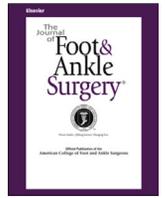




Contents lists available at ScienceDirect

The Journal of Foot & Ankle Surgery

journal homepage: www.jfas.org

Long-Term Results of Surgical Treatment of Valenti Procedures for Hallux Rigidus: A Minimum Ten-Year Follow-Up Retrospective Study

Gabriele Colò, MD¹, Mattia Alessio-Mazzola, MD¹, Giacomo Dagnino, MD¹, Lamberto Felli, MD²

¹ Surgeon, Department of Surgical Sciences (DISC), Orthopaedic and Traumatologic Clinic, University of Genova, Genoa, Italy

² Professor, Department of Surgical Sciences (DISC), Orthopaedic and Traumatologic Clinic, University of Genova, Genoa, Italy



ARTICLE INFO

Level of Clinical Evidence: 4

Keywords:

arthroplasty
first metatarsophalangeal joint
foot type
great toe arthritis
hallux limitus

ABSTRACT

Few studies reporting long-term results of surgical treatment of hallux rigidus have been published. The aim of this study is to assess the clinical outcome of Valenti procedures in a series of patients with hallux limitus/rigidus with a minimum 10-year follow-up time. We retrospectively evaluated 38 patients (40 feet) who underwent a Valenti procedure with a mean follow-up of 132 ± 19.6 (range 114 to 184) months. All patients were clinically reassessed on the basis of the evaluation of pain (visual analogue scale), function (American Orthopaedic Foot and Ankle Society Hallux Metatarsophalangeal-Interphalangeal Scale Assessment and Foot & Ankle Disability Index), and subjective satisfaction. The scores before and after treatment, obtained from clinical recordings and clinical evaluation during the last follow-up visits, were compared. We found significant improvement of the mean values of the visual analogue score ($p < .0001$), Foot & Ankle Disability Index ($p < .0001$), and American Orthopaedic Foot and Ankle Society Hallux Metatarsophalangeal-Interphalangeal Scale Assessment ($p < .0001$) during the latest follow-up visits. The results suggest that the Valenti technique represents a safe, reproducible surgical procedure that allows satisfying long-term results. The few reported complications were essentially the progressive worsening of the joint stiffness, but no sesamoiditis, metatarsal overload, secondary surgeries, or failures were documented.

© 2018 by the American College of Foot and Ankle Surgeons. All rights reserved.

Hallux rigidus is the clinical manifestation of osteoarthritis of the first metatarsophalangeal (MTP) joint and represents the most common arthritic condition of the foot, with an estimated prevalence of 1 in 40 for individuals > 50 years old (1). Surgical indication for hallux rigidus is pain and degenerative changes of the first MTP joint. Several surgical techniques have been described to relieve pain and restore function of the first MTP joint, including cheilectomy, interposition arthroplasty, resection or excision arthroplasty, implant arthroplasty, and arthrodesis (2,3).

Cheilectomy is indicated as surgical treatment for patients with early arthritic changes; however, further invasive procedures may be required for advanced stages of hallux rigidus (3–7). Although the joint resection procedures have good clinical results, there are potential complications that raise concerns in young and active patients. Although joint preserving procedures conserve the bone stock while improving the joint motion and articular stability, several surgical options (arthroplasty or arthrodesis) remain available in case of revision surgery (8).

At the 1987 Hershey Seminar in Pennsylvania, Valente Valenti, an Italian orthopedic foot surgeon, presented a personal communication regarding a surgical treatment for hallux limitus and rigidus. He described an 80° sagittal plane “V” resection of the first MTP joint with preservation the first ray length, the plantar portion of the first metatarsal head and first proximal phalangeal base, conserving also the flexor hallucis brevis and the sesamoid function.

Few studies reporting long-term results of this surgical technique have been published in the literature. The aim of this study is to assess the clinical outcome and the grade of satisfaction of the Valenti procedure in a series of patients with hallux limitus/rigidus, with a minimum 10-year follow-up time.

Patients and Methods

From January 2001 to December 2007, the authors reviewed at their institution the clinical data and the radiographs of patients who underwent Valenti arthroplasty for painful hallux limitus/rigidus. Preoperative indications for surgery included hallux limitus and hallux rigidus unresponsive to conservative measures. Patients with a history of diabetes were excluded. All preoperative radiographs were reviewed by a single board-certified foot surgeon (D.G.) to classify the grade of joint degeneration. All patients were classified with grade 4 Coughlin and Shurnas classification (Table 1) (4).

A total of 75 patients underwent surgical procedures for symptomatic hallux limitus/rigidus; 45 of them underwent Valenti arthroplasty. Seven patients were excluded because they did not meet the inclusion/exclusion criteria. A total of 38 patients (40 feet)

Financial Disclosure: None reported.

Conflict of Interest: None reported.

Address correspondence to: Mattia Alessio-Mazzola, MD, Padiglione 40, IRCCS Policlinico San Martino, Largo Rosanna Benzi 10, 16132 Genoa, Italy.

E-mail address: mattia.alessio@hotmail.com (M. Alessio-Mazzola).

Table 1
Coughlin and Shurnas (4) grading of hallux limitus/rigidus based on a combination of range of motion, radiographic, and clinical findings

Grade	Description
0	40° to 60° of dorsiflexion or 10% to 20% of loss of the normal total ROM, normal radiographic findings, no pain, only stiffness
I	30° to 40° of dorsiflexion or 20% to 50% of loss of total ROM, dorsal osteophytes, minimal joint space narrowing, minimal periarticular sclerosis or head flattening, mild or occasional pain at extremes of motion
II	10° to 30° of dorsiflexion or 50% to 70% of loss of total ROM, mild to moderate joint space narrowing or sclerosis and osteophytes, moderate to severe pain at extremes of motion
III	< 10° of dorsiflexion or 75% to 100% of loss of total ROM, severe radiographic changes with hypertrophied cyst or erosions or irregular sesamoids, constant moderate to severe pain and stiffness at extremes of motion but not of midrange of motion
IV	Stiff joint, radiographic loose bodies or osteochondral defects, pain throughout entire ROM

Abbreviation: ROM, range of motion.

were clinically reassessed by 2 fellows (C.G., A.-M.M.) not involved in the initial surgery or follow-up care. Preoperative data were collected with inspection of all medical records at the time of the surgery. Postoperative data were assessed at the final follow-up visit through subjective questionnaires about the level of function and pain in the setting of the present study.

The visual analogue scale (VAS), the American Orthopaedic Foot and Ankle Society (AOFAS) Hallux Metatarsophalangeal-Interphalangeal Scale Assessment, and the Foot & Ankle Disability Index (FADI) were used for pre- and postoperative functional evaluation and pain (9,10). Self-reported satisfaction (unsatisfied, partially satisfied, satisfied, very satisfied) was requested at the end of follow-up period. All patients were clinically reassessed for passive range of motion (ROM) evaluation with an orthopedic goniometer by the same board-certified foot surgeon before surgery and at the end of follow-up period. Any complications (ie, persistent pain, superficial or deep infection, wound problems, thromboembolism, algodystrophy, or osteonecrosis), secondary surgeries, and failures were documented. All continuous values were compared by use of the paired *t* test. A *p* value < .05 was considered statistically significant.

Surgical Technique

A 4-cm dorsal longitudinal incision was performed over the first MTP joint. A linear capsulotomy was performed, and the bursal tissue and the synovium, if present, were

excised. Dorsal and medial metatarsal eminences and lateral hypertrophic bone were excised with an oscillating micro-saw.

The dorsal metatarsal osteotomy line was performed with an angulation of 30° and extending from the dorsal cortex and preserving two thirds of articular surface. The dorsal phalangeal osteotomy was performed at a 45° angle from distal to proximal. The intraoperative mobilization after the osteotomies should obtain a dorsal flexion of approximately 90°. The joint capsule was accurately sutured at the end of the procedure with careful retightening of its dorsal aspect to avoid residual joint instability. No postoperative surgical drain was used. The main surgical steps are shown in Fig. 1.

Three-month postoperative radiographs were obtained to assess the resection angle. A Baruk postoperative shoe was used for 2 weeks with full weightbearing. Suture removal was preferred within 2 weeks. Normal shoe wear was permitted after 1 month. Return to running was generally permitted after 3 months, depending on the patient's symptoms.

Results

We reviewed 38 patients (40 feet) who underwent a Valenti procedure with a mean follow-up of 132 ± 19.6 (range 114 to 184) months. The mean age at the time of surgery was 57.9 ± 8.3 (range 41 to 69) years; 31 (81.6%) patients were female, and 7 (18.4%) were male. Twenty-six (65%) procedures were performed on the right foot and 14 (35%) on the left foot. Twenty (50%) cases had a preoperative Coughlin and Shurnas grade III score, and 20 (50%) cases had a grade IV score. The mean preoperative VAS score was 7.8 ± 1.2 (range 4 to 8) points. No patient underwent revision surgery.

The preoperative dorsiflexion and plantar flexion was $7.1^\circ \pm 4.1^\circ$ (range 0° to 15°) and $5.6^\circ \pm 3.0^\circ$ (range 0° to 10°), respectively, with a total mean ROM of $12.8^\circ \pm 5.2^\circ$ (range 5° to 20°). The mean FADI sport module was 35.3 ± 9.8 (range 21.9 to 59.4) points. Table 2 shows the preoperative clinical features of the patients.

There was a significant improvement of the mean values of the VAS ($p < .0001$), FADI ($p < .0001$), and AOFAS Hallux Metatarsophalangeal-Interphalangeal Scale Assessment ($p < .0001$) at the latest follow-up visit (Table 3). Table 4 shows the results of the present series in the setting of this study.

At the end of follow-up care, 29 (76.3%) patients reported that they were satisfied or very satisfied with the surgical results, 3 (7.9%) were partially satisfied, and 6 (15.8%) were unsatisfied. Joint rigidity with restricted ROM was detected in 11 (27.5%) cases at the end of follow-

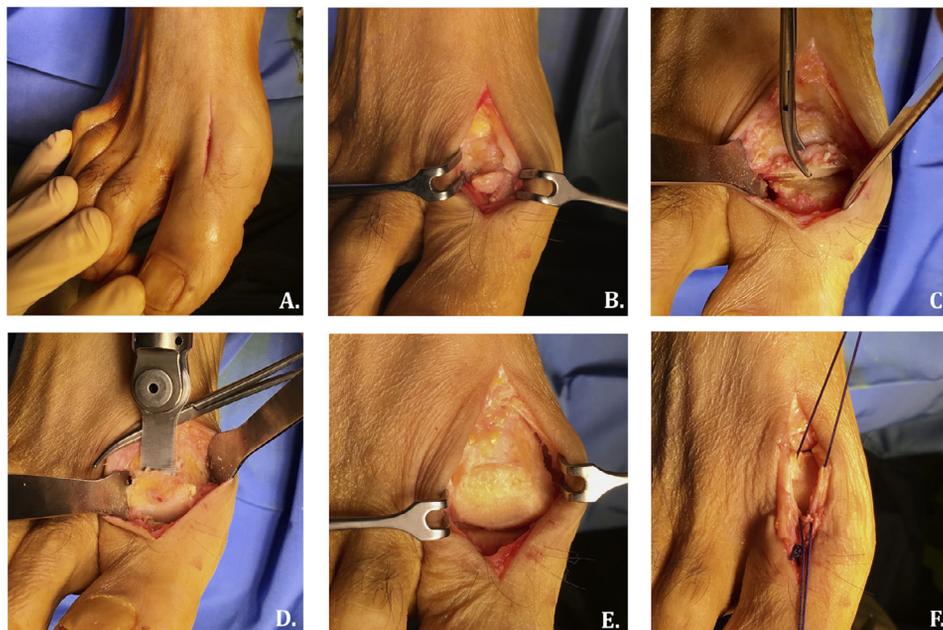


Fig. 1. Surgical steps of the Valenti technique for hallux rigidus: dorsomedial 4-cm skin incision (A); identification of the dorsal osteophyte (B) and its excision (C). Dorsal metatarsal osteotomy with oscillating micro-saw (D). Final joint view at the end of the procedure (E) and accurate capsular retightening (F).

Table 2
Preoperative patients features

Parameters	Value
No. of patients/feet	38/40
Mean age (years \pm SD)	57.9 \pm 8.3 (range 41 to 69)
Sex (Male/Female)	7/31
Side (Right/Left)	26/14
Mean follow-up (months \pm SD)	132 \pm 19.6 (range 114 to 184)
Coughlin grade (III/IV)	20/20

Abbreviation: SD, standard deviation.

up; however, no pain on joint motion was reported. In all cases of long-term rigidity, the first MTP joint demonstrated ROM that was satisfying after surgery but progressively worsened over time. No complications or revision surgeries were reported.

Discussion

Osteoarthritis in the first MTP joint is the most common arthritic condition in the foot. The progression of joint involvement is associated with pain, loss of motion, and progressive decline in the quality of life of the patients (3,6).

The first approach in the early stages of this condition begins with shoe modifications and orthotics designed to limit MTP impingement (11). In advanced stages, the surgical treatments include joint-sparing or joint-sacrificing techniques (12,13), and the indications vary according to the joint involvement and the patient's expectations.

In mild first MTP joint arthritis, cheilectomy is indicated because removing excess osteophytes may prevent dorsal impingement with or without metatarsal osteotomy and improve ROM. In patients with advanced joint changes, arthrodesis of the first MTP joint could be required. Multiple joint-sparing procedures have been described with unsatisfactory results (13). Despite the potential benefit of maintaining joint movement, multiple complications have been described for arthroplasty, such as implant failure, soft tissue instability, aseptic mobilization of components, pathologic wear, and infection (14,15).

Horisberger et al (14) reported results of 29 prostheses of the first MTP joint, with a mean follow-up time of 49.5 months. The authors observed a high variability of the ROM, which initially increased from 37.8° (range 0° to 60°) to 88.6° (range 45° to 125°) during surgery and decreased to 29° (range 11° to 52°) at the latest follow-up visit.

Nagy et al (15) described a second-generation ceramic, first MTP joint implantation performed on 31 feet with a mean follow-up time of 81 \pm 27 months. The authors reported 1 superficial wound infection and 5 revisions (16%) for loosening, shrinkage, subluxation, pain, or fracture. The overall implant survival rate was 92% at 5 years, 85% at 7 years, and 68% at 9 years.

Over the years, numerous studies have been published on surgical techniques of cheilectomy and arthroplasty in younger patients. In the

literature, few studies have been conducted on the Valenti technique, and results over 10 years of follow-up visits have not been reported.

Grady and Axe (16) treated 21 cases of hallux limitus with a modified Valenti technique, with a mean follow-up time of 19.2 months. The authors reported a main increase in dorsiflexion of 12.24°, and the most common complication was sesamoiditis.

Saxena (17) treated 11 patients with the Valenti procedure: 6 had excellent results, 3 good, 1 fair, and 1 poor. The improvement of dorsiflexion was 27.5°. The most common complication was sesamoiditis, which was reported in 3 (27%) patients. There was no shortening of the toe and the flexural function of the hallux was maintained, which are common failures of the Keller procedure (18,19).

Kurtz et al (20) published a retrospective analysis on 33 patients (36 feet), reporting 91.7% excellent and good results and 8.3% fair and negative results after 4.16 years of follow-up care.

In 2009, Harisboure et al (21) evaluated 24 patients (32 feet) with a mean follow-up of 5.5 years. Only 2 cases of algodystrophy occurred. The pain was absent in 12 (38%) cases, occasionally present in 18 (56%) cases, and present daily in 2 (6%) cases.

One benefit of the Valenti procedure is joint preservation. This technique presents several additional advantages: a greater ROM, a low learning curve, preservation of the length of the first ray, and maintenance of the flexural muscles. This technique also respects the complexity of the sesamoid ligament and intrinsic plantar muscle that provide stability to the metatarsal head, and decreases the rehabilitation time, allowing early weightbearing (6 to 8 weeks).

This surgical procedure avoids destructive articular procedures such as the Keller technique and avoids the prolonged non-weightbearing associated with metatarsal or arthrodesis osteotomies. Cheilectomy has good results during the initial stages of osteoarthritis but produces poor results when used for advanced phases of hallux rigidus (22–25). Interpositional arthroplasty demonstrated loss of strength of the hallux and an increase in the transfer of the load to the other toes (26). The Keller arthroplasty can be indicated for older patients with low functional demands and advanced osteoarthritis, but shortening the first ray and the high incidence of secondary metatarsalgia exclude its large-scale use (27–29).

Arthrodesis is still the gold standard for the treatment of advanced hallux rigidus in older patients with lower functional expectancy and high joint pain. It is a technically demanding procedure that can take 2 to 3 months to get the necessary bone healing, and in the long term, it can overload the interphalangeal joint, resulting in osteoarthritis (24,30–33). The partial or total replacement of the first MTP joint, in addition to being a technically demanding and high-cost procedure, demonstrated low survival rates and potentially serious complications in several studies (34–43).

The Valenti procedure offers reproducible results with low complication rates and good functional results for different degrees of arthritis. However, this technique is not indicated in patients with metatarsus primus elevatus, because it does not approach the principal cause of the

Table 3
Preoperative results and final scores, with *p* values representing comparison with the preoperative data (N = 40 feet in 38 patients)

Parameters	Preoperative Mean Value \pm SD (Range)	Final Follow-Up Mean Value \pm SD (Range)	<i>p</i> Value
Mean VAS (points)	7.8 \pm 1.2 (4 to 8)	1.6 \pm 1.7 (0 to 4)	<.0001
Mean dorsal flexion (°)	7.1 \pm 4.1 (0 to 15)	20.8 \pm 7.6 (10 to 30)	<.0001
Mean plantar flexion (°)	5.6 \pm 3.0 (0 to 10)	26.3 \pm 8.1 (10 to 35)	<.0001
Total mean ROM (°)	12.8 \pm 5.2 (5 to 20)	47.0 \pm 13.5 (20 to 65)	<.0001
Mean FADI score (points)	42.6 \pm 3.2 (39.4 to 47.1)	89.7 \pm 16.3 (51.9 to 100)	<.0001
Mean FADI sport module (points)	35.3 \pm 9.8 (21.9 to 59.4)	78.2 \pm 20.9 (34.4 to 100)	<.0001
Mean AOFAS (points)	35.3 \pm 10.9 (21 to 52)	83.8 \pm 14.3 (52 to 95)	<.0001

Abbreviations: AOFAS, American Orthopaedic Foot and Ankle Society; FADI, Foot & Ankle Disability Index; ROM, range of motion; SD, standard deviation; VAS, visual analogue scale.

Table 4
American Orthopaedic Foot and Ankle Society results of feet (N = 40 feet) included at the end of the follow-up period

Results	Score	Feet
Excellent	90 to 100	14 (35%)
Good	70 to 89	20 (50%)
Fair	60 to 69	0
Poor	< 60	6 (15%)

hallux limitus. Although the Valenti procedure involves resection of a portion of the joint surface, it does not represent a contraindication if other more invasive procedures (arthroplasty or joint arthrodesis) are necessary. Conversely, arthrodesis, arthroplasty, and the Keller technique have high rates of complications, particularly overload metatarsalgia (40–43).

This study has several limitations, including the retrospective nature, the absence of a comparative or control group for long-term follow-up, and the limited number of treated patients without long-term radiographic imaging, which limited stronger statistical analysis and considerations. More higher-powered, prospective, or randomized controlled trials are necessary to further evaluate this procedure.

Although numerous studies are still needed to define the most appropriate treatments in relation to the different degrees of osteoarthritis of the first MTP joint, we can conclude that our outcomes are satisfactory and in line with the literature on the latest Valenti study with a low complication rate.

In conclusion, the treatment of hallux rigidus is a difficult problem. The Valenti technique is a safe, reproducible, and low-cost surgical procedure that has excellent long-term results. The high rate of satisfied or very satisfied patients has been reported with satisfying long-term ROM preservation. This operative technique avoids total joint replacement in a middle-aged patient, maintaining the flexural and extensor muscular function and the thrust force, and allowing quick return to the activities of daily living. Complications of the Valenti procedure were essentially a progressive worsening of joint stiffness, but no sesamoiditis, metatarsalgia overload, secondary surgeries, or failures were documented.

Supplementary Materials

Supplementary material associated with this article can be found in the online version at <https://doi.org/10.1053/j.jfas.2018.08.055>.

References

- Lau JT, Daniels TR. Outcomes following cheilectomy and interpositional arthroplasty in hallux rigidus. *Foot Ankle Int* 2001;22:462–470.
- Hamilton WG, O'Malley MJ, Thompson FM, Kovatis PE. Capsular interposition arthroplasty for severe hallux rigidus. *Foot Ankle Int* 1997;18:68–70.
- Yee G, Lau J. Current concepts review: hallux rigidus. *Foot Ankle Int* 2008;29:637–646.
- Coughlin MJ, Shurnas PJ. Soft-tissue arthroplasty for hallux rigidus. *Foot Ankle Int* 2003;24:661–672.
- Easley ME, Davis WH, Anderson RB. Intermediate to long-term follow-up of medial approach dorsal cheilectomy for hallux rigidus. *Foot Ankle Int* 1999;20:147–152.
- Brage ME, Ball ST. Surgical options for salvage of end-stage hallux rigidus. *Foot Ankle Clin North Am* 2002;7:49–73.
- Granberry WM, Noble PC, Bishop JO, Tullos HS. Use of a hinged silicone prosthesis for replacement arthroplasty of the first metatarsophalangeal joint. *J Bone Joint Surg Am* 1991;73:1453–1459.
- Giannini S, Ceccarelli F, Faldini C, Bevoni R, Grandi G, Vannini F. What's new in surgical options for hallux rigidus? *J Bone Joint Surg Am* 2004;86:72–83.
- Kitaoaka HB, Alexander IJ, Adelaar RS, Nunley JA, Myerson MS, Sanders M. Clinical rating systems for the ankle-hindfoot, midfoot, hallux, and lesser toes. *Foot Ankle Int* 1994;15:349–353.
- Martin RL, Burdett RG, Irrgang JJ. Development of the Foot and Ankle Disability Index (FADI). *J Orthop Sports Phys Ther* 1999;29:A32–A33.
- Gould N, Schneider W, Ashikaga T. Epidemiological survey of foot problems in the continental United States: 1978–1979. *Foot Ankle* 1980;1:8–10.
- Smith SM, Coleman SC, Bacon SA, Polo FE, Brodsky JW. Improved ankle push-off power following cheilectomy for hallux rigidus: a prospective gait analysis study. *Foot Ankle Int* 2012;33:457–461.
- Perler AD, Nwosu V, Christie D, Higgins K. End-stage osteoarthritis of the great toe/hallux rigidus: a review of the alternatives to arthrodesis: implant versus osteotomies and arthroplasty techniques. *Clin Podiatr Med Surg* 2013;30:351–395.
- Horisberger M, Haeni D, Henninger HB, Valderrabano V, Barg A. Total arthroplasty of the metatarsophalangeal joint of the hallux. *Foot Ankle Int* 2016;37:755–765.
- Nagy MT, Walker CR, Sirikonda SP. Second-generation ceramic first metatarsophalangeal joint replacement for hallux rigidus. *Foot Ankle Int* 2014;35:690–698.
- Grady J, Axe T. The modified Valenti procedure for the treatment of hallux limitus. *J Foot Ankle Surg* 1994;33:365–367.
- Saxena A. The Valenti procedure for hallux limitus/rigidus. *J. Foot Ankle Surg* 1995;34:485–488.
- O'Doherty DP, Lowrie IG, Magnussen PA, Gregg PJ. The management of the painful first metatarsophalangeal joint in the older patient. Arthrodesis or Keller's arthroplasty? *J Bone Joint Surg* 1990;72:839–842.
- Quinn M, Wolf K, Hensley J, Kruljac S. Keller arthroplasty with autogenous bone graft in the treatment of hallux limitus. *J Foot Surg* 1990;29:284–291.
- Kurtz DH, Harrill JC, Kaczander BI, Solomon MG. The Valenti procedure for hallux limitus: a long-term follow-up and analysis. *J Foot Ankle Surg* 1999;38:123–130.
- Harisboire A, Joveniaux P, Madi K, Dehoux E. The Valenti technique in the treatment of hallux rigidus. *Orthop Traumatol Surg Res* 2009;95:202–209.
- Feltham GT, Hanks SE, Marcus RE. Age-based outcomes of cheilectomy for the treatment of hallux rigidus. *Foot Ankle Int* 2001;22:192–197.
- Geldwert JJ, Rock GD, McGrath MP, Mancuso JE. Cheilectomy: still a useful technique for grade I and II hallux limitus/rigidus. *J Foot Surg* 1992;21:154–159.
- Keiserman LS, Sammarco VJ, Sammarco GJ. Surgical treatment of the hallux rigidus. *Foot Ankle Clin* 2005;10:75–96.
- Womack JW, Ishikawa SN. First metatarsophalangeal arthrodesis. *Foot Ankle Clin* 2009;14:43–50.
- Aynardi MC, Atwater L, Dein EJ, Zahoor T, Schon LC, Miller SD. Outcomes after interpositional arthroplasty of the first metatarsophalangeal. *Joint Foot Ankle Int* 2017;38:514–518.
- Cleveland M, Winant EM. An end-result study of the Keller operation. *J Bone Joint Surg Am* 1950;32:163–175.
- Wrighton JD. A ten-year review of Keller's operation. *Clin Orthop Relat Res* 1972;89:207–214.
- Coutts A, Kilmartin TE, Ellis MJ. The long-term patient focused outcomes of the Keller's arthroplasty for the treatment of hallux rigidus. *Foot (Edinb)* 2012;22:167–171.
- Lombardi CM, Silhanek AD, Connolly FG, Dennis LN, Keslonly AJ. First metatarsophalangeal arthrodesis for treatment of hallux rigidus: a retrospective study. *J Foot Ankle Surg* 2001;40:137–143.
- Mann RA, Oates JC. Arthrodesis of the first metatarsophalangeal joint. *J Foot Ankle* 1980;1:159–166.
- Roukis TS. First metatarsal-phalangeal joint arthrodesis: primary, revision, and salvage of complications. *Clin Podiatr Med Surg* 2017;34:301–314.
- Chraim M, Bock P, Alrabai HM, Trnka HJ. Long-term outcome of first metatarsophalangeal joint fusion in the treatment of severe hallux rigidus. *Int Orthop* 2016;40:2401–2408.
- Wrighton JD. A ten-year review of Keller's operation. Review of Keller's operation at the Princess Elizabeth Orthopaedic Hospital, Exeter. *Clin Orthop Relat Res* 1972;89:207–214.
- Pontell D, Gudas CJ. Retrospective analysis of surgical treatment of hallux rigidus/limitus: clinical and radiographic follow-up of hinged, silastic implant arthroplasty and cheilectomy. *J Foot Surg* 1988;27:503–510.
- Sinha S, McNamara P, Bhatia M, Louette L, Stephens I. Survivorship of the bio-action metatarsophalangeal joint arthroplasty for hallux rigidus: 5-year follow-up. *Foot Ankle Surg* 2010;16:25–27.
- Konkel KF, Menger AG, Retzlaff SA. Mid-term results of Futura hemi-great toe implants. *Foot Ankle Int* 2008;29:831–837.
- Gupta S, Masud S. Long term results of the Toefit-Plus replacement for first metatarsophalangeal joint arthritis. *Foot (Edinb)* 2017;31:67–71.
- Baumbauer JF, Marcolongo M. The science behind wear testing for great toe implants for hallux rigidus. *Foot Ankle Clin* 2016;21:891–902.
- Johnson MD, Brage ME. Total toe replacement in the United States: what is known and what is on the horizon. *Foot Ankle Clin* 2016;21:249–266.
- Chee YH, Clement N, Ahmed I, Thomson CE, Gibson JN. Functional outcomes following ceramic total joint replacement for hallux rigidus. *Foot Ankle Surg* 2011;17:8–12.
- Pulavarti RS, McVie JL, Tulloch CJ. First metatarsophalangeal joint replacement using the bio-action great toe implant: intermediate results. *Foot Ankle Int* 2005;26:1033–1037.
- Raikin SM, Ahmad J, Pour AE, Abidi N. Comparison of arthrodesis and metallic hemiarthroplasty of the hallux metatarsophalangeal joint. *J Bone Joint Surg Am* 2016;89:1979–1985.