Pinning across the Metatarsophalangeal Joint for Hammertoe Correction: Where Are We Aiming and What Is the Damage to the Metatarsal Articular Surface?

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A hammertoe is a lesser toe deformity that is characterized by flexion of the proximal interphalangeal joint (PIP), and, in many cases, the metatarsophalangeal joint (MTP) is hyperextended and the distal interphalangeal joint is in an extended, flexed, or neutral position (1–3). Hammertoe deformity can present in 1 or multiple toes, with varying degrees of severity (4), most commonly affecting the second toe (4,5). The condition develops insidiously over time, with an increasing incidence between the fourth and seventh decades of life (5). Patients often present with pain and pressure over the dorsal aspect of the PIPJ. Initially, conservative treatments, such as shoe modification, padding, and physical therapy, can be used. In patients with continued pain refractory to conservative management, surgical intervention should be considered. Identifying the etiology of the deformity is a key component in preventing its progression and determining the proper treatment.

Hammertoe deformity is multifactorial in origin. The causes can be both intrinsic and extrinsic in nature. Given the higher incidence of lesser toe deformities in women, fashion footwear has been implicated as a primary contributor (1–3,6). Additional causes include trauma (7), inflammatory arthritis (1), neuromuscular and metabolic diseases (7,8), and patient anatomy, specifically, longer toes (1,4). Once the causation has been identified, the proper treatment can be employed.

Although mild flexible deformities can become asymptomatic with passive manipulation and bracing, the more severe, fixed deformities often require surgical intervention. Surgical correction of hammertoe is best achieved with PIPJ resection arthroplasty or arthrodesis (8,9). Fusion has been credited to provide more predictable results in multiple planes with lower recurrence rates (10). According to the criteria defined by D’Angelantonio et al (11), fusion is indicated for patients with a recurring deformity, a digital deformity in the transverse plane, a deformity of neuromuscular etiology, inadequate flexion strength at the MTPJ, or requiring a more

Kirschner wire (K-wire) fixation across the metatarsophalangeal joint (MTPJ) is commonly used in hammertoe repair surgery. The purpose of the present study was twofold: (1) to determine where the K-wire penetrates the metatarsal articular surface to achieve a rectus digit; and (2) to quantify the percentage of cartilage disruption to better understand the consequences of K-wire transfixation of the MTPJ. Arthrodesis was conducted on the second, third, and fourth proximal interphalangeal joints of 10 below-the-knee cadaver specimens, using a 1.6-mm K-wire. Digital alignment was confirmed with simulated weight bearing intraoperatively and radiographically. The K-wire was removed, and the MTPJ was dissected until the metatarsal head was fully exposed. The penetration point was plotted on a quadrant system with deviation noted from the epicenter. Center was defined as the point equidistant from the medial-to-lateral and superior-to-inferior edges on the distal surface of the metatarsal head, excluding the planter condyles. Statistically significantly deviations were found in the K-wire placement from the center (35.9% ± 17.5%, p < .001), medial-to-lateral width (22.2% ± 19.2%, p < .001), and dorsal-to-plantar height (15.8% ± 25.0%, p = .002). Relative to the center, the K-wire was superior in 22 (79%), inferior in 6 (21%), medial in 22 (79%), and lateral in 6 (21%) of the cadaveric MTPJs. The mean percentage of disruption of the articular cartilage was 1.8% ± .4% and was similar for the second, third, and fourth MTPJs (p = .13) and for the left and right feet (p = .75). This information could be used to guide surgeons when they transfixate the MTPJ during hammertoe correction and might contribute to preservation of the articular cartilage.

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predictable outcome at the expense of a stiff toe. Although a multitude of surgical fixation techniques have recently been introduced, Kirschner wire (K-wire) fixation remains 1 of the most popular treatments to correct and stabilize hammertoe deformity.

In 1940, Taylor (12) first described arthrodesis of the PIPJ with intramedullary K-wire fixation. Thereafter, Selig (13) suggested modifying the procedure by bending the K-wire just proximal to the distal terminal to prevent proximal migration. Because of the simplicity (11) and consistent results (10), K-wires have continued to be used for arthrodesis fixation. Despite their routine use, no study has evaluated whether central placement correlates with a straight toe. Given the variability in patient anatomy, we hypothesized that rectus alignment of the corrected digit could be best achieved when the point of insertion of the K-wire on the metatarsal’s distal articular surface deviated from the anatomic center of the metatarsal head. The center was defined as the point equidistant from the medial-to-lateral and superior-to-inferior edges on the distal surface of the metatarsal head, excluding the plantar condyles. Although K-wire fixation across the MTPJ is often indicated in the treatment of hammertoe deformity, the consequences of articular disruption that occurs with fixation have not yet been investigated.

Although interruption of cartilage is a well-recognized consequence of K-wire fixation (14), the extent of damage has not previously been quantified or defined in published studies. We hypothesized that a clinically negligible percentage of the metatarsal surface would be disrupted. The metatarsal surface was defined as the distal articular surface, excluding the plantar condyles. Because of the undulating nature of the plantar condyles and the disruption of the MTPJ tissue necessary for accurate measurement, we did not include this area in the examination. We believed it important that our method was synonymous with our routine surgical regimen to gain the most benefit from the present research. Presumably, if the plantar condyles were included, the percentage of disruption would be even more clinically negligible. The purpose of the present study was twofold: (1) to determine where the K-wire penetrates the metatarsal articular surface to achieve a rectus digit, and (2) to quantify the percentage of cartilage disruption in order to better understand the consequences of K-wire transfixation of the MTPJ.

Materials and Methods

Aims

The primary aims of the present study were to quantify and evaluate whether K-wire placement significantly deviated from the center of the metatarsal head and to report the percentage of cartilage disruption when hammertoe repair is performed using PIPJ arthrodesis fixated with a 1.6-mm (0.062-in.) K-wire. We also wanted to determine precisely where on the metatarsal head the K-wire was most consistently inserted. We also sought to determine whether the percentage of cartilage disruption varied from the second to third to fourth metatarsal and/or from the left to right side. The Coordinated Health institutional review board approved the study protocol.

Assessors

Two investigators (M.M.G. and N.M.P.) collected the data used in the present study. At dissection, the limb (left or right) and joint (second, third, or fourth MTPJ) being transfixied with the K-wire were recorded. The distance from the K-wire point of entry to the medial and superior borders of the metatarsal head was recorded. Additional measurements included the height (dorsal-to-plantar) and width (medial-to-lateral) of the distal metatarsal head. The data were entered into a password-protected, secure database.

Study Population

Ten fresh-frozen, below-the-knee, research-grade, cadaver specimens (Lifequest Anatomical, Allentown, PA) were examined after thawing to room temperature. Of the 10 specimens, 3 (30.00%) were from the right side and 7 (70.00%) from the left side; 7 (70.00%) were from males and 3 (30.00%) from females. Documentation was provided indicating that the specimens were hepatitis and human immunodeficiency virus free.

Intervention

Sequential arthrodesis was conducted on the second, third, and fourth digits of each specimen after sharp joint resection with MTPJ transfixation. All the arthrodeses were performed by the principal investigator (M.M.G.). Using a dorsoinlay incision from just distal to the MTPJ to just distal to the PIPJ, the anatomic layers were dissected at the level of the PIPJ and about the proximal phalanx until the extensor tendon and the collateral ligaments of the PIPJ were transected using sweeping J strokes. The head of the proximal phalanx was then resected, and the base of the middle phalanx was denuded of articular cartilage using a sagittal saw. The digit was then held in gross rectus alignment, and a 1.6-mm K-wire was drilled retrograde to transfix the arthrodesis of the PIPJ, along with the MTPJ and distal interphalangeal joint, each of which was also manipulated into rectus digital alignment and stabilized. Rectus digital alignment was confirmed radiographically as the foot was held in a simulated weightbearing position (Fig. 1).

After confirmation of the digital alignment, the dorsal incision was extended proximally over the MTPJ, and the K-wire was removed from the ray. The size of the distal metatarsal head in the dorsal-to-planter (height) and medial-to-lateral (width) directions was measured using a digital caliper, and the measurements were recorded. The distance from the point of entry of the K-wire into the metatarsal head to the superior and medial borders of the metatarsal head were also measured using the digital caliper, and these measurements were recorded. The digital caliper was calibrated to zero for each measurement.

Endpoints

The study had 2 primary endpoints: deviation of the K-wire from the center of the metatarsal head and the percentage of articular disruption. The overall deviation from the center of the metatarsal head was computed. First, the deviation in height was calculated as the difference in the height from the center to the top of the metatarsal head, and the height from the center of the K-wire placement to the top of the metatarsal head (ΔH). Next, the deviation in width was calculated as the difference in the width from the center to the medial border of the metatarsal head and the width from the center of the K-wire placement to the medial border of the metatarsal head (ΔW). The deviation in height and width were normalized to the height and width of the metatarsal head. These values were entered into an equation to compute the overall deviation from the center of the metatarsal head:

\[
\sqrt{\left(\frac{ΔH}{H}\right)^2 + \left(\frac{ΔW}{W}\right)^2}
\]

The total surface area of the metatarsal head was computed using the equation for an ellipsoid:

\[
\text{ellipsoid} = \left(\frac{I}{2}\right) \times \left(\frac{H}{2}\right) \times \left(\frac{W}{2}\right)
\]
The cross-sectional area of a 1.6-mm K-wire was calculated. The difference between the area of the metatarsal head and the cross-sectional area of the K-wire was then multiplied by 100, providing the percentage of metatarsal articular disruption.

**Statistical Analysis**

Statistical analyses were performed by a research associate and coauthor (N.M.P.). The independent variables were the specific joint (second, third, and fourth MTPJ) and foot (left or right). The dependent variables were the K-wire deviation from the center (overall deviation, width deviation, height deviation) in millimeters. The data were tested for normality, and an approximately normal distribution was confirmed. A 1-sample t test for a mean was performed to test whether the sample mean was significantly different from zero (center of metatarsal head). A repeated measure 2-factor analysis of variance (joint × foot) was used to compare the overall deviation, width deviation, and height deviation.

Additional statistical analyses were performed to investigate the relationship between the percentage of metatarsal articular disruption and K-wire size. Articular disruption was defined as the cross-sectional area on the distal metatarsal articular surface that was damaged by fixation with a 1.6-mm K-wire.

For these analyses, the independent variables included the specific MTPJ (second, third, or fourth) and the specific foot (left or right), and the dependent variable was the percentage of disruption. The data were also tested for normality, and an approximately normal distribution was confirmed. Repeated measures 2-factor analysis of variance (joint × foot) was used to compare the percentage of disruption. Finally, paired and unpaired Student’s t tests with Bonferroni’s correction were used as post hoc tests of differences among pairs of means, when appropriate. The significance level for all statistical tests was set at the 5% (p < .05) level. The data are reported as the mean ± standard deviation in the text and displayed as the mean ± standard error in the figures.

**Results**

Of the 30 cadaver rays (toe and corresponding metatarsal), 2 (6.67%), 1 (3.33%) on the left side and 1 (3.33%) on the right side, were not able to be fixed with an intramedullary K-wire because each second metatarsal had previously been osteotomized through the head (Weil osteotomy) and fixed with implanted hardware that persisted. Thus, 28 rays were included in the present analysis.

**Overall Deviation**

For the 28 digits fixed with a 1.6-mm K-wire, the mean deviation from the center was 35.9% ± 17.5%, which was significantly different from zero (t[27] = 13.5, p < .001). Relative to the midline, the K-wire was superior (dorsal to the midline) in 22 joints (79%), inferior in 6 (21%), medial in 22 (79%), and lateral in 6 (21%; Fig. 2). The mean deviation from the center was similar for the second (31.0% ± 10.4%), third (38.6% ± 14.7%), and fourth (41.7% ± 16.9%) metatarsals (p = .10). Similarly, the mean deviation from the center was similar between the left (35.0% ± 12.4%) and right (43.4% ± 19.2%) feet (p = .25). No statistically significant interaction was found for the deviation from the center, indicating that the deviation from the center was similar across the joints for the left and right feet (joint × foot, p = .21).

**Width Deviation**

The mean width deviation from the center was 22.2% ± 19.2%, which was significantly different from zero (t[27] = 6.1, p < .001; Fig. 2). The mean width deviation from the center was similar for the second (16.0% ± 23.0%), third (17.7% ± 15.0%), and fourth (26.6% ± 15.5%) metatarsals (p = .25). The mean width deviation was also similar between the left (20.5% ± 18.2%) and right (18.9% ± 19.1%) feet (p = .87). No statistically significant interaction was found for width, indicating that the deviation in width was similar across the joints for the left and right feet (joint × foot, p = .40).

**Height Deviation**

The mean height deviation from the center was 15.8% ± 25.0%, which was significantly different from zero (t[27] = 3.3, p = .002; Fig. 2). The mean height deviation from the center was similar for the second (6.6% ± 18.2%), third (13.7% ± 33.5%), and fourth (22.9% ± 24.9%) metatarsals (p = .44). The mean height deviation was similar between the left (7.4% ± 24.7%) and right (35.4% ± 18.3%) feet (p = .66), and no significant interaction was found for height, indicating that the deviation in height was similar across the joints for the left and right feet (joint × foot, p = .69).

The overall deviations and deviations in height and width (expressed in mm²) are provided in Table 1.

**Percentage of Articular Disruption**

For the 28 digits fixed with a 1.6-mm K-wire across the MTPJ, the mean percentage of disruption was 1.80% ± .39%. The mean percentage of disruption of the articular surface was similar for the second (1.63% ± 0.54%), third (1.88% ± 0.37%), and fourth (1.89 ± 0.37%) metatarsals (p = .70; Fig. 2). Additionally, the percentage of articular disruption was similar between the left (1.76% ± 0.34%) and right (1.91% ± 0.56%) feet (p = .58). No significant interaction was found, indicating that the difference in the percentage of articular disruption was similar across the MTPJs for the left and right feet (joint × foot, p = .26; Fig. 3). An inverse, nearly linear, relationship was observed between the size of the metatarsal head and the percentage of disruption (Fig. 4).

**Discussion**

Hammertoe deformity is 1 of the most common causes of forefoot pain in adults (15). Consequently, surgical correction of fixed hammertoe is 1 of the most frequently performed forefoot procedures (16). Although some practitioners have foregone pin fixation for adhesive strips (17) and some have encouraged retained internal fixation (18–20), others have advocated K-wire fixation for hammertoe correction. Although K-wire fixation has routinely been advocated since the 1940s (12), deficits exist in published studies.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Width (mm²)</th>
<th>Height (mm³)</th>
<th>Overall (mm²)</th>
</tr>
</thead>
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<tr>
<td>Metatarsophalangeal joint</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Second</td>
<td>0.92 ± 1.36</td>
<td>0.44 ± 1.34</td>
<td>1.36 ± 0.66</td>
</tr>
<tr>
<td>Third</td>
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<td>0.95 ± 2.43</td>
<td>2.52 ± 1.06</td>
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<tr>
<td>Fourth</td>
<td>1.43 ± 0.80</td>
<td>1.48 ± 1.71</td>
<td>2.52 ± 1.06</td>
</tr>
<tr>
<td>Foot</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Left</td>
<td>1.11 ± 1.02</td>
<td>0.46 ± 1.75</td>
<td>2.18 ± 0.78</td>
</tr>
<tr>
<td>Right</td>
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<td>2.81 ± 1.29</td>
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<tr>
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<td>1.19 ± 1.04</td>
<td>1.07 ± 1.78</td>
<td>2.40 ± 0.95</td>
</tr>
</tbody>
</table>
What Is the Resultant Damage to the Metatarsal Articular Surface?

Regarding this treatment method. Consequently, we sought to answer 2 basic questions.

Where Are We Aiming?

The primary objective of fixing the K-wire across the MTPJ is to achieve a rectus digit. Purportedly, central placement of a K-wire on the metatarsal head will produce a straight toe. Although widely discussed, no study has demonstrated that central placement of the K-wire is associated with a straight toe. The results of the present cadaveric investigation have demonstrated that rectus alignment is most often achieved when the K-wire has been superiorly and medially inserted on the metatarsal head. Ultimately, this information could be useful in minimizing the number of attempts needed to achieve transfixation of the MTPJ when performing hammertoe repair using PIPJ fusion. In turn, this would aid in preserving the articular surface of the proximal and distal phalangeal bases, the middle phalangeal head, and the metatarsal head.

What Is the Resultant Damage to the Metatarsal Articular Surface?

In the present investigation, we chose to quantify the articular disruption that occurs to the metatarsal surface as a consequence of hammertoe correction with K-wire fixation. We recognize that K-wire fixation also causes articular disruption of the proximal and distal phalangeal bases and the middle phalangeal surface. However, during loading, greater forces are exerted on the MTPJs than on the phalanges. Perhaps, the forces acting on the damaged metatarsal articular surface could accelerate degenerative processes.

In the foot and ankle data, previous trauma has been the most common cause of arthrosis (22). With disruption of the collagen framework, joint surfaces are at risk of progressive degeneration. Although investigators have theorized that damage to the metatarsal head can result in early arthrosis (23), no studies have suggested that the articular disruption that occurs with K-wire fixation could contribute to its progression.

Presumably, investigators have assumed that a negligible percentage of the metatarsal surface will be disrupted by K-wire insertion. However, no studies have quantified and reported the extent of the damage. Our findings adhered to our hypothesis. When the K-wire was fixed in 1 attempt, <2% of the articular surface was directly affected by pin transfixation in conjunction with PIPJ arthrodesis for hammertoe correction. Although many surgeons will choose to use smaller diameter K-wires, our research was conducted with the largest diameter K-wire in common use to estimate the maximum amount of articular surface disruption. When only considering the K-wire size, a linear relationship was found between the K-wire size and the percentage of disruption. Simply stated, a smaller diameter wire will produce less articular damage, as long as the wire has been inserted in the same fashion. However, with the largest wire disrupting <2% of the articular surface, the damage caused by smaller wires in the lesser MTPJs can be expected to be clinically negligible throughout the gait cycle, given the low demand placed on these joints compared with the first MTPJ (24,25). Considering these findings, it does not appear that the articular disruption caused by K-wires during hammertoe correction has a resultant effect on the progression of arthrosis. However, K-wire use is not without complications.

Although recent investigations have focused on identifying the etiology and demographics related to hammertoe repair, the limitations of K-wire fixation have also been uncovered. In a retrospective review, K-wire breakage occurred in 3.2% of 1002 lesser toes that underwent digital transfixation with a 0.045-in. K-wire (14). In all cases, K-wire failure occurred just proximal to the metatarsal head, and in 1/3 of the failure cases, the metatarsal cortex had been pierced by the proximal tip of the wire. Zingas et al (14) also demonstrated that the K-wire failure rates varied across toes, with the second toe having the greatest incidence (6%) of K-wire breakage, followed by the third toe (2%). The fourth and fifth toes had a similar incidence of breakage, each <1%. Additionally, the rheumatic population with metatarsal head excision demonstrated higher K-wire failure than controls (4.0% versus 2.3% of K-wires). In examining the incidence of K-wire breakage when the lesser toes underwent transfixation using 0.062-in. K-wires, no breakage occurred. However, additional disadvantages were identified, including difficult placement in small medullary canals and greater damage to the articular cartilage (14).

In addition to the potential to bend, break, and interrupt the articular surface (14), K-wires do not provide compression between bone fragments; rather, they stabilize by splinting. Without interfragmental compression, an intramedullary K-wire could migrate proximally, and delayed union or nonunion of the interphalangeal fusion interface could develop (4,11,26). Although nonunion reportedly occurs in approximately 20% of K-wire fixation cases (4,5), patient satisfaction has been shown to be independent of fusion (4,26). Rather, misalignment, incomplete pain relief, and numbness have been associated with unsuccessful hammertoe repair (4,5).

In a critical evaluation of PIPJ fusion with K-wire fixation, Baig and Geary (26) reported that 21% of toes demonstrated distal interphalangeal
joint instability and deformity. Similarly, after resection arthroplasty of the PIPJ with intramedullary K-wire fixation for correction of hammertoe, Coughlin et al (4) reported that 13% of patients developed hyperextension deformity of the PIPJ and 23% lacked ground toe pulp contact. Of the 118 toes examined by Coughlin et al (4), misalignment was observed in 18 patients, 15 of whom were dissatisfied, and numbness was observed in 7 patients, 4 of whom were dissatisfied.

Because patient satisfaction is adversely influenced by digital misalignment after hammertoe correction, proper intramedullary pin placement should be a primary surgical objective. In 1995, Zingas et al (14) demonstrated that wire failure typically occurred just proximal to the metatarsal head. Therefore, intraoperative radiographic visualization has been advocated to confirm proper placement. This should include the depth of placement (length of pin propagation into the metatarsal shaft) and the medial-to-lateral and dorsal-to-plantar orientation. Although direct visualization of the MTPJ by open dissection allows inspection, comparing the residual length of the K-wire protruding distal to the tip of the toe with the length of an uncut K-wire is a well-known method of estimating the level to which the proximal end of the K-wires resides in the foot. Recent studies have considered radiographic alignment successful when the long axes of the proximal and middle phalanges, as measured in the medial-to-lateral (transverse) and dorsal-to-plantar (sagittal) planes, measures <10 degrees (5).

Percutaneous hardware placement can also be a source of complications. The K-wire protrudes distally from the patient’s toe, increasing the risk of trauma to the K-wire, and, from an aesthetic perspective, increasing the potential of negative psychological ramifications for the patient (11). This could, in fact, be a strong rationale for the recent focus of many surgeons on buried internal fixation for PIPJ fusion.

Moreover, the distal end of the pin is exposed, increasing the likelihood for pin tract infection, especially if pin or digital instability is present, and movement of the skin about the pin occurs. Reportedly, pin tract infection rates have ranged from 0% to 18% (27,28), and higher infection rates have been associated with the duration of K-wire transfixation postoperatively (28). However, in a prospective, randomized study, Klammer et al (27) demonstrated a lower rate of recurrent misalignment and more stable fibrous union without any K-wire-associated complications.

Given the complications associated with surgical correction of hammertoe deformity, continued efforts have focused on identifying variables that significantly contribute to the clinical result. In analyzing the second MTPJ transverse plane alignment in 51 feet after arthrodesis correction, Co et al (29) demonstrated that the outcomes were better in younger patients than in older patients (≥56 years), the outcomes improved with surgeon experience, and, in patients with an initial transverse plane deformity within 15 degrees of neutral, the deformity was more readily corrected and maintained. However, the percentage of favorable outcomes was reduced in association with the presence of concomitant first ray pathologic features, a ruptured plantar plate, crossover second toe deformity, or deformities requiring a first ray adjacent procedure or metatarsal osteotomy. Co et al (29) also noted that none of their patients who exhibited persistent second toe transverse plane deformity adducted >15 degrees achieved a satisfactory outcome.

An increased understanding of the high-risk patient population has promoted ongoing technical modifications in the surgical correction of hammertoe repair. In 1999, Weil (17) proposed a method to achieve hammertoe arthrodesis—the use of conical reamers with impaction K-wire and “shish-kabob” pinning. In subsequent reports, intramedullary cannulated screws were suggested as a method of achieving arthrodesis and minimizing infection, nonunion, and mallet toe deformity (5,30). Despite the inherent benefits, a reoperation rate of 14% (7 of 51) was reported. The primary reason for screw removal was persistent pain at the tip of the toe because of the head of the screw. To resolve this problem, headless cannulated screws were recommended (2,30). Additional methods for hammertoe correction have included the use of absorbable intramedullary fixation (31), intrasosseous box wire-loop arthrodesis between phalanx fragments with and without intramedullary axial K-wire placement in a peg fashion (19), sagittal plane chevron interface arthrodesis with buried intramedullary K-wire fixation (32), and oblique dynamic compression screws (33). Most recently, a closed antegrade intramedullary reduction and pinning with K-wires in a metatarsal fracture model was advocated as a method of avoiding damage to the metatarsal head articular cartilage (23). As with intramedullary, cannulated screws, each technique has advantages and disadvantages. Even with the wide range of fixation methods, limited data are available prospectively comparing the techniques with K-wire transfixation. Although single and multicomponent intramedullary devices have gained popularity, resection arthroplasty and arthrodesis with K-wire fixation remains the most widely advocated and least expensive (in crude terms of implant cost, although incremental cost-effectiveness in terms of quality-adjusted life years has not been determined, to our knowledge) technique for surgical correction of fixed hammertoe.

Similar to all retrospective studies, a number of methodologic shortcomings have the potential to threaten the validity of our conclusions. A primary limitation was the use of a cadaveric model. Translation from the cadaveric model to human hammertoe deformity is limited to speculation. With large deformities, achieving a resect digit could present a challenge, given that our cadaveric findings might not translate directly to a living human patient. In such cases, the question of where to aim the K-wire to transfixed the MTPJ to achieve proper alignment would be left unanswered. Furthermore, we arbitrarily defined the center of the metatarsal head and did not use a previously cited reference point. Also, we did not undertake any testing (model, cadaver, diagnostic imaging, or otherwise) to establish a point known to be the “center” of the MTPJ. We did, however, define our reference point. Furthermore, we continuously focused our concern on the influence that the K-wire had on the articular surface of the metatarsal head, without expressing much concern for the articular cartilage of the base of the proximal phalanx or that of the distal interphalangeal joint, both of which are subject to injury secondary to placement of the K-wire. Still further, cases occur when we do not want to pin through (or pin centrally) the metatarsal head, such as when a Weil or similar metatarsal osteotomy or other fixation device has been used in the PIPJ or more distally in the toe. Also of note, the results we have presented were determined from achieving K-wire fixation in 1 attempt. Because the number of passes across the MTPJ is dependent on surgeon experience, the extent of articular damage would likely vary from surgeon to surgeon and by experience. In addition to the diameter of the K-wire and the type of tip (trocac versus bayonet, sharp versus dull), multiple factors have the potential to influence the percentage of metatarsal head articular cartilage and subchondral bone disruption. An in vivo model with magnetic resonance imaging would provide additional insight into the circumferential effect of the wire, particularly in terms of reactive marrow edema. The insertion of a K-wire might cause more disruption than the fixation itself through the mechanical and thermal effects of insertion. In a human meta-carpal model, Franssen et al (34) compared variations in temperature during 3 K-wire insertion methods. Drilling without irrigation caused greater elevations in temperature than drilling with irrigation and pneumatic hammering (34,35), and it should be remembered that thermal necrosis is a byproduct of the time, temperature, drill speed, insertion force, K-wire characteristics, bony characteristics, and irrigation factors (34,35). To determine the extent of damage imparted to the articular surface and subchondral bone, an advanced imaging...
and/or a thermodynamic model would be required. By the same token, a clinical study using a valid health measurement to determine foot-related quality of life or pain, could also be useful in this regard. Finally, we did not consider the effect of transfixating the K-wire on the articular surfaces of the phalanges, including the proximal and distal phalangeal bases and the middle phalangeal head. Instead, we focused our attention on the metatarsal articular surface because of the greater load placed on the metatarsals compared with the phalanges (21). Despite these limitations, we believe that these results could be useful in understanding the extent of damage caused by K-wire transfixation of the MTPJ for hammertoe correction.

In conclusion, from our understanding of the published data and our observations in the investigation we have presented, we believe the results of the present investigation can be used to minimize damage to the articular cartilage and subchondral bone cortex of the metatarsal head. Because the extent of disruption will be influenced by the number of times the K-wire is passed through the metatarsal head, the K-wire should be aimed superiorly and medially on the metatarsal head to achieve satisfactory stability without the need to reorient the wire and perforate the metatarsal head more than once. By minimizing the number of attempts needed to achieve fixation, the articular disruption can be limited to <2% of the surface (as we have defined it for the purposes of the present study), based on our interpretations of our observations in this investigation. We also believe that it could be clinically useful to obtain an intraoperative radiograph to ascertain the orientation of the transfixation. Additional investigation is required to determine the meaning and influence of this information in the clinical realm.

References