

# Technical Errors May Affect Accuracy of Torque Limiter in Locking Plate Osteosynthesis

David D. Savin, MD, Simon Lee, MD, MPH, Frank C. Bohnenkamp, MD, Andrew Pastor, MD, Rajeev Garapati, MD, and Benjamin A. Goldberg, MD

## Abstract

In locking plate osteosynthesis, proper surgical technique is crucial in reducing potential pitfalls, and use of a torque limiter makes it possible to control insertion torque.

We conducted a study of the ways in which different techniques can alter the accuracy of torque limiters. We tested 22 torque limiters (1.5 Nm) for accuracy using hand and power tools under different rotational scenarios: hand power at low and high velocity and drill power at low and high velocity. We recorded the maximum torque reached after each torque-limiting event.

Use of torque limiters under hand power at low velocity and high velocity resulted in significantly ( $P < .0001$ ) different mean (SD) measurements: 1.49 (0.15) Nm and 3.73 (0.79) Nm. Use under drill power at controlled low velocity and at high velocity also resulted in significantly ( $P < .0001$ ) different mean (SD) measurements: 1.47 (0.14) Nm and 5.37 (0.90) Nm. Maximum single measurement obtained was 9.0 Nm using drill power at high velocity.

Locking screw insertion with improper technique may result in higher than expected torque and subsequent complications. For torque limiters, the most reliable technique involves hand power at slow velocity or drill power with careful control of insertion speed until 1 torque-limiting event occurs.

Proper surgical technique must be used to ensure that surgical fracture management is long-lasting. Plate implantation and screw implantation are among the most common orthopedic procedures performed. Plate and screw osteosynthesis can be done with nonlocking or locking plate and screw constructs or with hybrid fixation that incorporates both methods.

Nonlocking plate and screw osteosynthesis uses friction-fit for fixation. In osteoporotic bone, less torque is generated because of poor bone quality, and thus less friction force between plate and bone.<sup>1,2</sup> Locked plating has dramatically changed fracture management, especially in frail and comminuted osteoporotic bone, with significant advantages over conventional plating.<sup>3-7</sup>

Development of locked plating systems, including the Less Invasive Stabilization System (LISS; DePuy Synthes) with its soft-tissue and fracture-fragment preservation, has changed treatment of distal femur and proximal tibia fractures. Cole and colleagues<sup>8</sup> reported stable fixation and union in 97% of their patients. The LISS system proved to be stable, but there were cases of implant removal difficulty with this titanium construct. In 1 of the 10 cases in which the LISS plate was removed, 4 of the 11 locking screws were welded to the plate.<sup>8</sup>

Cold welding, in which similar metals are chemically bonded together under extreme pressure, is a complication associated with use of titanium-only plates and screws.<sup>9</sup> This process, which is more likely to happen if cross-threading occurs within the screw-plate interface, can make screw removal extremely difficult. Screw removal difficulty strips screw heads, and often the surgeon must use either metal cutting instruments or trephines to remove screw remnants, which often results in

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retained implant or debris and damage or necrosis to surrounding bone.<sup>9,10</sup>

Locking screws are often inserted under power with a torque-limiting device attached to the drill mechanism to reduce the risk of lock screw over-tightening and to try to prevent difficult implant removal. Although standard practice is to insert the screw and stop just before screw head engagement, with final tightening with a torque limiter and hand power, final tightening is often inadvertently done under power.<sup>3</sup> Most technique guides instruct surgeons how to insert screws under power while using a torque limiter, but the exact technique is not emphasized.

We conducted a study to determine if rotational speed of screw insertion affects maximum torque on screw with use of a torque limiter. We describe proper use of a torque limiter as well as possible pitfalls. We hypothesized that improper use would result in substantially higher than expected insertion torque.

## Materials and Methods

### Torque-Limiting Attachments, Torque Wrench, and Drill

The Small Fragment Locking Compression Plate System (Synthes) includes a 1.5-Nm torque-limiting attachment and quick-coupling wooden handles and Star Drive attachments. All devices in this study were in active use at 6 urban institutions (3 level I trauma centers, 2 level II trauma centers, 1 level III hospital). Permission to obtain and test each

device was granted by each institution.

A 0.25-inch dial torque wrench (751LDIN; CDI Torque Products) was purchased through an established distributor. The manufacturer includes a traceable certificate of accuracy to verify correct calibration. The torque wrench has a torque range of 0 to 9 Nm with visual increment demarcations of 0.2 Nm and a memory needle to retain maximum torque measurement. The same torque wrench was used in each experiment in order to maintain consistent measurements between devices. It was reset to zero after each use.

This study used a 0.5-inch, 19.2-V lithium drill (Craftsman C3) with 2 speed options: 0 to 440 rpm high torque and 0 to 1600 rpm high speed. This device provides variable torque output with a maximum output of 38.4 Nm. For this study, all measurements were done with the device on its high torque setting.

### Maximum Torque Determination for Different Scenarios

Each torque limiter was evaluated for variations in maximum torque under 4 different scenarios. In each scenario, the torque limiter was coupled to the Star Drive attachment and then to that scenario's rotating force. The completed system was then inserted into the torque wrench, which was secured to a flat working surface and rotated in accordance with each scenario; maximum torque was measured and recorded (**Figures 1, 2**).

A torque-limiting event was defined as a single audible click on the torque limiter.



**Figure 1.** Experimental setup: Synthes torque-limiting device with Star Drive attachment attached to quick-coupling wooden handle.



**Figure 2.** Experimental setup: Synthes torque-limiting device with Star Drive attachment attached to Craftsman C3 drill.

In scenario 1, each torque-limiting attachment system was attached to a quick-coupling wooden handle. The completed system was then rotated at controlled low velocity under hand power until 1 torque-limiting event occurred. This scenario was also used as an internal control to verify that the torque limiters were calibrated correctly.

In Scenario 2, the device was again attached to a quick-coupling wooden handle. The completed system was rotated at high velocity under hand power until multiple torque-limiting events occurred in a row. High velocity was defined as the operator freely rotating the wooden handle in a single action with full power resulting in multiple torque-limiting events.

In Scenario 3, the device was attached to a power drill braced to the flat working surface and rotated at low velocity under power until 1 torque-limiting event occurred.

In Scenario 4, the device was again attached to

a power drill braced to the flat working surface. The completed system was rotated at high velocity under power until multiple torque-limiting events occurred.

After each trial, we recorded maximum torque achieved before each device's torque-limiting event. Either an orthopedic surgery resident or a qualified medical student tested each torque-limiting device in each standardized testing scenario.

### Statistical Analysis

Experiments for each torque limiter were repeated for 3 trials of each of the 4 different scenarios. For comparative statistics between experiments, maximum torque measurements were expressed as means and SDs; 95% confidence interval (95% CI) was calculated and reported to determine extent of variation within a single group. One-way analysis of variance (ANOVA) and Tukey post hoc tests were performed between groups for comparison of the normally distributed data. Significance was set at  $P \leq .05$ .

### Results

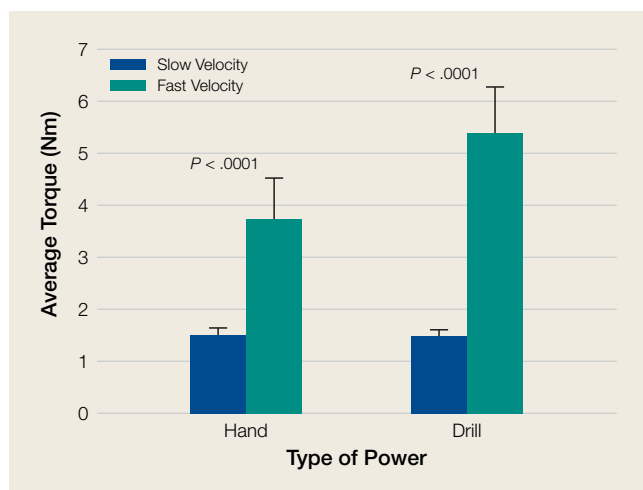
During simulation, we successfully measured maximum torque achieved with each torque limiter under the 4 different scenarios. All testing was done by 2 operators. ANOVA demonstrated significant ( $P \leq .001$ ) differences in torque among the scenarios.

In scenario 1, mean (SD) maximum torque under hand power at low velocity was 1.49 (0.15) Nm (95% CI, 1.43-1.55), near the advertised maximum torque of

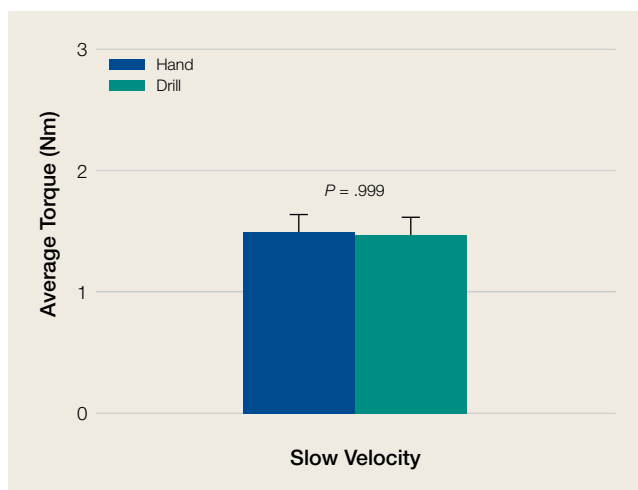
**Table. Maximum Torque Achieved With Synthes 1.5-Nm Torque-Limiting Device Under Hand and Drill Power at Slow and Fast Velocities (N = 22)**

Power	Maximum Torque (Nm)			
	Mean	Range	SD	95% CI
Hand				
Slow	1.49	1.25-1.93	0.15	1.43-1.55
Fast	3.73	2.27-5.53	0.79	3.33-4.13
Drill				
Slow	1.47	1.10-1.73	0.14	1.37-1.56
Fast	5.37	3.40-6.92	0.90	4.92-5.83

Abbreviations: CI, confidence interval; SD, standard deviation.



**Figure 3.** Mean maximum torque achieved under hand and drill power at slow (blue bar) and fast (green bar) velocities.



**Figure 4.** Mean maximum torque achieved under hand power (blue bar) and drill power (green bar) at slow velocity.

1.5 Nm, with relatively minimal variation between devices. This scenario confirmed proper calibration of properly used torque limiters. Mean maximum torque ranged from 1.25 to 1.93 Nm.

In scenario 2, mean (SD) maximum torque under hand power at high velocity was 3.73 (0.79) Nm (95% CI, 3.33-4.13), a 2.5-fold increase compared with scenario 1 ( $P < .0001$ ) (**Figure 3**). There also was an increase in variation of maximum torque between trials of individual devices and between different devices. Mean maximum torque ranged from 2.27 to 5.53 Nm.

In scenario 3, mean (SD) maximum torque under drill power at controlled low velocity was 1.47 (0.14) Nm (95% CI, 1.37-1.56), again near the advertised maximum torque of 1.5 Nm, with relatively minimal variation. Mean maximum torque ranged from 1.10 to 1.73 Nm.

In scenario 4, mean (SD) maximum torque under drill power at full power/high velocity was 5.37 (0.90) Nm (95% CI, 4.92-5.83), a 3.65-fold increase compared with scenario 3 ( $P < .0001$ ) (**Figure 3**). Mean maximum torque measured in 3 tests ranged from 3.40 to 6.92 Nm.

There was no significant difference in mean maximum torque between the scenarios of hand power at low velocity and drill power at low velocities ( $P = .999$ ) (**Figure 4**). Highest maximum torque from any device was 9.0 Nm (drill at full power). Results are summarized in the **Table**. There was no statistical significance in the test between the 2 test operators.

## Discussion

Maximum torque was measured using a torque-limiting attachment under 4 different simulated scenarios. Our goals were to determine if varying practice and rotational velocity would affect maximum insertional torque and to measure consistency among torque limiters. We designed the scenarios to mimic practice patterns, including hand insertion and power insertion of locking screws. Results demonstrated that misuse of a torque-limiting device may inadvertently produce insertional torque substantially higher than recommended. Highest maximum torque was 9.0 Nm, which is 6.0-fold higher than expected for a locking screw using a 1.5-Nm torque limiter.

Our study results showed that insertion under controlled hand power (and low-velocity drill power) until 1 torque-limiting event occurred produced the most consistent and predictable results. Insertion under drill power or high-velocity hand power produced multiple sequential torque-limiting events, yielding inaccurate insertion torque.

Low-velocity insertion under hand power, or carefully controlled drill power, consistently produced torque similar to advertised values.

Manufacturers' technique guides are available for proximal humerus locking compression plate (LCP) systems, small-fragment LCP systems, the Proximal Humeral Interlocking System (PHILOS; DePuy Synthes), and the LISS. These technique guides clearly state that insertion can be performed under power. Only the PHILOS and LISS guides state that insertion should be performed under power until a single click is heard or that final tightening should be completed under hand power. The proximal humerus LCP guide states that surgeons should insert the locking screw under power until the torque-limiting device clicks. The small-fragment LCP guide states that insertion under power should always be completed with the torque-limiting attachment; there is no mention of reducing power or a single click (this may give the surgeon a false sense of security).

Screw overtightening and head/thread stripping can make screw removal challenging.<sup>10</sup> Removal rates for LISS plates range from 8% to 26%, and removal is often reported as taking longer than the index procedure, with complication rates as high as 47%.<sup>11-13</sup> Bae and colleagues<sup>3</sup> reported significant difficulty in removing 24 of 279 self-tapping locking screws (3.5 mm).

It is important to note that these complications, most notably cold welding, are mostly associated with titanium locking plate and screw constructs. Although stainless steel constructs have gained favor, titanium constructs are still widely used around the world.<sup>14,15</sup>

In 10% of cases in a laboratory setting, insertion of a 3.5-mm locking screw at 4 to 6 Nm damaged the screw.<sup>9</sup> Removal of 3.5-mm locking screws had a stripping rate of 8.6%, and use of the torque limiter did not make removal easy all the time.<sup>3</sup> Torque limiters are set specific to each screw diameter to reduce the risk of damage/stripping or even overtightening. Even when a surgeon intends to stop a drill before locking, final tightening often inadvertently occurs under power.<sup>3</sup>

Cold welding is often described as a cause of difficult implant removal.<sup>3,12</sup> According to a newer definition, this process is independent of temperature and can occur when 2 metallic surfaces are in direct contact.<sup>16</sup> High contact pressures between 2 similar metals can lead to this solid state welding.<sup>17</sup> Theoretically, improper use of torque limiters can increase the risk of welding; however, it appears to be associated only with titanium locking plate and screw constructs.

Locked plating osteosynthesis is a valuable tool for fracture management, but improper use can have significant consequences, including morbid implant removal procedures, which are more difficult and time-consuming than the index surgery. We determined that proper use of torque limiters involves insertion under hand or power control at slow velocity until 1 torque-limiting event occurs. Many orthopedic surgeons may assume that torque limiters are accurate no matter how screws are inserted into locking plates. In addition, they may be unaware guidelines exist, as these are often deeply embedded within text. Therefore, we must emphasize that torque limiters can be inaccurate when used improperly.

One limitation of this study is that it tested only the Synthes 1.5-Nm torque-limiting attachment, though we can speculate that torque limiters designed for larger screws and limiters manufactured by different companies will behave similarly. Another limitation is that we did not obtain the hospitals' service records for the tested equipment and assumed the equipment was properly checked for accuracy by the providing company. However, we hypothesized that, if maintenance were an issue, then our results would not be similar across all sites tested.

These tests involved a torque limiter linked to a torque-measuring device and may not perfectly represent actual torque measured at the locked screw-thread interface. However, we think our construct accurately determines the torque produced at the level of the driver tip. Also, we can speculate that the torque produced with improper use will lead to the complications mentioned and demonstrated in previous studies. Welding of the screw-plate interface may simply be a result of improper trajectory and cross-threading. However, if we assume that torque limiters prevent excessive torque no matter how they are used, high insertion speeds may compound the effect of welding. Additional biomechanical studies with full locked plate osteosynthesis constructs on bone specimens are planned to further characterize the potential complications of this issue.

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Dr. Savin is an Orthopedic Resident Physician, Department of Orthopedic Surgery, University of Illinois, Chicago, Illinois. Dr. Lee is an Orthopedic Resident Physician, University of Michigan, Ann Arbor, Michigan. Dr. Bohnenkamp is in practice at Crystal Lake Orthopedics, Crystal Lake, Illinois. Dr. Pastor is in practice at Puget Sound Surgical Center Orthopedics, Woodinville, Washington. Dr. Garapati is Clinical Instructor, Illinois Bone and Joint Institute, Morton Grove, Illinois. Dr. Goldberg is Chief of

Shoulder and Elbow Services, Department of Orthopedic Surgery, University of Illinois, Chicago, Illinois.

Address correspondence to: David D. Savin, MD, Department of Orthopedic Surgery, University of Illinois, 835 S Wolcott Ave, Room E270, M/C 844, Chicago, IL 60612 (tel, 818-523-2757; fax, 312-996-9025; email, ddsavin@gmail.com).

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