In reality, the presence of the surrounding soft tissues such as muscles and skin may act as a barrier reducing the splatter displacement outside the surgical wound. Furthermore, the shorter drilling times used in this study compared with certain trauma and orthopaedic operative procedures may underestimate the cumulative volume of splatter generation over the course of a single operation with the presence of laminar air flow, which may contribute to further droplet propagation when drilling.

In the first wave of COVID-19 pandemic, efforts were made to reduce the risk of viral transmission during aerosol-generating procedures within the operating theatre. In our study, we have shown the splatter that can be generated from high-speed drilling during orthopaedic procedures. Operating a drill at a distance away from the bone in order to test it can result in a large splatter distance and we advise against this, particularly if the drill has been exposed to human fluid or tissue. The use of a drill guide significantly reduces splatter at all heights, and we recommend its use at all times.



Take home message

- Our study has shown lower than anticipated drill splatter generation.

- The use of a drill guide acted as a protective measure and significantly reduced drill splatter.

- We therefore recommend using a drill guide at all times to reduce the risk of viral transmission in the operative setting.

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- N. Green: Conceptualization, Investigation, Writing – review & editing.
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Ethical review statement:

- As an experimental study with no patient nor cadaveric contact, formal ethical approval was deemed not to be required.

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