

WEIGHT BEARING ANALYSIS OF THE KELLER ARTHROPLASTY

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The Keller arthroplasty has been performed for several years in patients with end stage hallux abducto valgus and hallux limitus/rigidus deformities. In 1904, Keller presented the first of two articles describing a procedure that involved resection of the medial eminence of the first metatarsal and the base of the proximal phalanx of the hallux.^{1,2}

KELLER COMPLICATIONS

The Keller procedure has been criticized for postoperative complications which may fall into two distinct categories. The first is related to the loss of intrinsic musculature attachments to the hallux. Resection of the proximal phalangeal base releases the tendinous attachments of the adductor hallucis, abductor hallucis, flexor hallucis brevis, and extensor hallucis brevis. This results in muscular imbalance of the hallux and proximal retraction of the sesamoidal apparatus. This instability has been noted to result in several problems including lack of hallux plantar purchase, flail hallux, and hallux elevatus. All of these may result in lesser metatarsalgia with possible development of a stress fracture and an apropulsive gait.

The second major category is related to resection of the hallux proximal phalangeal base. Excessive resection of the base results in cosmetically unacceptable shortening. Inadequate resection may lead to painful pseudoarthrosis and jamming of the residual first metatarsophalangeal joint.³⁻⁹

KELLER MODIFICATIONS

A number of modifications have been attempted to assist in preventing the complications of the Keller arthroplasty. The amount of resection of the proximal phalanx of the hallux has been the subject of much debate. Jordan and Brodsky recommended no less than two-thirds of the

proximal phalangeal base be excised during a Keller arthroplasty. They reported that the greater the postoperative "floppiness," the better the functional result.¹⁰ Wrighton, in a ten year review of the procedure, concluded that excessive resection of the proximal phalanx base was related to poor results.¹¹ Fuson advocates a "silver dollar" resection of the proximal phalanx and fabrication of a concavity to promote stabilization of the proximal phalanx against the head of the first metatarsal.¹² The more current and established recommendation is for resection of approximately one-third of the proximal aspect of the phalanx.^{11,13}

Thomas, in 1962, promoted distraction of the residual first metatarsophalangeal joint with Kirschner wire or external staples. This fixation was held in place for three weeks in an attempt to promote fibrous ingrowth and thus prevent shortening. He related an improvement in function and cosmetic appearance of the hallux.⁹ McLaughlin and Fish, in 1990, performed a retrospective study comparing the Keller arthroplasty with Kirschner wire distraction versus a straight Keller arthroplasty. They concluded that the use of distraction weakly correlated with an increase in range of motion and patient satisfaction.⁵ Pitts, et al. recommend the use of crossed Kirschner wires or a single threaded wire to maintain distraction and avoid migration of the hallux along a single smooth Kirschner wire.⁴

Soft tissue interposition between the metatarsal head and proximal phalanx is currently utilized by most surgeons as a biological spacer. Wrighton reported good results in only 59% of his Keller arthroplasties when flap interposition was performed, as compared to a 76% favorable result when a conventional Keller was performed. He concluded that the pseudoarthrosis did not appear to be enhanced by this modification.¹¹ Several different configurations have been recommended, with the more common being the inverted "L" as well as the proximally and distally based "U" designs.¹⁵ Besides serving as a biological spacer, the

capsular flap assists in stabilizing the hallux and preventing recurrence of a hallux valgus deformity.

Tenodesis and tendon transfer procedures have been recommended by surgeons to improve plantar purchase of the hallux and reduce the extensus deformity of the hallux. Fuson discussed the suturing of the flexor hallucis longus tendon to the proximal phalanx of the hallux to reestablish proper hallux function.¹² Ganley et al. advocated the transplantation of a strip of the extensor hallucis brevis tendon into the medial aspect of the first metatarsophalangeal joint capsule. He related that this adaptation converts a tendon with a deforming influence into a ligament that improves medial stability.¹³ McGlamry et al. recommend the reattachment of the flexor hallucis brevis tendon into the stump of the proximal phalanx to improve sagittal plane stability (purchase) of the hallux.¹⁴

The use of a synthetic joint implant was popular during the 1970s. The silastic implants were used primarily as spacers, and could not resist the deforming forces placed upon them.⁴ The implants then went on to create additional complications, most notably prolonged edema and disability, breakage or absorption of the implant, tissue reactivity, progressive degeneration and a failure or revision rate greater than 10%.^{3,13} Currently, synthetic joint implants are rarely used in conjunction with the Keller arthroplasty.

CLINICAL ASSESSMENT

The impetus for this clinical outcome study was based upon the evaluation of individuals that had undergone the Keller arthroplasty procedure. It was noted that they did not express many of the common complications associated with the procedure. They appeared to ambulate with adequate hallux purchase and push-off strength. Most importantly the patients noted subjective improvements in their ability to perform pain-free activities of daily living.

LITERATURE REVIEW

A review of the literature revealed five articles in which researchers attempted to objectively evaluate the Keller arthroplasty procedure. Henry and Waugh utilized a Harris-Beath foot printing pad in a retrospective study evaluating patients who had

undergone either a Keller arthroplasty or first metatarsophalangeal joint arthrodesis. They concluded that if the hallux lacked plantar purchase, than there was increased plantar pressure beneath the lesser metatarsals.¹⁶

Dhanendran, Pollard, and Hutton analyzed vertical load on 31 patients with bilateral hallux valgus, and 32 individuals with no evidence of foot or gait abnormalities. The subject's vertical load was assessed by means of ambulating over a strain gauge load cell system. Comparison of the group data revealed that the subjects with hallux valgus carried less load on the hallux and second toe while the lateral three metatarsals carried more load. Seventeen feet of the patients with hallux valgus underwent a Keller arthroplasty procedure. Reassessment one year postoperatively revealed a further reduction in hallux loading, increased load beneath the first metatarsal head, and a diminished contact time for all the toes.¹⁷

Samnegard, Turan, and Lanshammar evaluated patients who had undergone either a Keller arthroplasty or first metatarsal joint arthrodesis on an EMED plantar pressure system. They compared the study group to non age-matched normal subjects. The participants walked barefoot across the EMED plates at slow, normal, and fast gait patterns. The investigators concluded that the Keller subjects had a mildly decreased maximum pressure beneath the hallux, and that there was no significant increase in pressure beneath the lesser metatarsals.¹⁸

Stokes, Hutton, and Evans recorded the distribution of load beneath the foot in 13 patients prior to and after undergoing a Keller arthroplasty. Measurements were obtained by having the subjects walk over electrical resistance strain gauges. Results were compared to 55 healthy subjects with no foot complaints or obvious abnormalities. They concluded that the hallux in individuals with hallux valgus carries an abnormally low load, and that the Keller arthroplasty procedure resulted in little change in the load-bearing function of the foot.¹⁹

Banks studied his postoperative Keller arthroplasty patients utilizing an electrodynagram to investigate the load bearing function of their feet. He noted their hallux purchase was as good as that seen preoperatively.²⁰

MATERIALS AND METHODS

Research Questions

Due to a deficiency of sound objective research on the Keller arthroplasty, the authors devised a clinical outcomes investigation. The following research questions were used:

1. Does objective gait analysis demonstrate an apropulsive gait in the end stage hallux abducto valgus/hallux limitus patient?
2. What are the plantar pressures preoperatively and postoperatively in the Keller arthroplasty population?
3. Is there a significant increase in plantar pressures beneath the lesser metatarsals after undergoing the Keller procedure?
4. Can torque about the first metatarsophalangeal joint be produced over a greater range of motion in these individuals?

Research Design

Individuals for inclusion in the study are either male or female with no specific age criteria. They needed to clinically and radiographically have end stage hallux abducto valgus/hallux limitus to be a surgical candidate for the Keller arthroplasty procedure. The investigation is focused on five different criteria.

1. Preoperative and postoperative evaluation of radiographs (dorsoplantar, lateral, medial-oblique)
2. Objective gait analysis on the Musgrave Footprint System (plantar pressures, push-off force, gait velocity)
3. Evaluation of first MPJ torque on custom designed apparatus
4. Completion of a McGill Pain Questionnaire
5. First MPJ range of motion measurements (dorsoflexion, plantarflexion)

These criteria will be completed prior to undergoing the Keller arthroplasty and approximately five months postoperatively. The data collection and evaluation will be performed at the Gait Study Center of the Pennsylvania College of Podiatric Medicine, Philadelphia, Pennsylvania.

Procedure

A uniform Keller arthroplasty procedure was decided upon to insure reproducible results. The procedure consists of standard components that are performed on every patient: resection of one-third of the base of the proximal phalanx of the hallux; tenodesis of the flexor hallucis longus tendon to the proximal phalanx of the hallux; and a "U" capsular interpositional flap. Modifications of the procedure that may be decided upon intraoperatively include extensor hallucis longus lengthening, and temporary distraction of the arthroplasty site with a Kirschner wire.

Projected Conclusions

The current clinical and limited objection data analysis leads the investigators to believe that:

1. Patients with end stage hallux abducto valgus/hallux limitus are relatively apropulsive prior to undergoing the Keller arthroplasty procedure.
2. Keller arthroplasty patients will have improved pain-free range of motion about the 1st metatarsophalangeal joint and will produce torque about a greater excursion.
3. Improvements in the Keller arthroplasty will help to minimize the commonly accepted complications of the procedure.
4. Keller arthroplasty is a reliable procedure that improves function and eliminates pain in properly selected patients.

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