ORIGINAL ARTICLE

Factors affecting accurate drill sleeve insertion in locking compression plates

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Summary

Background: Accurate positioning of locking screws depends on accurate insertion of the drill sleeve into the locking compression plate (LCP). The purpose of the present study was to determine factors affecting accurate drill sleeve insertion.

Hypothesis: Tilting and shallow locking screw holes and combination-type holes make it difficult to insert the drill sleeve in the LCP.

Materials and methods: Twenty-seven 3.5 mm LCP metaphyseal insertion holes were selected (Philos®, LPHP®, DMTP®, low-band DMTP® [Synthes, Solothurn, Switzerland]). Two orthopedic surgeons checked the time taken for accurate insertion of the drill sleeve into the plate. Variables relating to LCP drill sleeve insertion time were analyzed.

Results: It took an average 6.6 seconds to insert the drill sleeve accurately in the holes. Insertion time increased with the tilt of the screw hole but not with shallowness. Insertion time in combination-type holes was longer (8.8 seconds) than in single locking holes (5.6 seconds).

Discussion: Tilted screw holes and combination-type holes affect the insertion of the drill sleeve into 3.5 mm LCPs.

Level of evidence: Level IV, experimental study.

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Introduction

Fixation by locking compression plate (LCP) is useful, especially in osteoporotic or highly comminuted fractures, as the bone-to-plate interface is not dependent on screw purchase in the bone [1–4]. Unlike the conventional plate, where fixation relies on friction between the plate and the bone, the LCP achieves fracture fixation by angular stability from a plate/screw construct with the locking screw hole and the locking screw head [5,6]. Therefore, accurate insertion of the LCP drill sleeve into the locking screw hole is important for achieving angular stability [7]. However, when treating fracture by LCP, our team had occasional difficulties in ensuring the accurate insertion of...
the drill sleeve into the LCP, with an incorrectly inserted locking screw seen on postoperative X-ray. In addition, removing the LCP has been recognized as another problem, and one cause of difficulty of removal was found to be incorrect insertion of the locking screw, damaging the thread of the locking screw hole and the locking screw head [8,9].

LCPs are becoming popular in fracture treatment, and the widespread use of minimally invasive plate osteosynthesis (MIPO) increases the use of LCPs. We hypothesized that accurate insertion of the drill sleeve to the LCP was affected by the following factors: screw hole tilt, screw hole depth, and whether it is a combination-type hole (figure-of-eight hole with one locking hole and one standard hole) or single pure locking hole. The purpose of this study was to identify the factors that affect accurate insertion of a 3.5 mm LCP drill sleeve.

Materials and methods

Two types of 3.5 mm LCP were selected for the distal tibia (Distal Medial Tibia Plate [DMTP®], and low band DMTP® [Synthes, Solothurn, Switzerland]) and 2 types for the proximal humerus (Philos®, and Locking Proximal Humerus Plate [LPHP®] [Synthes, Solothurn, Switzerland]). The study focused on screw holes in the metaphyseal area, and an identification number was allotted to each of 27 target screw holes in total: Philos, 9; LPHP, 5; DMTP, 4; and low band DMTP, 9 (Fig. 1). The 3.5 mm LCP was chosen because improper positioning of the drill sleeve is encountered mainly for small-diameter targeting devices and screws [8].

Two orthopedic surgeons performed insertion of the LCP drill sleeve into the 27 target screw holes of 4 plates; insertion into each hole was performed 20 times by each investigator. Given that LCPs are used with minimally invasive techniques, only the plate applicable to the metaphysis was exposed, the rest being embedded in a cotton roll to ensure it was invisible (Fig. 2), and the time taken for accurate insertion of the LCP drill sleeve in an environment similar to that of the actual operation was measured. Time taken for accurate insertion was defined as the time measured after confirmation that the drill sleeve was firmly inserted in the locking hole but without instability, as a result of defective insertion of the drill sleeve. While one tester carried out the test, another tester held the cotton roll firmly on the table. The tester inserted the LCP drill sleeve without touching the LCP directly. Accurate locking screw insertion was determined by comparison to the position of the LCP drill sleeve, which should have been inserted exactly fitting the hole after attaching the guide block.

The tilt of the locking screw hole was measured as the distance from the vertical of the metal plate. Then, the distance between the vertical down to the table from the top of an accurately inserted LCP drill sleeve and the center of each hole was measured so that it could be used as an indication of how far the hole was tilted with respect to the vertical down to the table (Fig. 3). This distance ranged from 0° (vertical) to 28 mm (maximal tilt with respect to the plate), and was converted by trigonometry to an angular value, which ranged from 0° to 57°. Hole depth was measured at the thinnest point in the threaded line, vertical to the spiral, using an electronic vernier caliper that

Figure 2  Design simulating minimally invasive technique. The metaphyseal part of the plate was exposed and the diaphyseal part was embedded in cotton roll.

Figure 1  Identification numbers allotted to the 27 target screw holes. Philos®, 9, LPHP® 5, DMTP® 4, low band DMTP® 9 holes.
Table 1 Depth of each screw hole.

<table>
<thead>
<tr>
<th>Hole number</th>
<th>Philos® (mm)</th>
<th>LPHP® (mm)</th>
<th>DMTP® (mm)</th>
<th>Low band DMTP® (mm)</th>
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</thead>
<tbody>
<tr>
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<td>2.20</td>
</tr>
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<tr>
<td>8</td>
<td>3.10</td>
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<td>2.40</td>
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<tr>
<td>9</td>
<td>3.10</td>
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</table>

Table 2 Insertion time of locking sleeve into each screw hole (Mean time for 40 measurements per hole.).

<table>
<thead>
<tr>
<th>Hole number</th>
<th>Philos® (sec)</th>
<th>LPHP® (sec)</th>
<th>DMTP® (sec)</th>
<th>Low band DMTP® (sec)</th>
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measured to the nearest 1/100 mm. The shallowest hole was 1.77 mm, and the deepest 3.18 mm (Table 1). There were 9 combination-type screw holes and 18 single locking screw holes.

Multivariate logistic regression was performed to explore variables related to drill sleeve insertion time. All statistical analyses used the SPSS package (version 14.0; SPSS, Chicago, IL, USA), with statistical significance defined as $P<0.05$.

Results

The mean time taken for accurate insertion of the LCP drill sleeve into a screw hole was 6.6 seconds (1.6–12.4 seconds) (Table 2). Inter-rater reliability as estimated by interclass correlation coefficient was 0.81, indicating high reproducibility. The regression coefficient ($\beta$) correlating screw hole tilt and insertion time was 0.159 (statistically significant: $P=0.024$): time taken was longer for greater tilt (Fig. 4). Screw hole depth was not a significant factor ($\beta = -0.435$ and $P = 0.784$). In combination-type holes, mean insertion time was significantly longer than in single locking screw holes (8.8 versus 5.6 seconds; $\beta = 3.271$ and $P = 0.010$) (Table 3).

![Figure 3](image1.png)

**Figure 3** Measurement method for locking hole tilt.

![Figure 4](image2.png)

**Figure 4** Relation between screw hole tilt angle and insertion time.
Discussion

Screw anchorage stability is essential in implants based on angular stability [7]. However, orthopedic surgeons experienced difficulty in accurately inserting the LCP drill sleeve, and the authors also had occasionally found inaccurate insertions of locking screws in their holes on postoperative radiography. In particular, inaccurate insertion in the metaphysis could interrupt insertion of another locking screw, resulting in failure to complete insertion to a sufficient length.

According to our own unpublished data, 74 (2.8%) out of 2,644 locking screws (2.7 mm, 3.5 mm and 5.0 mm screws) were not inserted correctly in the LCP in the diaphyseal area. Considering that the team had used the LCP from its launch period, with more than 10 years’ experience, and that a higher failure rate could be expected in locking screws in the metaphyseal area, due to the varying angles of the locking screws, the actual rate of incorrect insertion would likely be higher than the above findings.

Kaab et al. reported that 5.0 mm locking screws were associated with significantly decreased fixation strength when tilted more than 5° compared to accurately inserted screws [7]. Improper locking screw insertion could lead to screw loosening and impaired angular stability. They recommended the use of a drill sleeve-aiming device to provide optimal angular stable fixation to limit the risk of screw loosening since it is difficult to insert the locking screws precisely without a drill guide.

Inaccurately inserted locking screws might induce a “cold welding” phenomenon, which becomes a big problem for the removal of the LCP [10]. However, Ehlinger et al. reported that this phenomenon did not exist in the metallic sense of the term in the context of screws in the plate [8]. Difficulty in removing locking screws is caused by technical errors such as inappropriate insertion of the drill sleeve, over-tightening the screw when a torque-limiting screwdriver is not used, or using a worn screwdriver. They insisted that it is necessary to use drill sleeves and torque-limiting screwdrivers to avoid stripping the screw heads and blocking the screws. Hamilton et al. reported 1 case in which screws seemed to be cross-threaded and difficult to remove [11]. This happens more often with minimally invasive techniques, and can result in stripping the screw heads and angulation of the screws because of the difficulty of judging orientation without direct visualization [4]. Despite the use of drill guides, inappropriate screw insertion axes may occur with minimally invasive techniques and result in screw cross-threading or stripping of the screw. This cannot be checked by simply feeling the purchase of the locking screw in the bone since locking screws always feel tight [4]. Accurate screw insertion is essential, and surgeons should check correct insertion on intraoperative radiography when there is any doubt.

In the present study, the more the screw was tilted, and in case of combined-type screw holes, the longer accurate insertion took in 3.5 mm LCPs. This longer insertion time entails a greater risk of incorrect insertion. As exact insertion can be obtained by use of a guide block, a new model of LCP, with accurate insertion of the locking screws using a guide block, will be helpful for shortening insertion time, as well as for correct insertion of the locking screw.

The present study involved certain limitations. The number of threads composing a complete circle would have been a useful variable, but no information was available on this; screw hole depth was therefore used as a variable. The authors tried to reproduce a minimally invasive fracture treatment technique, similar to the actual operating room situation; but performing the study with waterless bare hands without surgical gloves proved easier than LCP drill sleeve insertion in the real-life conditions of the operating room. A further study limitation was the difference in tension and feeling of the cotton roll compared to the actual tension and feeling of soft tissues.

In conclusion, screw hole tilt angle and combination holes affect the insertion of the LCP drill sleeve into 3.5 mm LCPs. One should be very careful with the insertion of the locking sleeve, especially in tilted screw holes or combination holes.

Disclosure of interest

The authors declare that they have no conflicts of interest concerning this article.

References


