Plunging When Drilling: Effect of Using Blunt Drill Bits

Giuseppe Alajmo, MD,† Urs Schlegel, PhD,† Boyko Gueorguiev, PhD,‡ Romano Matthys,† and Emanuel Gautier, MD§||*

Objective: Plunging when drilling can be a detrimental factor in patient care. There is, although, a general lack of information regarding the surgeon's performance in this skill. The aim of this study was to determine the effect that using sharp or blunt instruments had on the drill bit's soft tissue penetration, using a simulator.

Materials and Methods: Surgeons taking part in an International Trauma Course were invited to participate. Two groups were defined: experienced and inexperienced surgeons. Twelve holes were drilled in the following order: 3 holes with a sharp drill bit in normal bone (SNB), 3 holes with a sharp drill bit in osteoporotic bone (SOB), 3 holes with a blunt drill bit in normal bone, and 3 holes with a blunt drill bit in osteoporotic bone. Mean values and Student *t* tests were used for statistical analysis.

Results: Thirty-seven surgeons participated, 20 experienced and 17 inexperienced surgeons. Mean plunging depths for SNB, SOB, blunt drill bit in normal bone, and blunt drill bit in osteoporotic bone were, respectively, 5.1, 5.4, 21.1, and 13.9 mm for experienced surgeons and 7.6, 7.7, 22, and 15.9 mm for inexperienced surgeons. Drilling with SNB and with SOB was statistically different, with inexperienced surgeons plunging 2.5 mm ($P = 0.31$) and 2.6 mm ($P = 0.042$) deeper, respectively. There was a difference ($P < 0.001$) between sharp and blunt drill bits in all drilling conditions for both the groups.

Conclusions: Our study showed a significant difference in plunging depth when sharp or bunt drill bit was being used. Surgeons, regardless of their experience level, penetrate over 20 mm in normal bone and over 10 mm in osteoporotic bone.

Key Words: simulation, surgical performance, plunging, bone drilling, patient safety

(*J Orthop Trauma* 2012;26:482–487)

INTRODUCTION

Medical errors account for over 1 million injuries in the United States alone.[1] Results from the Harvard Medical Practice Study show that approximately 4.1% of hospitalized orthopaedic patients have some type of adverse event, with more than 26% of those being caused by negligence.[2] As pressure to provide safer environments for patients becomes greater, there is a need to improve every aspect of patient care to diminish the risk of iatrogenic injuries.[3]

With vascular, nerve, and tendon damage being reported as clinical relevant complications,[4,5] plunging when drilling can be a detrimental factor in patient care. There is, although, a general lack of information regarding the performance of orthopaedic surgeons in bone drilling. Although intuitively recognized as risk factor for plunging, we could not find any information on the actual effect of using blunt drill bits in soft tissue perforation.

As part of the AO Trauma Courses, a new educational tool called the "Playground for Orthopedic and Trauma Surgeons" was developed to teach basic skills (practical and cognitive) in fracture management. With a "hands on" approach, the playground is a multistation workshop that tackles different principles in 4 major orthopaedic trauma topics: bone healing, fracture reduction, fracture fixation, and surgical skills. One of its stations was developed to teach and practice plunging (soft tissue penetration) when drilling, which makes it ideal for investigating the influence different drilling conditions, such as blunt or sharp drill bits, could have on surgical performance.

The principal aim of our study was to determine the real effect that using sharp or blunt instruments has on the performance of experienced and inexperienced surgeons. Having knowledge on how different conditions affect surgical performance allows us to develop new methods or improve old ones that can lead the surgeons to avoid detrimental conditions or at least to provide them with tools to better overcome those that are unavoidable.[6,7]

MATERIALS AND METHODS

The experiment was done in December 2010 during an International Trauma Course. Surgeons from the cranio-maxillo-facial, trauma, and orthopaedic fields were invited to participate. Enrollment in the study was voluntary, although an encouragement gift was offered. Surgeons were allowed to participate according to their experience level. Two groups were defined: experienced and inexperienced surgeons. A surgeon with more than 5 years of working experience, including their residency years, was defined as experienced. A surgical resident

Accepted for publication August 10, 2011.

From the *Fundacion Santafe de Bogota, Universidad del Rosario, Bogota, Colombia; †Innovations Group; ‡Biomechanical Services Group, AO research Institute, Davos, Switzerland; §Department of Orthopedics, Kantonsspital Fribourg, Fribourg, Switzerland; and ||University of Lausanne School of Medicine, Lausanne, Switzerland.

Supported by AO Research Institute, Davos, Switzerland.

The authors report no conflict of interest.

Reprints: Giuseppe Alajmo, MD, Innovations Group, AO Research Institute, Clavadelerstrasse 8, 7270 Davos Platz, Switzerland (e-mail: alajmo_g@hotmail.com).

with less than 2 years of working experience was defined as inexperienced. Surgeons with 2–5 years of experience were considered neither experienced nor inexperienced and were not allowed to participate. The experiment was conducted using the "Soft Tissue Penetration" station from the AO's Playground for Orthopedic and Trauma Surgeons.

The station (Fig. 1) consisted of 2 foam bone holders, normal and osteoporotic generic synthetic bone (Synbone, Malans, Switzwerland), a drill-tool, and sharp and blunt 3.2 drill bits (Synthes, Hägendorf, Switzerland) prepared with plastic sleeves, which helped in the measurement of plunging depth (PD) (Fig. 2). First, the total drilling depth (TTD) was recorded in millimeters after each hole was drilled. TTD was the distance from the tip of the drill bit to the far end of the sleeve. To measure PD, the known and constant synthetic bone diameter was subtracted from the TTD. To avoid measurement bias, the participant had to leave the sleeve resting on the proximal cortex once the drill hole was started and was not allowed to touch it any more.

Each participant was asked to perform 12 holes. Starting with a sharp drill bit, they performed 3 holes in normal generic synthetic bone and 3 holes in osteoporotic generic synthetic bone. Then all participants changed to blunt drill bits and drilled 3 holes in normal and 3 holes in osteoporotic generic synthetic bone, collecting information from both drill bits and bone qualities. In summary, the 12 holes were drilled in the following order: 3 holes with a sharp drill bit in normal bone (SNB), 3 holes with a sharp drill bit in osteoporotic bone (SOB), 3 holes with a blunt drill bit in normal bone (BNB) and 3 holes with the a blunt drill bit in osteoporotic bone (BOB). Thus, 4 different drilling conditions were defined for every surgeon. For analysis purposes, the mean value from the 3 attempts in each drilling condition was used. All participants knew the scope of the study.

The following baseline data were collected for every participant: age, gender, handedness, and working experience. Three subgroups for the inexperienced surgeons (0–1 month, 1–12 months, and 1–2 years) and 2 subgroups for the experienced surgeons (5–10 years and >10 years) were defined.

Statistical analysis was performed with the use of SPSS software (PASW Statistics 18.0.0; SPSS, Inc, Chicago, IL). Independent and paired Student t tests were used for detection of significant differences. Significance was defined as $P < 0.05$.

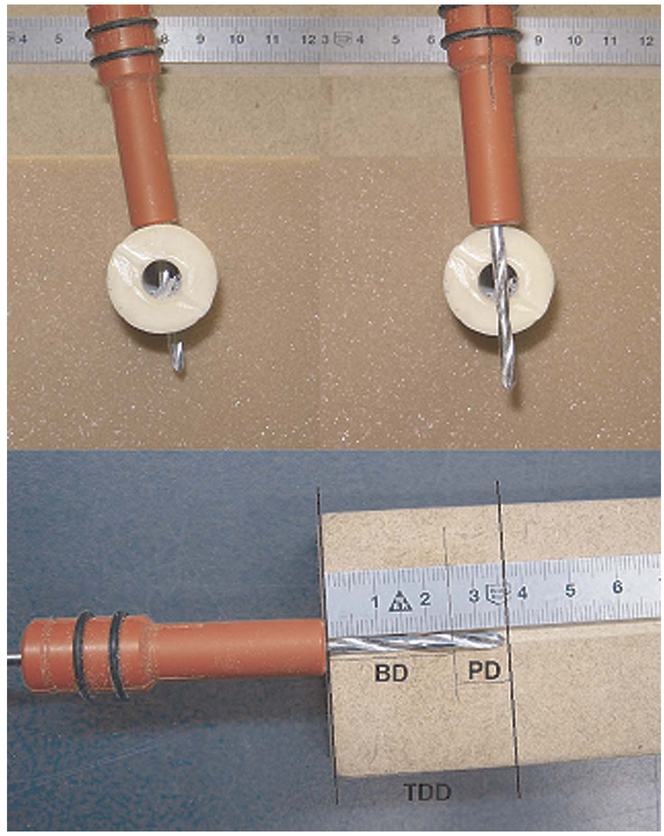

FIGURE 2. PD measuring device. BD, bone diameter.

RESULTS

Thirty-seven surgeons participated in our study: 20 experienced and 17 inexperienced. General characteristics and mean PDs for each drilling conditions for both groups are listed in Table 1.

FIGURE 1. Soft tissue penetration station from the AO's Playground for Orthopedic and Trauma Surgeons.

TABLE 1. General Characteristics and Mean PDs

No.	Age (yr)	Gender	Laterality	Experience	SNB*	SOB*	BNB*	BOB*
Experienced surgeons								
1	60	M	Right	>10 yr	4.7	4.0	15.7	7.3
2	44	M	Both	>10 yr	2.7	8.0	33.7	9.0
3	45	M	Right	>10 yr	9.3	4.7	27.7	11.3
4	58	M	Right	>10 yr	6.0	8.3	28.3	21.3
5	56	M	Right	>10 yr	12.0	6.3	24.3	17.7
6	35	M	Right	5–10 yr	5.3	4.7	25.0	11.0
7	35	M	Right	5–10 yr	2.7	2.7	12.0	10.3
8	36	M	Right	>10 yr	3.3	6.3	28.7	15.0
9	46	M	Right	>10 yr	3.0	3.0	16.7	8.3
10	44	M	Right	>10 yr	3.0	2.7	17.3	9.7
11	37	M	Right	>10 yr	5.3	3.3	19.0	10.7
12	41	M	Right	5–10 yr	3.7	5.3	18.3	8.0
13	34	M	Right	5–10 yr	7.7	11.0	22.7	23.0
14	35	M	Right	5–10 yr	9.3	12.7	24.3	27.0
15	43	M	Right	>10 yr	0.7	2.0	18.0	9.0
16	40	M	Right	5–10 yr	3.3	2.7	15.3	9.0
17	31	M	Right	5–10 yr	8.7	8.7	23.7	24.3
18	50	M	Right	>10 yr	2.0	2.7	12.3	14.7
19	41	M	Both	>10 yr	7.7	5.7	26.0	19.3
20	58	M	Right	>10 yr	1.3	3.0	13.7	11.7
Inexperienced surgeons								
1	29	M	Right	1–2 yr	14.0	8.7	18.3	14.3
2	31	M	Right	1–12 mo	8.3	10.3	21.7	14.0
3	34	M	Right	1–2 yr	4.0	7.3	21.7	14.0
4	33	M	Right	1–2 yr	7.7	4.3	23.0	16.3
5	31	F	Right	1–2 yr	8.0	4.3	35.0	23.0
6	34	M	Right	1–2 yr	5.7	3.7	17.7	11.3
7	26	M	Right	1–2 yr	3.0	6.0	31.7	20.0
8	30	M	Right	1–12 mo	8.0	13.7	27.0	22.0
9	34	M	Right	1–2 yr	9.0	3.0	24.3	15.0
10	33	F	Right	1–2 yr	7.0	5.3	21.7	13.3
11	34	M	Right	1–2 yr	9.7	5.7	19.3	10.3
12	26	M	Right	1–12 mo	8.0	13.0	25.3	23.0
13	27	F	Left	1–12 mo	17.7	14.3	25.0	21.0
14	30	M	Right	1–2 yr	4.0	5.3	9.0	12.0
15	30	M	Right	1–12 mo	7.7	10.7	19.7	20.7
16	29	M	Both	1–2 yr	3.0	6.0	16.0	8.0
17	33	M	Right	1–2 yr	5.0	9.0	17.7	12.0

*Mean from 3 attempts, in millimeters.
F, female; M, male.

Hundred percent of the experienced surgeons were men, 90% were right-handed, and 65% had more than 10 years of experience. Seventy-six percent of the inexperienced surgeons were men and 88% were right-handed. Seventy percent had between 1 and 2 years of experience, 22% had between 1 and 12 months of experience, and none had less than 1 month of experience.

Differences between experienced and inexperienced surgeons in all 4 drilling conditions are listed in Table 2. PDs in SNB and SOB were statistically different between the 2 experience groups, with inexperienced surgeons plunging 2.5 mm ($P = 0.31$) and 2.6 mm ($P = 0.042$) deeper, respectively. There was no statistical significance between experienced and inexperienced surgeons when drilling with a blunt drill bit in any bone quality (BNB or BOB). Mean PDs for BNB and BOB were, respectively, 21.1 and 13.9 mm for experienced surgeons and 22 and 15.9 mm for inexperienced surgeons.

Differences in-between the 4 different drilling conditions for both the groups are listed in Table 3. For the experience surgeons, there was no difference between SNB and SOB. There was a statistical difference with $P < 0.001$ between sharp and blunt drill bits in both the bone qualities (SNB vs BNB and SOB vs BOB), with a mean difference

TABLE 2. Differences Between Experienced and Inexperienced Surgeons in 4 Different Drilling Conditions

Drilling Condition	Drilling Characteristics	Level of Experience	N	Mean (mm)	Mean Difference (mm)	Significance (*P*)*	95% CI* Lower	95% CI* Upper
SNB	Sharp drill bit in normal bone	Experienced	20	5.1	−2.6	0.031	−4.8	−0.3
		Inexperienced	17	7.6				
SOB	Sharp drill bit in osteoporotic bone	Experienced	20	5.4	−2.3	0.042	−4.5	−0.1
		Inexperienced	17	7.7				
BNB	Blunt drill bit in normal bone	Experienced	20	21.1	−0.9	0.667	−4.9	3.2
		Inexperienced	17	22.0				
BOB	Blunt drill bit in osteoporotic bone	Experienced	20	13.9	−2.0	0.277	−5.7	1.7
		Inexperienced	17	15.9				

*Independent Student t test.
CI, confidence interval.

between sharp and blunt drill bits of 16.1 and 8.5 mm in normal and osteoporotic bone, respectively. In the inexperienced group, there was also no difference between SNB and SOB. There was a statistically significant difference ($P < 0.001$) between SNB vs BNB and SOB vs BOB, with mean differences being 14.4 and 8.2 mm, respectively.

DISCUSSION

As expected, our study showed that penetration with blunt instruments was significantly worse than with sharp instruments. Furthermore, experienced surgeons seemed to loose their technical advantage when blunt drill bits were being used, as they performed at the same level under this condition as the inexperienced surgeons. We think this is the result of losing fine motor control as the surgeon had to push harder for a blunt drill bit to penetrate the bone.

Being statistically significant is not the same as being clinically relevant. The difference in PD between experienced and inexperienced surgeons with sharp instruments was only 2 mm. Whether any soft tissues could be in jeopardy with such a small difference is a matter of controversy. We could not find any evidence on how much soft tissue penetration would be "safe" to tolerate, but common sense indicates that less penetration is better. Assuming experienced surgeons with sharp drill bits drilled in a safe zone, we think a 2-mm difference is quite small, thus we believe inexperience surgeons with more than 1 month of working experience were also in a safe zone as long as they were using sharp drill bits.

With blunt drill bits, there was a completely different situation. Soft tissue penetration for both experienced and inexperienced surgeons in normal bone was over 20 mm. According to the anatomic site, this amount of plunging can jeopardize important neurovascular structures. Lo et al[8] show

TABLE 3. Comparison of Drilling Conditions

Variables	Characteristics	Experienced Surgeons N	Mean (mm)	Mean Difference (mm)	Significance (*P*)*	95% CI* Lower	95% CI* Upper	Inexperienced Surgeons N	Mean (mm)	Mean Difference (mm)	Significance (*P*)*	95% CI* Lower	95% CI* Upper
SNB vs SOB	SNB: sharp drill bit in normal bone	20	5.1	−0.3	0.613	−1.5	0.9	17	7.6	−0.05	0.961	−2.0	1.9
	SOB: sharp drill bit in osteoporotic bone	20	5.4					17	7.7				
SNB vs BNB	SNB: sharp drill bit in normal bone	20	5.1	−16.1	0.000	−18.6	−13.5	17	7.6	−14.4	0.000	−17.7	−11.0
	BNB: blunt drill bit in normal bone	20	21.1					17	22.0				
SOB vs BOB	SOB: sharp drill bit in osteoporotic bone	20	5.4	−8.5	0.000	−10.4	−6.6	17	7.7	−8.2	0.000	−10.4	−6.0
	BOB: blunt drill bit in osteoporotic bone	20	13.9					17	15.9				
BNB vs BOB	BNB: blunt drill bit in normal bone	20	21.1	7.3	0.000	4.1	10.4	17	22.0	6.1	0.000	4.1	8.2
	BOB: blunt drill bit in osteoporotic bone	20	13.9					17	15.9				

*Paired Student *t* test.
CI, confidence interval.

in a cadaveric study that distances from the tip of the coracoid to various neurovascular structures (axillary nerve, musculocutaneous nerve, lateral cord of the brachial plexus and axillary artery) range from 24 to 39 mm. In the humerus, the radial nerve has proven to be within 10 mm of the bone both at the midshaft as it crosses the spiral grove[9] and near the lateral epicondyle.[10,11] Even in the lower extremity, where neurovascular structures tend to be further away from the bone, the femoral artery, vein, and nerve lie between 21 and 25 mm of the anterior capsule.[12] Hansen et al[13] in their magnetic resonance imaging anatomic study of tibia report that the neurovascular bundle lies 11.5 mm behind the posterior cortex. All those structures could be at risk with a blunt drill bit plunging over 20 mm.

Perforation of the third extensor compartment[4] and delayed rupture of the extensor tendons with the fixation of distal radius fractures with volar plates[14] are both reported due to plunging when drilling and/or too-long screw placement. Safar et al[15] report one popliteal artery rupture caused by tibia drilling, and Grimaldi et al[16] report a femoral artery lesion associated with interlocking of a proximal femur nail. Although no comments were made on the use of sharp or blunt drill bits in the case reports mentioned, they demonstrate the risk of serious tendon or vascular injuries associated with drilling.

Although we founded a difference between drilling with blunt drill bits in different bone qualities, with both experience groups plunging less in osteoporotic bone, soft tissue penetration was still over 10 mm in this bone quality, which we think is beyond any possible safe zone.

There were some potential drawbacks in our study that should be mentioned. All participants knew they were being measured and compared with other participants, which could have biased the results. We think that, because all participants were aware of this fact, the Hawthorne effect, although surly present, was equal for both the groups and thus played a minimal role on the results. We acknowledge that our analog-measuring device could have the potential for biasing the results, but we believe it allowed a simple, fast, and reliable method for measuring PD as long as the sleeve was not handled once the drilling began. Extra care was taken not to allow the surgeon to touch the sleeve from the point the drilling began until the measurement was taken, so we think our measurements were accurate. This is greatly supported by the fact that we were able to find a statistically significant difference between experienced and inexperienced surgeons if they used a sharp instrument, which was something expected and proof of the reliability and accuracy of the measuring device. Furthermore, we found a significant difference between sharp and blunt drill bits for all surgeons in all bone qualities.

There is one important topic that was not addressed in our study but is still a matter of concern. It has been shown that drilling elevates cortical bone temperature, which in theory could lead to thermal necrosis and subsequent implant failure.[17] Although the exact role that necrosis due to drilling plays in bone osteosynthesis has not been completely studied, it is our belief that every step should to be taken to reduce the risk of a bad outcome. Blunt drill bits considerably slow the feed rate, and there is consisting evidence[18] showing that slow feed rates are associated with increasing bone temperature, thus elevating the risk of thermal necrosis.

In summary, with PDs with blunt drill bits over 20 mm in normal bone and over 10 mm in osteoporotic bone in both the groups, we think we provide enough evidence for surgeons to check and replace or sharpen blunt drill bits before drilling in every surgery to avoid the risk of significant soft tissue damage and preventable patient adverse outcomes, independent of bone quality.

CONCLUSIONS

Our study showed a significant difference in PD when sharp or blunt drill bits were being used. Surgeons, regardless of their experience level, penetrate over 20 mm in normal bone and over 10 mm in osteoporotic bone. Furthermore, experienced surgeons loose their technical advantage when they drill with blunt instruments. Inexperienced surgeons with 1 month to 2 years of working experience, although they plunge significantly more than experienced surgeons, seemed to be in a safe zone as long as they use sharp drill bits. Our results support the replacement or sharpening of blunt drill bits in a regular basis.

ACKNOWLEDGMENTS

The authors would like to thank all the fellows (Aswin Beck; Marios Petrou; Fabian Duttenhoefer; Endre Varga; Ahmed Fuad Seifeldin) and the Innovations group team members (Peter Daescher, Dieter Wahl) at the AO Research Institute, who helped with the logistics of the experiment.

REFERENCES

1. Weingart SN, Wilson RM, Gibberd RW, et al. Epidemiology of medical error. *BMJ*. 2000;320:774–777.
2. Brennan TA, Leape LL, Laird NM, et al. Incidence of adverse events and negligence in hospitalized patients. Results of the Harvard Medical Practice Study I. *N Engl J Med*. 1991;324:370–376.
3. Berwick DM, Leape LL. Reducing errors in medicine. *BMJ*. 1999;319: 136–137.
4. Pichler W, Grechenig W, Clement H, et al. Perforation of the third extensor compartment by the drill bit during palmar plating of the distal radius. *J Hand Surg Eur Vol*. 2009;34:333–335.
5. Manner M, Rosch B, Roy K. [Vascular injuries complicating osteosynthesis in proximal femur fractures]. *Unfallchirurg*. 1999;102:227–231.
6. Pine M, Fry DE. Linking processes and outcomes to improve surgical performance: a new approach to morbidity and mortality peer review. *Am Surg*. 2006;72:1115–1119.
7. Fried MP, Satava R, Weghorst S, et al. Identifying and reducing errors with surgical simulation. *Qual Saf Health Care*. 2004;13(Suppl 1):i19–i26.
8. Lo IK, Burkhart SS, Parten PM. Surgery about the coracoid: neurovascular structures at risk. *Arthroscopy*. 2004;20:591–595.
9. Carlan D, Pratt J, Patterson JM, et al. The radial nerve in the brachium: an anatomic study in human cadavers. *J Hand Surg Am*. 2007;32:1177–1182.
10. Apivatthakakul T, Arpornchayanon O, Bavornratanavech S. Minimally invasive plate osteosynthesis (MIPO) of the humeral shaft fracture. Is it possible? A cadaveric study and preliminary report. *Injury*. 2005;36:530–538.
11. Apivatthakakul T, Patiyasikan S, Luevitoonvechkit S. Danger zone for locking screw placement in minimally invasive plate osteosynthesis (MIPO) of humeral shaft fractures: a cadaveric study. *Injury*. 2010;41:169–172.
12. Davis ET, Gallie PA, James SL, et al. Proximity of the femoral neurovascular bundle during hip resurfacing. *J Arthroplasty*. 2010;25: 471–474.

13. Hansen M, Roux P, Adolph J, et al. [Risk of iatrogenic neurovascular damage by proximal 3-dimensional intramedullary nailing of the tibia]. *Unfallchirurg*. 2010;113:476–480.
14. Al-Rashid M, Theiyendran K, Craigen MA. Delayed ruptures of the extensor tendon secondary to the use of volar locking compression plates for distal radial fractures. *J Bone Joint Surg Br*. 2006;88:1610–1612.
15. Safar HA, Farid E, Nakhi H, et al. Vascular injuries caused by orthopaedic screws. A case report. *Med Princ Pract*. 2004;13:230–233.
16. Grimaldi N, Courvoisier A, Tonetti J, et al. Superficial femoral artery injury resulting from intertrochanteric hip fracture fixation by locked intramedullary nail. *Orthop Traumatol Surg Res*. 2009;95:380–382.
17. Augustin G, Davila S, Mihoci K, et al. Thermal osteonecrosis and bone drilling parameters revisted. *Arch Orthop Trauma Surg*. 2008;128: 71–77.
18. Davidson SR, James DF. Drilling in bone: modeling heat generation and temperature distribution. *J Biomech Eng*. 2003;125:305–314.