Smart Toe® Implant Versus Buried Kirschner Wire for Proximal Interphalangeal Joint Arthrodesis: A Comparative Study

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Abstract

The surgical correction of hammer digits offers a variety of surgical treatments ranging from arthroplasty to arthrodesis, with many options for fixation. In the present study, we compared 2 buried implants for arthrodesis of lesser digit deformities: a Smart Toe® implant and a buried Kirschner wire. Both implants were placed in a prepared interphalangeal joint, did not violate other digital or metatarsal joints, and were not exposed percutaneously. A retrospective comparative study was performed of 117 digits with either a Smart Toe® implant or a buried Kirschner wire, performed from January 1, 2007 to December 31, 2010. Of the 117 digits, 31 were excluded because of a lack of 90-day radiographic follow-up. The average follow-up was 94 to 1130 days. The average patient age was 61.47 (range 43 to 84) years. Of the 86 included digits, 48 were left digits and 38 were right. Of the digits corrected, 54 were second digits, 24 were third digits and 8 were fourth digits. Fifty-eight Smart Toe® implants were found (15 with 19-mm straight; 2 with 19-mm angulated; 34 with 16-mm straight; and 7 with 16-mm angulated). Twenty-eight buried Kirschner wires were evaluated. No statistically significant difference was found between the Smart Toe® implants and the buried Kirschner wires, including the rate of malunion, nonunion, fracture of internal fixation, and the need for revision surgery. Of the 86 implants, 87.9% of the Smart Toe® implants and 85.7% of the buried Kirschner wires were in good position (0° to 10° of transverse angulation on radiographs). Osseous union was achieved in 68.9% of Smart Toe® implants and 82.1% of buried Kirschner wires. Fracture of internal fixation occurred in 12 of the Smart Toe® implants (20.7%) and 2 of the buried Kirschner wires (7.1%). Most of the fractured internal fixation and malunions or nonunions were asymptomatic, leading to revision surgery in only 8.6% of the Smart Toe® implants and 10.7% of the buried Kirschner wires. Both the Smart Toe® implant and the buried Kirschner wire offer a viable choice for internal fixation of an arthrodesis of the digit compared with other studies using other techniques.

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piece design, avoiding the weak points created by screws and resulting from other 2-part interlocking devices (2,4,8,13,14). The intramedullary design avoids implant exposure complications such as pin tract infection or sensitivity to the distal digit. Additionally, the Smart Toe® design provides frontal plane stability, preventing rotational motion at the arthrodesis site (4–6,9,14,21). Studies of the Smart Toe® implant have demonstrated consistent results with few complications, even in patients with diabetes (7,8,13,18).

In the present study, we compared 2 unique techniques for intramedullary fixation (the buried K-wire and the Smart Toe® implant) to determine which method leads to fewer complications and a less frequent need for postoperative surgical revision. The K-wire was buried in the same fashion as the Smart Toe® implant. In our study, the K-wire has been used only to fixate the proximal interphalangeal joint of the digit and has neither invaded the DIPJ nor exited the distal digit percutaneously.

Patients and Methods

We performed a retrospective chart review of patients who had undergone hammer digit correction with arthrodesis (the surgical immobilization of a joint so that the bones grow solidly together) with either a Smart Toe® implant or a buried intramedullary K-wire. All procedures were performed by the same operating surgeon. Four types of Smart Toe® implants were used: 19 mm and 16 mm and either straight or angulated (10° of plantarflexion). Included in the study were surgeries performed by the same surgeon on patients aged 18 years or older, who had undergone correction of a hammer digit with either method from January 1, 2007 to December 31, 2010. The exclusion criterion was the absence of radiographic follow-up at 90 days to check for osseous union.

The data collected included gender, age, medical history (diabetes mellitus, osteoporosis/osteopenia, inflammatory disease requiring steroid use, psychiatric disorders, peripheral arterial disease, coronary artery disease), chief complaint, previous foot surgery, smoking status and packs per day, revision digit surgery, internal fixation, duration of postoperative follow-up, malunion and a less frequent need for postoperative surgical revision. The study included 117 digits treated with the Smart Toe® implants and 28 received buried K-wires (in 22 digits), resulting in 46 Smart Toe® implants and 28 K-wires. A total of 51 (87.9%) of Smart Toe® implants and 24 (in 22 digits) of buried K-wires were in a good position (0° to 10° of transverse angulation). Osseous union was achieved in 68.9% of Smart Toe® implants and 82.1% of buried K-wires; 50% of the 19-mm angulated and 57.1% of the 16-mm angulated implants resulted in fibrous union. Fixation of internal fixation occurred in 12 (20.7%) of the Smart Toe® implants and 2 (7.1%) of the buried K-wires. Of the 12 fractured Smart Toe® implants, 7 (58.3%) were 16-mm straight, 3 (25%) were 16-mm angulated, 2 (16.7%) were 19-mm straight, and 0 were 19-mm angulated. Revision surgery was needed in 5 (8.6%) of the Smart Toe® and 3 (10.7%) of the buried intramedullary K-wire implants.

Although not statistically significant, the research showed a substantial (clinically significant) amount of fractured implants in the Smart Toe® group (12 [20.7%] of Smart Toe® group compared with the buried K-wire group (12 [20.7%] of Smart Toe® and 2 [7.1%] of buried K-wire implants). Also, more cases achieved osseous union in the buried K-wire group (82.1%) than in the Smart Toe® group (68.9%). Even with the greater fracture and nonunion rates with the Smart Toe®, the rate of revision surgery was close to equal (8.6% and 10.7%; Fig. 4).

Discussion

Many fixation options for arthrodesis of a digit have been documented. Our study found no statistically significant difference between a Smart Toe® implant and a buried intramedullary K-wire with respect to the complication and revision rates. Thus, a K-wire using an intramedullary technique similar to that for the Smart Toe® implant can provide similar outcomes. With the increasing healthcare costs and lower reimbursement rates, surgeons should be aware of these cost-saving techniques.

Although not statistically significant, the Smart Toe® did have a greater rate of radiographic nonunion, defined as the absence of bone bridging the arthrodesis site.

Table 2

<table>
<thead>
<tr>
<th>Fracture and revision surgery</th>
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### Fixation Method

<table>
<thead>
<tr>
<th>Fractures/Total Fixation Type (%)</th>
<th>Needed Revision Surgery (%)</th>
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</thead>
<tbody>
<tr>
<td>K-wire</td>
<td></td>
</tr>
<tr>
<td>Smart Toe® 19-mm straight</td>
<td>2/28 (7.1)</td>
</tr>
<tr>
<td>Smart Toe® 19-mm angulated</td>
<td>0/2 (0.0)</td>
</tr>
<tr>
<td>Smart Toe® 16-mm straight</td>
<td>7/34 (20.6)</td>
</tr>
<tr>
<td>Smart Toe® 16-mm angulated</td>
<td>3/7 (42.9)</td>
</tr>
<tr>
<td>Total Smart Toe®</td>
<td>12/58 (20.74)</td>
</tr>
</tbody>
</table>

Abbreviation: K-wire, Kirchner wire.

Data presented as n (%).
osseous healing within a 3-month period, than the buried K-wire. This might have resulted from their ability to resist frontal micromotion and secondary bone healing. Finally, if full compression from the device was not achieved, the device could inadvertently hold the site distracted. However, the revision rates were similar for both devices.

Our study revealed a 68.8% radiographic osseous union rate with the Smart Toe® implant, significantly lower than that reported by previous studies of this implant. Roukis (18) used the Smart Toe® for digital arthrodesis in a neuropathic diabetic population and reported fusion for 28 of 30 digits (93%). Augoyard et al (1) reported a 97% union rate with 32 Smart Toe® implants, with the remaining asymptomatic. Even with the relatively high fibrous union rate in this study, most were asymptomatic. Only 8.6% of the Smart Toe® implants needed revision surgery.

The fracture rate of the Smart Toe® implant was an impressive 20.7% (12 of 58). Although the sample size of the K-wire group was approximately one half that of the Smart Toe® group, the fracture rate of the K-wires in our study was significantly lower, 7.1% (2 of 28). Roukis (18) reported no fracture in 30 corrected toes of patients with diabetic neuropathy. The patients in that study were admitted to the hospital with orders for bed rest for 5 to 7 days and were kept strictly non-weightbearing on the operated side. In our study, the patients were non-weightbearing or weightbearing, depending on the other forefoot and rearfoot procedures performed. None of our patients required inpatient hospitalization immediately after surgery.

In our study, the most common fracture site of the Smart Toe® implant was at the thinner distal and proximal legs, which might

Fig. 1. Distal fracture after Smart Toe® implant of bilateral fourth digits. Proximal placement of left second digit implant.

Fig. 2. Proximal fracture of Smart Toe® implant.

Fig. 3. Fractured Smart Toe® implant after removal from toe.

Fig. 4. When combining the less than optimal outcomes of fracture, nonunion, and revision surgery, 52.1% of Smart Toe® and 33.3% of K-Wire had at least 1 of these outcomes.
have been secondary to the legs not being as strong, resulting in lower resistance to stress, even with a uni-body construction. Fracture could also have occurred because of improper implantation of the Smart Toe® implant during compression of the arthrodesis site over the distal legs. The Smart Toe® implant can be inadvertently pushed further into the proximal phalanx canal (Fig. 1), owing to overzealous broaching techniques or osteoporotic bone. These can, in turn, place the Smart Toe® implant in a less than ideal position. The result will be increased stress on the distal thinner legs, with fracture as the final outcome. Since our study was performed, the Smart Toe® implant has been purchased by Stryker Osteosynthesis, and the implantation technique has been altered, with the incorporation of a new design that uses a pin within the central aspect of the implant for prevention of the abovementioned migration into the proximal phalanx. To explain the proximal leg fractures, the size of the implant used could have been too short or too long (16 mm versus 19 mm), which might place more torque on the proximal legs. Malposition of the implant could also result in too long (16 mm versus 19 mm), which might place more torque on fractures, the size of the implant used could have been too short or migration into the proximal phalanx. To explain the proximal leg with the incorporation of a new design that uses a pin within the Osteosynthesis, and the implantation technique has been altered, with the incorporation of a new design that uses a pin within the central aspect of the implant for prevention of the abovementioned migration into the proximal phalanx. To explain the proximal leg fractures, the size of the implant used could have been too short or too long (16 mm versus 19 mm), which might place more torque on the proximal legs. Malposition of the implant could also result in breakage. The Smart Toe® implant II is now available in size increments of 15, 16, 19, 20, 21 and 22 mm, with straight and angulated options. Measuring the length of the proximal and middle phalanx during preoperative planning will determine the estimated size of the implant needed for final formal fixation. Additional study with evaluation of the Smart Toe® implant II compared with the original Smart Toe® implant used in our study is needed to determine whether the pin will decrease the overall complication rate and subsequent fracture rate. The buried K-wire did not fracture as often; however, it did present with its own complications. The K-wires migrated from the intramedullary canal and even protruded from the bone in some cases.

Creighton and Blustein (6) researched buried K-wires in digital fusion. The K-wire is buried just under the skin of the distal phalanx and crossed the DIPJ. This technique was used to decrease the potential for pin tract infections from percutaneous K-wires. Of the buried K-wires, 33% had to be removed during revision surgery because they had begun to extrude from the skin. When the pin starts to extrude, pin tract infections become a concern, prompting their removal. Caterini et al (4) used an intramedullary cannulated screw for arthrodesis. Revision surgery to remove the screws was necessary because of persistent pain at the tip of the toe, where the head of the screw was located. Of the 51 screws implanted, 7 (13.7%) were removed during revision surgery. Using our true buried technique will avoid these complications.

A likely limitation of our study was the small sample size. With a larger sample size, it is possible that statistically significant differences might have been identified. Longer follow-up might help determine the progression of nonunion to osseous union if given more time. A more systematic postoperative radiographic plan to evaluate the arthrodesis site for a longer period would make data collection easier to compare. Additionally, our study only evaluated postoperative radiographs in an anteroposterior position, measuring the transverse plane of the digit corrected. Rotational or sagittal deformity could not be measured in our study because of the overlapping of the surrounding digits on the lateral foot radiographs. Radiographic evaluation in medial oblique, lateral oblique, and lateral projections with the corrected digit isolated or elevated would allow even more detailed evaluation in other planes. Advanced imaging (computed tomography and magnetic resonance imaging scans of the digits) might provide more detailed information on union rates; however, these methods could have limitations owing to metallic internal fixation effects on the images. Furthermore, we did not have some information that reasonable surgeons would consider important, such as smoking data, body mass index, and other independent variables. Additionally, the surgeons who performed the surgery also measured the outcomes, and this is always understood to convey certain biases.

In conclusion, many options are available for hammertoe correction using intramedullary fixation. Each product has its own advantages, disadvantages, and learning curve for successful implantation and outcomes. As with any surgical intervention, patient selection and thorough surgical planning to account for potential complications is critical.

References

19. Smart Toe Intramedullary Memory Implant. Surgical Technique. MMI–USA Foot and Ankle.