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Publication Date
2024-04-01

DOI
10.2460/ajvr.24.01.0006

AJVR

K-wire is more damaging than standard or acrylic drill bits when evaluating torsional properties of rabbit (*Oryctolagus cuniculi*) femurs

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OBJECTIVE
The objective of this study is to compare drilling variables and torsional mechanical properties of rabbit femora after bicortical drilling with a 1.5-mm standard surgical drill bit, acrylic drill bit, and K-wire.

SAMPLES
24 pairs of rabbit femora.

METHODS
After drilling under controlled axial displacement rate, each bone was biaxially loaded in compression followed by rapid external torsion to failure. Maximum axial thrust force, maximum drill torque, integral of force and displacement, change in temperature, maximum power spectral density of the torque signal, torque vibration, and torque and angle at the yield and failure points were collected. Pre- and postyield stiffness, yield and failure energies, and postyield energy were calculated.

RESULTS
The work required to drill through the cis- and transcortices (integral of force and displacement) was greater for the K-wire, followed by the acrylic and then standard drill bits, respectively. The K-wire demonstrated higher maximum torque than the drill bits at the ciscortex, and the force of drilling was significantly greater. The vibration data was greater with the acrylic and standard drill bits than the K-wire. There was no difference in torsional strength between drilling types.

CLINICAL RELEVANCE
Mechanical differences exist between different drill bits and K-wire and demonstrate that the K-wire is overall more damaging than the surgical drill bit.

Keywords: biomechanics, drill hole, rabbit bone, torsional properties, drill bit

Rabbit long bone fractures surgically repaired with a bone plate and screws or external skeletal fixation have a poor prognosis for successful bone healing.[1,2] Femurs carry the poorest prognosis, with only a 73% success rate of clinical union.[3] Rabbits carry 70% of their weight in their pelvic limbs, have a very plantigrade stance with high motion during ambulation, and possess significant overlying muscle and soft tissues, resulting in inherent downsides to external skeletal fixation use.[4,5] While internal fixation with a bone plate and screws provides a more rigid construct and avoids some of the downsides, its application has been met with unacceptably high failure rates at the bone-implant interface.[6–8] In one study,[8] though iatrogenic fracture resulted in sample size being too low for statistical analysis, an external fixation construct withstood approximately twice the compression and bending forces before failure compared to an internal fixation with a bone plate and screws. The appropriate application of these constructs, including predrilling,

Received January 5, 2024
Accepted March 12, 2024

doi.org/10.2460/ajvr.24.01.0006

hand tapping, size of implant, and rigidity of construct, has not been established in rabbits.

In vitro torsional mechanical testing has demonstrated the brittle behavior of rabbit femurs, characterized by the lack of postyield plastic deformation.[9] This brittle mechanical behavior likely contributes to the low-impact catastrophic fractures clinically and experimentally seen in rabbit femora intraoperatively or shortly after fracture repair.[1–3,7–8]

Fracture stabilization with internal and external fixation relies on the ability of bone fragments to accept and sustain implants and postoperative loads. Cortical holes for screw or pin implantation reduce the torsional strength of the bone, with a reduction greater than 50% considered suboptimal and associated with a greater risk of bone failure.[10] A previous study[9] evaluated bicortical free-hand drilling of clinically relevant hole sizes (1.1, 1.5, and 2.0 mm) associated with commercially available screws to determine their effects on the torsional strength of rabbit femora. Only the smallest, a 1.1-mm defect corresponding to a 1.5-mm bone screw, did not decrease the torsional strength to failure beyond 50%. Clinically, a 1.5-mm bone plate is likely too weak to withstand weight bearing in the postoperative period, eliminating bone plating as an acceptable surgical option. However, other factors, such as drill or pin tip design, drill speed, temperature when drilling, drill or pin sharpness, and axial force while drilling, may all contribute to the weakening and fracture of such brittle bone. These factors were not tested in the previous study[9] and could explain why a clinically relevant-sized implant (1.5-mm drill bit/2.0-mm bone plate) was found unsuitable. Because of this, a 1.5-mm hole was elected for this study, with the assumption that controlling axial force, displacement, and lateral "wobble" will decrease the damage caused by drilling these holes.

Surgical drill bits have not changed significantly since 1959.[11] Drill bits must displace and remove bone from the hole without causing significant damage to surrounding bone. Geometric parameters, such as rake, clearance, wedge, helix lead, and point angles; flank; chisel edge and point; cutting face; flute geometry; web; land; and body, influence the mechanics of a drill hole through bone.[11,12] Drill bit sharpness and heat generation can also affect the efficiency of the drill bit and damage to the surrounding bone.[11,13] The large number of variables makes it impossible to design a single drill bit that would be optimized for all types of bone quality. Drill bits used for brittle materials, such as acrylics in manufacturing, are designed to prevent grabbing material aggressively but rather gradually widen the hole due to a sharper point.[14] Alternately, drilling with a K-wire requires more thrust and generates more heat than drilling with a surgical drill bit.[15,16] K-wire tip characteristics would therefore be expected to cause greater clinical complications than surgical drill bits. Investigating the effects of penetrating rabbit bone with K-wires and different drill bits may provide insight into what repair method is the most appropriate in this species.

The objective of this study is to evaluate and compare drilling variables and torsional mechanical properties of rabbit femora after bicortical drilling with a 1.5-mm standard surgical drill bit, a 1.5-mm acrylic drill bit, and a 1.5-mm K-wire while controlling for axial speed/displacement rate. The null hypotheses are that drilling variables and torsional strength to failure of rabbit femora would not be different among the 2 drill bits and K-wire. A 1.5-mm defect is hypothesized to not decrease the torsional strength of the bone by over 50% when axial drilling speed and wobble are controlled.

Methods

Study design

The effects of drill bits or K-wire (a 1.5-mm surgical drill bit [DePuy SynthesVET], a 1.5-mm acrylic drill bit ["Plexi-Point Drill," Vortex Tool Company Inc], and a 1.5-mm K-wire ["1.5 mm diameter half-point wire," Hofmann]) on drilling variables and the torsional structural properties of 48 rabbit femora (24 pairs) were studied. A randomized balanced block design was used such that all combinations of comparisons between drill types and between the intact condition were compared pairwise within a rabbit for the same number of replicates. The effects of treatment (a hole made with an acrylic bit, standard surgical drill bit, or K-wire; compared with an intact bone) on drilling and torsional structural properties were assessed using an analysis of variance that accounted for the repeated measures within rabbit.

Drill bits/K-Wire

The key features of the surgical and acrylic drill bits and K-wire are summarized **(Table 1 and Figure 1)**.

Specimen preparation and drilling

Skeletally mature female intact New Zealand White rabbit cadavers, with mean weight of 3.75 kg (range, 3.28 to 4.20 kg), that had been euthanized for reasons unrelated to this study at an outside facility were used. Therefore, no IACUC was needed. Whole rabbits were frozen at −20 °C directly following euthanasia. Each rabbit was thawed at room temperature and weighed. Both femora were harvested,

Table 1—Key features of the surgical drill bit, acrylic drill bit, and K-wire.

	Drill type		
Drill tip feature	Surgical drill bit	K-wire	Acrylic drill bit
Point angle	86	45	76
Clearance length	0.583	1.4	1.07
Helix angle	15.2	NA	21.7
Major cutting edge (lip) length	0.99	1.56	1.15
Chisel edge length	0.45	0.1	0.6
Clearance/relief angle	25	NA	15
Relief facet (yes/no)	No	Very slight	Yes

NA = Not applicable.

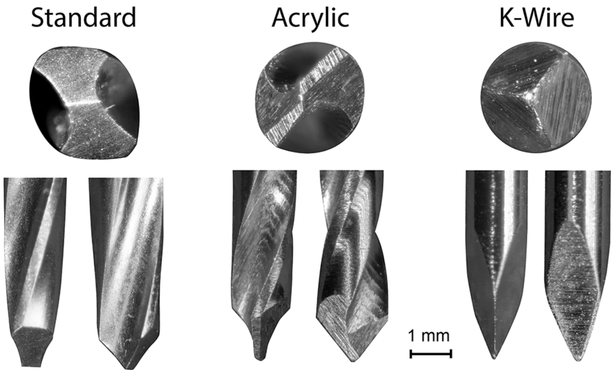

Figure 1—Side views and tips of the 1.5-mm standard surgical drill bit, 1.5-mm acrylic drill bit, and 1.5-only to the lower/lateral images.

wrapped individually in saline-soaked towels, and stored in sealed plastic bags at –20 °C until testing.

The femora were thawed at 4 °C for 24 hours prior to use. Craniocaudal and lateromedial digital radiographs (NEXT digital system and HF100/30+ miniXray; NEXT Equine DR, Sound Technologies) of the femora were obtained at 48 kVp, 2 mAs. Femora were removed from the study if any orthopedic abnormalities were noted, including trauma, fracture, neoplasia, or osteoarthritis. Bone measurements, including diaphyseal length, craniocaudal and mediolateral diameters of the mid-diaphysis, and cortical thickness (measured after mechanical testing and fractures), were obtained with a digital caliper (Absolute digital caliper series 500, Mitutoyo America) as previously described.[9] The proximal diaphysis was defined as the distal aspect of the lesser trochanter, and the distal diaphysis was defined as the proximal aspect of the trochlear groove. The mid-diaphysis, equidistant to the marked proximal and distal diaphyseal points, was marked.

The proximal and distal bones were potted in custom-made cups using polymethylmethacrylate (PMMA) (Coe tray plastic, GC America Inc) to the described limits of the proximal and distal aspects of the diaphysis. Briefly, the femora were suspended in a clamp that allowed movement to ensure alignment. Vertical lasers were used perpendicular to the long axis of the bone from the cranial and medial/lateral sides to verify proper alignment prior to pouring PMMA, ensuring that the center of axis of rotation of the materials testing machine (MTS) (Model 809 Axial/Torsional Testing System, MTS Systems Corporation) was parallel to and coincident with the center of the femoral diaphysis.[9]

After the proximal epiphysis was potted, the construct was placed in the MTS to drill the bicortical hole with a standard axial speed/displacement rate. The drill (4300 cordless driver, Stryker) was attached to the load cell, with the potted cup secured to a plate on the MTS so that the lateral side of the femur was facing the drill. The unpotted distal diaphysis of the bone was supported with PMMA and a fixture to prevent motion during drilling. An infrared thermometer (OS551A-V1-6, Omega Engineering) measured the heat generated during drilling at the lateral cortex of the femur where the drill bit contacted the bone. The thermometer was positioned 15.2 cm above the bone, resulting in the smallest possible field of measurement (3.9-mm diameter). Room temperature water was continuously and copiously pulsed from a 20-cc syringe at the drilling site. The drill bit or pin (Figure 1) was placed into the drill chuck with 25 mm of the bit exposed. The drill rotated at 500 rpm, and the MTS was set at a displacement rate of 0.5 mm/s so that axial speed was consistent throughout the drilling process. The hole was positioned at the mid-diaphyseal point and halfway between the cranial and caudal aspects of the bone. The axial force of the drill bit or pin was recorded at the cis- and transcortex; temperature was measured and recorded at the ciscortex **(Figure 2)**. Torque, axial force, and axial displacement were recorded at 10 Hz using a biaxial load transducer (MBA500, Fetek) and the linear variable differential transformer internal to the machine actuator (MTS). The axial/thrust force of the drill was used to separate the data of the cis- and transcortices for analysis. During drilling, each drill bit or K-wire was used 4 times prior to replacement.

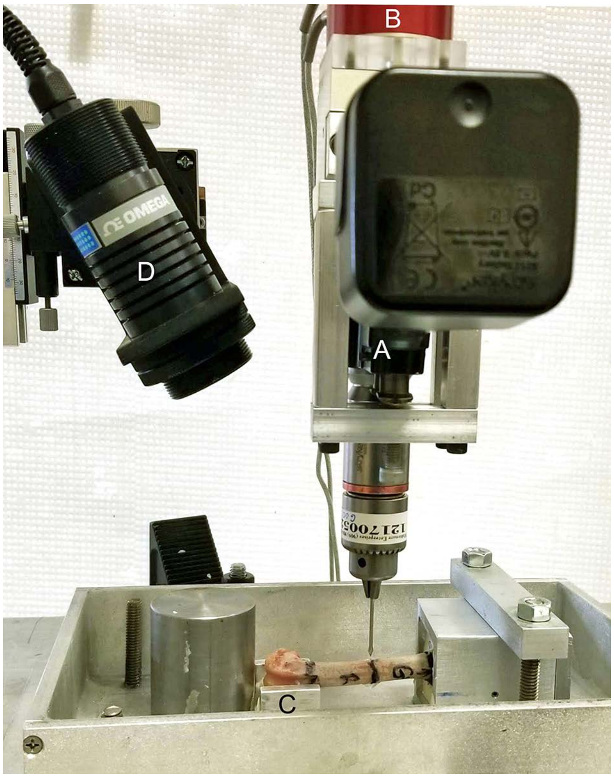

Figure 2—Setup for creating the bicortical defects. The proximal potted epiphysis was secured to the materials testing machine, and the drill (A) was attached to the load cell (B) so the drill or K-wire had 2.5 cm exposed and was centered craniocaudally on the lateral aspect of the mid-diaphysis of the bone. The unpotted distal epiphysis was supported with polymethylmethacrylate (C) to prevent movement during drilling. Water was pulsed at the drilling site while the temperature (D) was monitored. Consistent axial displacement was applied through the drilling process, and the axial force of the drill bit or K-wire was recorded at both cis- and transcortices.

The construct was attached to the MTS with the center of the femoral diaphysis aligned with the center of rotation of the MTS, and the distal end was potted in PMMA. The diaphysis was wrapped in saline-soaked towels while the PMMA cured.

Mechanical testing

Femurs were rigidly attached to the servohydraulic load frame using the potted cups with the bone positioned to align the axis of torsion at the center of the diaphysis. An axial load was applied under load control at 5 N/s to 35% body weight to simulate weight bearing at stance. The corresponding axial displacement was held constant throughout testing. Torsion by external rotation was applied at 10°/s to failure, while torque and angular displacement data were acquired at 256 Hz. This load rate is consistent with a previous rabbit bone torsional study[9] and was chosen to approximate the load rate of a rabbit at a hop, during which the time to peak vertical ground reaction force of the hind limb of a rabbit is documented at 70 ms.[17] The limb was loaded at a load rate to 30% failure force (equivalent to peak ground reaction force in axial loading[8]) in approximately 100 ms.

Orthogonal radiographs and digital images were obtained after each test to document bone fracture. Fracture configuration was categorized as simple spiral, incomplete spiral (spiral fracture extending into PMMA and lacking a vertical component), spiral with additional fissures, spiral with < 2 additional fragments, and highly comminuted with ≥ 2 fragments.

Data analysis

A low-pass infinite impulse response filter (order 6, passband frequency 1.0 Hz, passband ripple 0.01 dB, sample rate 10 Hz) was used to filter drilling axial force and torque data to reduce vibrational noise. The continuous data from the force and torque of drilling were combined with the simultaneously collected temperature data using custom software (Matlab, MathWorks). Drilling data were reduced to include the maximum axial thrust force, maximum drill torque, integral of force and displacement, change in bone surface temperature, maximum of the power spectral density (PSD) of the torque signal (torque PSD), and integral of PSD over frequency (torque vibration). Torque PSD was calculated using unfiltered data sampled over the duration of cis- and transcortex drilling.

The absolute values of torque (N·mm) versus angular deformation (°) were plotted for each test. Yield was defined as the first point that the line of best fit deviated by 2% angular deformation offset. Preyield and postyield stiffness were calculated as the slope of the least-square linear fit through the central one-third of the respective initial and postyield linear regions of the curve. Maximum torque was defined as the failure point. Torque and angle at the yield and failure points were recorded. Yield and failure energies were determined by the area under the curve to their respective points. Postyield energy was determined from the difference between the energy values at yield and failure. The percentage of torsional strength reduction was determined by representing the intact bone as a 100% torsional strength to failure and comparing failure torque means of the different treatments.

Statistical analysis

Statistics were calculated using statistical software (SAS, version 9.4; SAS Institute Inc). Spearman correlation coefficients were calculated to determine the correlation of drill repetition number (1 to 4) with maximum force or work required to penetrate the cis- and transcortices (Proc Corr; SAS, version 9.4, SAS Institute). The effects of drill bit type on drilling forces were assessed using an ANOVA including the drill-use repetition as a fixed effect and repeated measures on rabbit (Proc Mixed; SAS, version 9.4; SAS Institute Inc). Pairwise comparisons were made using Tukey's honestly significant difference post hoc tests. The normality of the distribution of the residuals from the analysis of variance was analyzed using the Shapiro-Wilk statistic (Proc Univariate; SAS, version 9.4, SAS Institute Inc). Data was rank transformed prior to ANOVA if it was nonparametric.

The effects of treatment on stiffness, yield, and failure mechanical properties were assessed using an ANOVA including drill type (1.5-mm surgical drill bit, 1.5-mm acrylic drill bit, 1.5-mm K-wire; intact bone) as a fixed effect and repeated measures on rabbit. The association between intact and drilled bones with fracture configuration was evaluated with a chi-square test (Proc Logistic; SAS, version 9.4; SAS Institute Inc). Logistic regressions (Proc Logistic; SAS, version 9.4; SAS Institute Inc) were used to evaluate the association between drill type (standard vs acrylic, standard vs pin, or acrylic vs pin). Significance was set as $P < .05$.

Results

Drilling

The maximum force or work required to drill through the cortices (integral of force and displacement) was not significantly correlated to repeated use of the drill bits, with each being used 4 times. However, increasing use of the K-wire was correlated with the maximum force of penetrating the ciscortex ($P = .017$, $R = -.67$) and the transcortex ($P = .07$, R –.54), and there was a significantly greater ($P = .017$) maximum force required to penetrate the ciscortex between the first and fourth uses of the K-wire.

The work required to drill through the cis- and transcortices (integral of force and displacement) was markedly greater for the K-wire, followed by the acrylic and then standard drill bits, respectively **(Table 2)**. The K-wire demonstrated higher maximum torque than the drill bits at the transcortex, with no difference in torques reached at the ciscortex. The maximum force of drilling at the ciscortex was greater when comparing the K wire to the acrylic and standard bits, with no difference between the 2 drill bits. At the transcortex, the maximum force of drilling was the greatest with the K-wire, followed by

Table 2—Drilling variables at both cis- and transcortices using an acrylic drill bit, standard surgical drill bit, and 1.5-mm K-wire median [minimum, maximum].

Drilling variables	Cortex	Acrylic	Standard	K-wire
Maximum force (N)	Cis	17 [15, 23][a]	16 [15, 19][a]	35 [27, 56][b]
	Trans	20 [16, 24][a]	18 [15, 20][a]	40 [34, 54][b]
Maximum torque (N·mm)	Cis	22 [12, 63][a]	16 [6, 68][a]	20 [7, 32][a]
	Trans	33 [15, 88][ab]	48 [21, 179][a]	26 [9, 80][b]
Force-displacement integral (N·mm)	Cis	−23 [−33, −19][a]	−21 [−29, −16][a]	−65 [−110, −45][b]
	Trans	−23 [−29, −19][a]	−20 [−27, −15][a]	−61 [−75, −19][b]
Maximum PSD Torque [$(nm)^2$/Hz]	Cis	0.0011 [0.0005, 0.0054][a]	0.0011 [0.0006, 0.0017][a]	0.0005 [0.0002, 0.0017][a]
	Trans	0.0047 [0.0011, 0.0150][ab]	0.0061 [0.0025, 0.0441][a]	0.0021 [0.0010, 0.0049][b]
Integral of PSD torque $(nm)^2$	Cis	0.0010 [0.0006, 0.0039][a]	0.0009 [0.0003, 0.0009][a]	0.0004 [0.0002, 0.0013][b]
	Trans	0.0034 [0.0014, 0.0079][ab]	0.0040 [0.0015, 0.0171][a]	0.0017 [0.0011, 0.0040][b]
Temperature change (deg)	Cis	4.0 [0.4, 6.6][ab]	4.1 [0.2, 6.7][b]	6.3 [0.4, 12.8][a]

Deg = Degree. PSD = Power spectral density.
[a,b]The values within a row are not statistically significantly different if they share a common superscript.

Table 3—Torsion to failure data median [minimum, maximum].

Drill tip feature	Acrylic	Standard	K-wire	Intact bone
Yield angle (deg)	2.88 [2.15, 3.76][a]	3.71 [2.57, 4.65][a]	3.14 [2.67, 5.49][a]	4.67 [1.92, 5.69][b]
Yield torque (nm)	2.02 [1.56, 2.47][a]	2.10 [1.69, 3.13][a]	2.07 [1.77, 2.63][a]	2.78 [1.03, 3.57][b]
Preyield stiffness (nm/deg)	0.64 [0.54, 0.75][a]	0.63 [0.48, 0.73][a]	0.65 [0.42, 0.74][a]	0.57 [0.47, 0.68][b]
Yield energy (nm·deg)	2.96 [1.74, 4.74][a]	3.95 [2.40, 7.64][a]	3.74 [2.56, 6.53][a]	6.74 [1.07, 10.61][b]
Postyield stiffness (nm/deg)	0.55 [0.44, 0.65][a]	0.52 [0.33, 0.64][b]	0.55 [0.33, 0.70][c]	0.48 [0.31, 0.59][d]
Postyield energy (nm·deg)	7.00 [3.05, 8.84][a]	8.35 [2.31, 12.19][b]	7.51 [3.85, 17.51][c]	28.10 [11.82, 56.82][d]
Failure angle (deg)	5.60 [3.81, 6.40][a]	6.55 [5.11, 8.83][b]	5.95 [4.57, 8.85][a]	11.24 [7.73, 15.12][c]
Failure torque (nm)	3.18 [2.35, 3.68][a]	3.57 [3.06, 4.11][a]	3.37 [2.97, 4.71][a]	5.71 [4.29, 8.19][b]

Deg = Degree.
[a-d]The values within a row are not statistically significantly different if they share a common superscript.

the acrylic and standard drill bits. The temperature at the ciscortex increased more with the K-wire compared to the standard drill bit. The total PSD power torque (vibration data) was greater with the acrylic and standard drill bits than the K-wire at both the cis- and transcortex. All fractures occurred through the created holes in the femur.

Torsion tests

The failure angle (P = .015) and postyield energy (P = .003) were significantly less when an acrylic drill bit was used versus a standard surgical drill bit **(Table 3)**. The failure stiffness when drilled with the acrylic bit was greater than with the standard surgical bit (P = .010). The failure stiffness (P = .022) and postyield energy (P = .008) were also less when comparing the acrylic drill bit to the K-wire. All other values (yield angle, energy, stiffness, and torque and failure torque) showed no significant difference between drill bit/pin types (Table 3).

The mean torsional strength (failure torque) as a percentage of intact bone strength for paired limbs was 60.1% (SD, 24.0%) using the acrylic drill bit, 63.0% (SD, 13.9%) using the standard surgical drill bit, and 72.3% (SD, 17.5%) using the pin to create 1.5-mm bicortical defects in each bone. There was no significant difference in torsional strength between drilling types.

Fracture type was associated with whether the bone had a drill hole or not (P < .001). Except for 1 intact bone that fractured in a spiral configuration with mild comminution (< 2 additional fragments), all and only the intact bones fractured in a severely comminuted configuration. There were no significant associations between drill bit types and fracture configuration (chi-square P values ranging from .27 to .972) when analyzing bones with drill holes.

Discussion

The null hypothesis was partially accepted. Mechanical differences exist between different drill bits and K-wire when creating a defect in brittle rabbit bone. The K-wire dulled more rapidly than either of the drill bits over 4 uses. The integral of force and displacement, maximum torque, and maximum force to create the defect were greater with the K-wire than the surgical drill bit. The K-wire also created more thermal change despite consistent irrigation. The K-wire created less vibration than the drill bits. These findings demonstrate that the K-wire is more damaging when drilling than the surgical drill bit.

This study demonstrated significant dulling between the first and fourth uses of the K-wire, with a linear increase in force over time, allowing the conclusion that multiple K-wire usage to penetrate bone, particularly more than 3 times, should be avoided. With replacement of any used K-wires in a surgical pack, K-wires used for external fixation are generally only applied 1 time and left in situ, making this point mute. However, at human orthopedic centers, drill bits are replaced after each surgery in only 6% of facilities and guide wires in 19.8%,[18] while in veterinary orthopedic centers the use of new drill bits or K-wires is likely to occur even less often. The dulling of the K-wire was noted in the ciscortex but not the transcortex. The concave surface of the transcortex and stabilization from the ciscortex likely helped the pin stay centered, so there was less lateral resistance at the cutting tip.

The standard surgical drill bit was superior to both the acrylic drill bit and the K-wire when evaluating the integral of force and displacement. The K-wire required more force than both drill bits to penetrate each cortex. The standard surgical drill bit has been designed to decrease slippage on bone contact and increase the rate and efficiency of bone clearance during the drilling process to minimize the integral of force and displacement.[11] The acrylic drill bit is designed for brittle hard plastics to gradually widen the hole and not "grab" large portions of the material as the sharper drill point penetrates the material.[14] The K-wire has no ability to clear debris, likely leading to the increased force required, increased integral of force and displacement, and increased temperature despite continuous saline irrigation. Although a perfect surgical drill bit in all types of bone does not exist, the standard surgical drill bit demonstrates superior biomechanical performance compared to the other tips studied here. In this study, a drill bit designed to gradually widen the hole and a pin with no feature for debris clearance both required more work to pass through cortical bone. Further studies would be required to determine if a different drill bit design, potentially maximizing bone debris clearance, would be superior to the standard surgical drill in thin and brittle bones.

Increased temperatures above 50 °C can have detrimental effects on the bone, causing thermal necrosis that may be clinically significant.[19] This enforces the concept of limited reuse of K-wires during surgery and copious irrigation during the procedure to minimize temperature flux. When placing any pin/wire into rabbit or other brittle bone, the surgeon should consider predrilling with an appropriately sized drill bit to decrease the force, torque, and thermal changes associated with K-wire placement. While predrilling is generally recommended in humans and dogs, especially when threaded pins are used, no such guideline has been established in rabbits and other exotic species, and this step is anecdotally often skipped.[1,2] This study used smooth K-wires, and the necessity of predrilling smooth wires has not been established.

According to a landmark study[10] used in cross-species orthopedics, the assumption was made that any iatrogenic defect created in a bone should not weaken it beyond 50% of the original torsional strength. In a previous study,[9] this reduction in strength was evaluated in rabbit femurs, finding that no hole greater than 1.1 mm could safely be created in this bone. However, a 1.5-mm bone plate and screws, corresponding to a 1.1-mm drill hole, is not considered strong enough for this size of bone and animal. In the previous study,[9] the bone was drilled free hand, not controlling for force or advancement rate, and allowing more axial deviation or "wobble." In the present study, these parameters were controlled by mechanically advancing the drill at a very slow and steady rate to minimize the potential damage to the bone and potentially allow the use of more appropriately sized implants. When evaluating torsional strength to failure of each of these 1.5-mm drilling types, all 3 were above 50% of the original strength, in contrast to the previous study supporting the use of this sized implant in the clinical patient. The rabbit source, husbandry, and size were the same between studies. While this data supports that the bone should be drilled at a slow and steady rate of advancement, this is challenging to accomplish with free-hand drilling. When hand drilling the bone, as would be performed clinically, the progression of the drill bit would be more load controlled rather than displacement controlled. While difficult to establish in a laboratory setting without reintroducing other variables of hand drilling, these differences could influence the drilling data and temperature changes noted in this study. Further investigation is required to develop a method to achieve these results in clinical patients.

Despite its design not changing in 60 years,[11] the standard surgical drill bit was superior to the acrylic drill bit and K-wire in several important parameters, with decreased maximum force, thermal change, and integral of force and displacement. Further studies and histopathology investigating screw tapping and insertion with different sized threads would be required to determine if a subsequent surgical step is more detrimental in damaging or weakening the bone. Alternatively, despite causing more damage to the bone, the relative flexibility and surrounding slack of fixation using K-wires may be what makes the fixation effective in the clinical setting. While locking screws are the most rigid of the constructs previously reported, they also fail in a catastrophic manner.[3,6] Constructs created to be less stiff but with adequate strength may improve the clinical failures reported.

This study is limited by its ex vivo nature, evaluating only the torsional strength of bone, with an axial preload of the assumed stance phase of the rabbit. Other forces on the bone in vivo could change the significance of these findings. Clinically, the motion of the drill cannot be completely stabilized, and the displacement rate cannot be controlled as in this study. However, controlling these variables allowed the study to evaluate the effects of drill bits or K-wire alone most accurately on the mechanical properties of the rabbit femora.

Rabbit bone poses numerous technical challenges due to its brittle nature and thin cortices. Based on the findings of this study, drilling while maintaining low bone temperature does not mechanically cause the clinical failure seen postoperatively when there is control of force and advancement during drilling. Further studies are required to evaluate the histologic implications of drilling, tapping, screw insertion, and the biomechanical strength of a full-fixation apparatus.

Acknowledgments

The authors thank Celina Bravo and Catalina Laughrin for their help with specimen dissection and histology sample preparation.

Disclosures

The authors have nothing to disclose. No AI-assisted technologies were used in the generation of this manuscript.

Funding

Supported by grants from the Center for Companion Animal Health, School of Veterinary Medicine, University of California, Davis. This study was funded by a resident grant from University of California, Center for Companion Animal Health (CCAH). Publication was funded by CCAH and University of California open access library fund.

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