The incidence of fragility fractures has increased in recent years because of the aging of the population. Extracapsular fractures account for 65% of all proximal femoral fractures, and the critical issue in the treatment of extracapsular fractures is instability as a result of comminution and rupture of the posteromedial cortex. The reoperation rate for mechanical complications can be as high as 8%, including hardware problems and blade cutout with a risk of acetabular penetration. Greater instability and greater severity of osteoporosis are associated with a higher risk of mechanical complications. Therefore, many types of implants have been developed as intramedullary stabilizers. The screw-type implant has been used for many years, and a number of versions have been developed. A feature that is common to all versions is the type of screw used for the femoral neck. This type of screw does not rotate in the nail because of a locking bolt, but moves laterally in specially integrated grooves. With the helical blade type, the New Proximal Femoral Compaction Blade Provides Strong Antirotation Stability of the Femoral Head

Shinya Hayashi, MD, PhD; Yukiaki Hirata, MS; Daiki Okamoto, BS; Satoshi Kakunai, PhD; Shingo Hashimoto, MD, PhD; Koji Takayama, MD, PhD; Tomoyuki Matsumoto, MD, PhD; Takahiro Niikura, MD, PhD; Takaaki Fujishiro, MD, PhD; Takafumi Hiranaka, MD, PhD; Kotaro Nishida, MD, PhD; Ryosuke Kuroda, MD, PhD

abstract

This study investigated the mechanical properties of a new rectangular compaction blade and compared this blade with other types of nail. Three types of nail were tested: the Magnum lag screw (Robert Reid Inc, Tokyo, Japan), proximal femoral nail, and Magnum Fid blade (Robert Reid Inc). The nails were inserted into solid rigid polyurethane foam, and the torsional moments were loaded with an Instron testing machine (Instron, Kanagawa, Japan). The force curve was recorded, and the average maximum torque was calculated from this curve. A simulation study was performed with finite element models to determine the mechanism underlying differences in rotational stability. Mechanical testing showed that the new compaction blade had stronger resistance against rotational force than the helical blade and lag screw implants. Finite element analysis also showed that the new compaction blade had stronger resistance to migration of the polyurethane foam cylinder than the other implant types. In addition, the new compaction blade had strong rotational stability. This implant should be useful for the treatment of unstable trochanteric fracture in patients with osteoporosis. [Orthopedics. 2017; 40(3):e491-e494.]
load carrier for the femoral neck is a helical blade that provides rigid rotational stability.\(^7\)\(^,\)\(^8\) The dual femoral neck screw type, which has a smaller unthreaded bolt cranial to the femoral neck screw to prevent rotation of the main proximal fragment, also provides rigid rotational stability.\(^9\) The use of 2 femoral neck screw implant components has been successful, but problems include a Z effect, whereby the inferior lag screw migrates laterally and the superior lag screw migrates medially during physiologic loading.\(^10\) Conversely, the compaction blade-type implant uses a unique geometric profile of the femoral head stabilizer that is designed as a double T-blade.\(^11\)

The newly developed Magnum Fid blade (Robert Reid Inc, Tokyo, Japan) uses a compaction blade-type implant for the femoral head stabilizer that is designed as a rectangular blade. The new Magnum nail Fid blade has already been introduced in Japan for commercial use and will be available worldwide in several years. The Magnum nail contains nails, distal bone screws, cannulated lag screws or cannulated blades, and set screws, and it is similar to other intramedullary nail systems. The authors hypothesized that the rectangular compaction blade is advantageous as an intramedullary stabilizer, especially for rotation. This study investigated the mechanical properties of the new rectangular compaction blade and compared them with those of other nail types.

### Materials and Methods

#### Mechanical Testing

Composite cylinders made of solid rigid polyurethane foam (diameter, 40x75 mm; wall thickness, 9.1 mm; density, 20 per cubic foot; Sawbones Worldwide Pacific Research Laboratories, Inc, Vashon, Washington) were used to simulate spongy osteoporotic bone. The mechanical properties of this material are similar to those of materials used in a previous report and are believed to be within the osteoporotic to normal range of human bone (Figure 1A).\(^12\)\(^-\)\(^14\)

Three nail types were tested for this study: the Magnum lag screw (Robert Reid Inc), the proximal femoral nail antitrotation (PFNA) helical blade (DePuy Synthes, Warsaw, Indiana), and the Magnum Fid blade (Figure 1B). All nails were 90 mm long and were manually inserted into the center of the polyurethane foam cylinders to a consistent depth of 65 mm, according to manufacturer instructions. The cylinders containing the implants were fixed to a custom-built testing machine (Figure 2A). The torsional moments were loaded with an Instron testing machine (Instron, Kanagawa, Japan) (Figure 2B). To test rotational stability, a custom-built testing machine was designed to convert the unidirectional motion of the Instron machine to rotational movement that turned the implants within the test materials. The force curve was recorded, and average maximum torque was calculated from this curve. The descending speed of the Instron head was 1 mm/min, and it stopped after it reached a linear rate.

All data are expressed as mean±SD unless otherwise indicated. For normally distributed data, 2-tailed Student’s \(t\) test was used to compare the 2 groups. \(P<.05\) was considered significant.

#### Finite Element Modeling Analysis

To assess the strength of the rotational stability of the Magnum Fid blade, a simulation study was performed with fi-
nite element modeling. A surface grid was generated from triangular elements with ANSYS (ANSYS Japan, Tokyo, Japan), a commercial processor, and the data were routinely entered into the finite element program system (ANSYS), which formed the basis for finite element volume modeling. The mechanical properties of the composite cylinders are shown in Figure 1A, and the properties of the Magnum nails and the custom-built testing machine are shown in Figure 3A. The frictional contact constant was assumed to be 0.3. The finite element models were subjected to a rotational load of 1 N to analyze small loading changes around the nail. The basement of the nail was constrained in all axes, and the custom-built testing machine allowed the cylinders to rotate around the nail. Displacement of the axial plane of the polyurethane foam cylinder at a consistent depth of 42 mm was analyzed.

RESULTS

Resistance to Migration of Foam Cylinders

Color plots were used to illustrate the migration distance of the polyurethane foam cylinders with the Magnum lag screw and Fid blade by finite element analysis (Figure 3B). The migration distance was markedly different between the Magnum lag screw and the Fid blade (Figure 3B). The migration distance of the Magnum lag screw was greater than 0.003 mm in almost all simulations, but the migration distance of the Fid blade was less than 0.003 mm in almost all simulations. Further, the migration distance was approximately 0.03 mm around the nail with the Fid blade, but it was approximately 0.06 mm around the nail with the Magnum lag screw. These results show that the new compaction blade has strong rotational stability.

Resistance Against Rotational Force

Among the tested screws, the Magnum Fid blade had the highest resistance against rotational force. Average maximal rotational resistance force was 6.3±0.38 Nm for the Magnum lag screw, 10.0±0.97 Nm for the Magnum Fid blade, and 8.3±0.86 Nm for the PFNA (Figure 4). Resistance force for the Magnum Fid blade was significantly greater than that for the Magnum lag screw (P=.010) or PFNA (P=.001).

DISCUSSION

The use of a blade implant for osteoporotic fractures is gaining acceptance. In a clinical study, Simmermacher et al reported that the helical blade (PFNA) helped to prevent early rotation of the head and neck fragment in unstable trochanteric fractures, and the implant was
useful for the treatment of these fractures, even in osteoporotic bone. In a biomechanical study, Strauss et al.\(^8\) showed that fixation of the femoral head with a helical blade offered biomechanical advantages for fixation with a standard sliding hip screw in a cadaveric model of unstable intertrochanteric hip fracture.

O’Neill et al.\(^10\) compared the biomechanics of a standard dynamic hip screw and a dynamic hip screw on the blade with regard to resistance to pushout, pullout, and torsional stability. This study found that the dynamic hip screw blade had greater resistance to pushout and rotational force.\(^16\) The gliding nail, which was designed as a double-T blade, is conceptually the most similar implant to the Magnum Fid blade.\(^11\) Based on finite element analysis, Helwig et al.\(^17\) reported that rotational force on the blade of the gliding nail was less than that on the screw of the Gamma nail (Stryker Orthopaedics, Mahwah, New Jersey), making the gliding nail advantageous for rotational stability.

Consistent with previous reports,\(^7,8,16,17\) the current authors used mechanical testing and finite element analysis to show that the Magnum Fid blade had greater resistance against rotational force than the Magnum lag screw. In addition, they showed that the Magnum Fid blade had greater rotational resistance than the PFNA. This result may be dependent on surface shape. The Magnum Fid blade has a rectangular shape, and each surface has a wider area than that of helical blade-type implants. Thus, differences in surface shape may contribute to rotational stability. Further, the insertion method used for the Magnum Fid blade was direct impaction, which may lead to greater resistance to torque or displacement.

**Limitations**

A limitation of this study is that the authors did not determine the stability of the lag screw relative to the nail or the stability of the nail relative to bone. Further, the authors did not test other types of nails. These factors could affect rotational stability in vivo.

**Conclusion**

The current study showed that the new compaction blade, the Magnum Fid blade, had strong rotational stability in vitro and in simulation tests. This type of implant may be useful for the treatment of unstable trochanteric fractures in patients with osteoporosis.

**References**