DIABETIC FOOT & ANKLE

COACTION PUBLISHING

CLINICAL RESEARCH ARTICLE

Complication rates in diabetics with first metatarsophalangeal joint arthrodesis

John J. Anderson, DPM, FACFAS[1]*, Myron Hansen, DPM, FACFAS[2], Gregory Paul Rowe, DPM[3] and Zflan Swayzee, BS[3]

[1]New Mexico Bone and Joint Institute, Alamogordo, NM, USA; [2]Cactus Foot and Ankle, Chandler, AZ, USA; [3]American Foundation of Lower Extremity Surgery and Research, Alamogordo, NM, USA

Background: First metatarsophalangeal joint (MTPJ) arthrodesis has been an effective surgical entity when indicated, but a range of severe to mild complications can occur from this procedure. Patients with diabetes mellitus have an increased risk in surgical complications, most commonly associated with soft tissue and bone healing, when compared to non-diabetic patients. The purpose of this study was to evaluate the complication rates of first MTPJ arthrodesis in diabetic patients and compare them to the existing complication rates for the procedure.

Methods: A retrospective chart review was done on 76 diabetic patients, from June 2002 to August 2012. Thirty-two males and 44 females were included in the study. The authors evaluated many variables that could impact postoperative complications, including age, gender, bone graft incorporation, hemoglobin A1c, tobacco use, body mass index, peripheral neuropathy, hallux extensus, hallux interphalangeal arthritis, and rheumatoid arthritis, and compared them with the complication findings. Patient follow-up was no less than 24 months.

Results: Overall, approximately two-thirds of the patients had no complications and 35.5% of patients had at least one mild or moderate complication. Of the non-union and mal-union complications, 80 and 70% had peripheral neuropathy, respectively. One hundred percent of the patients that had mal-positions or hardware failure also had peripheral neuropathy. No severe complications were seen during follow-up. Only two of the moderate complications needed revisions, and the rest of those with moderate complications were asymptomatic.

Conclusion: In conclusion, first MTPJ arthrodesis is overall an effective and beneficial procedure in patients with diabetes mellitus. Diabetic patients with peripheral neuropathy have an increased risk for mild and moderate complications.

Keywords: *diabetes mellitus*; *complications*; *peripheral neuropathy*; *first metatarsophalangeal arthrodesis*

*Correspondence to: John J. Anderson, New Mexico Bone and Joint Institute, 2301 Indian Wells, Alamogordo, NM 88310, USA, Email: jsdsbanderson@aol.com

Received: 14 April 2014; Revised: 31 May 2014; Accepted: 1 June 2014; Published: 27 June 2014

First metatarsophalangeal joint (MTPJ) arthrodesis fusion rates have been documented to be around 90% (1–24). The reported indications for this procedure include hallux rigidus, post-traumatic arthritis, infective arthritis, rheumatoid arthritis, neuromuscular disease, chronic instability, salvage of replacement and resection arthroplasty, failed bunion procedures, osteoarthritis, severe hallux valgus, and gouty arthritis (1–3, 6–8, 10, 12, 15, 19, 21, 22, 25–31). First MTPJ arthrodesis is generally not performed until conservative treatment has been implemented. A variety of conservative options are shoe modifications, orthoses, activity modifications, non-steroidal anti-inflammatories, and steroid injections (21, 27, 32).

As with any surgical procedure, there exist severe to mild complications with first MTPJ arthrodesis. Of those reported, the most common are amputation, limb loss, ischemic limb, osteomyelitis, non-union, mal-union, mal-position, failed hardware, wound infections, hematoma or seroma, wound dehiscence, interphalangeal joint arthritis, and transfer metatarsalgia (3, 5, 6, 9, 15, 21, 27, 29, 30, 33–37). Because of some of the more severe complications that can occur, many surgeons have chosen alternate procedures including and limited to first MTPJ cheilectomy, decompression osteotomies, arthroplasty, implant surgery, sesamoid removal, arthrodiastasis, and cartilage resurfacing to treat their patients' symptoms (5, 9, 11, 14, 15, 19, 29, 32, 35, 38). Although complications do exist

 Citation: Diabetic Foot & Ankle 2014, **5**: 24649 - http://dx.doi.org/10.3402/dfa.v5.24649

with this procedure, most are considered mild or moderate and advanced surgical techniques are continually being developed to better the outcomes. Some of the various techniques for fixation include using Kirschner wires or Steinmann pins, cerclage wires, lag screws, plates, staples, and external fixators (3, 4, 9, 10, 12, 13, 16, 20, 21, 23, 28, 39, 35). All of these techniques are geared toward patient satisfaction and a successful postoperative course.

It has been well-documented that those patients with diabetes mellitus have an increased risk of surgical complications compared to non-diabetic patients (40–53). These complications have been associated with soft tissue healing as well as bone healing (40, 41, 44, 46, 48, 51). The reasoning behind these findings is unknown but has been speculated to be due to hyperglycemia and its short-term effects on immune function, pathogen growth, vascular permeability, and long-term effects on the microvascular system (42, 48, 51, 52, 54). Studies have also shown that diabetic patients with additional comorbidities such as peripheral neuropathy, history of ulceration, peripheral arterial disease, hemoglobin A1c $>7\%$, tobacco use, and Charcot neuropathy have a greater risk of having postoperative complications (40, 44, 45, 50, 52, 53, 55, 56). The purpose of this study was to evaluate the complication rates of first MTPJ arthrodesis in diabetic patients and compare them to the existing complication rates for first MTPJ arthrodesis.

Patients and methods

After IRB approval, a retrospective chart review was performed, from June 2002 to August 2012, reviewing the charts of 76 diabetic patients who underwent primary first MTPJ arthrodesis. The study included 32 males and 44 females. The follow-up was no less than 24 months and some were followed for approximately 10 years. Many variables were looked at that could possibly impact postoperative complications in this population. Differences in the age of patients, between males and females, bone grafting compared with no bone grafting, and assessment for those who admitted to smoking through the postoperative period, were reviewed. The patient's body mass index (BMI) was calculated by determining the patient's mass in pounds divided by the patient's height in inches squared and multiplying that result by 703. The hemoglobin A1c values that were documented were also used. Plantar foot neuropathic patients were diagnosed by doing a standard Semmes Weinstein monofilament exam. Influential medical comorbidities from the patient's medical history that could affect outcomes were reviewed. Patients were clinically evaluated for hallux extensus at the hallux interphalangeal joint prior to surgery. Three separate board certified surgeons interpreted radiographs for prior osteoarthritis of the hallux interphalangeal joint. Complications such as mal-position and metatarsalgia were determined on clinic examination postoperatively. Superficial infection and deep infection were diagnosed by evaluating signs and symptoms in correlation with laboratory findings. Non-union, mal-union, failed hardware, and hallux interphalangeal joint arthritis were interpreted radiographically, by the same three surgeons. Dehiscence was noted if the wound was open along the surgical site. Seroma and hematoma were determined by finding a pocket of clear serous fluid or a coagulated pocket of blood deep to the incision site. Complications were categorized as severe, moderate, and mild.

Results

Of the 76 patients included in the study the average age was 62.3 (range 38–90). The complications were noted in patients between the age of 45 and 90. Twenty-one of 44 (47.7%) female patients and 6 of 32 (18.8%) male diabetic patients had at least one complication. The differences between the two were not found to be significant in any of the complications recorded. Bone graft material was used in 12 patients. There was also no significance between the grafting versus non-grafting patients (57). The average time for radiographic union was 7.7 weeks (range 4–14), and average postoperative months of follow-up was 45 months (range 24–121). The average hemoglobin A1c was 7.3% and this was not obtained in 25 of the patients. There were 5 patients who admitted postoperatively that they continued to smoke through the time of surgery. Of the 5 patients who were admittedly smoked during the treatment period, 2 of 5 (40%) had at least one complication. The average BMI was 29.01 (range 16.8–51.8). Patients with complications had a BMI between 19.1 and 49.8. Nineteen of 72 (25%) patients were found to have peripheral neuropathy. Of the moderate complications, 80% of neuropathic patients had non-unions ($p = 2.9 \times 10^{-3}$) and 70% had mal-unions ($p = 3 \times 10^{-4}$), which was found to be significant. One hundred percent of the patients that had mal-positions ($p = 2.94 \times 10^{-6}$) and failed hardware ($p = 0.00025$) also had neuropathy. Twenty-seven percent of the bone healing complications were in non-neuropathic diabetic patients. Hallux extensus was found in 16 individuals prior to surgery. Four patients were previously diagnosed with rheumatoid arthritis. Fifty percent of patients with existing rheumatoid arthritis had at least one complication.

Overall, 49 of 76 (64.5%) had no complications similar to Fig. 1. No severe complications were recorded. No deep infections, seromas, or hematomas were noted. In 27 of the 76 patients (35.5%), at least one mild or moderate postoperative complication occurred, but only two of the moderate complications required revision, which were non-union. There were 7.9% of patients that had a mal-position, 6.6% had a non-union, 13.2% had a mal-union, and 5.3% had hardware failure as shown in Fig. 2. Superficial infection occurred in 3.9% and dehiscence

Citation: Diabetic Foot & Ankle 2014, **5**: 24649 - http://dx.doi.org/10.3402/dfa.v5.24649

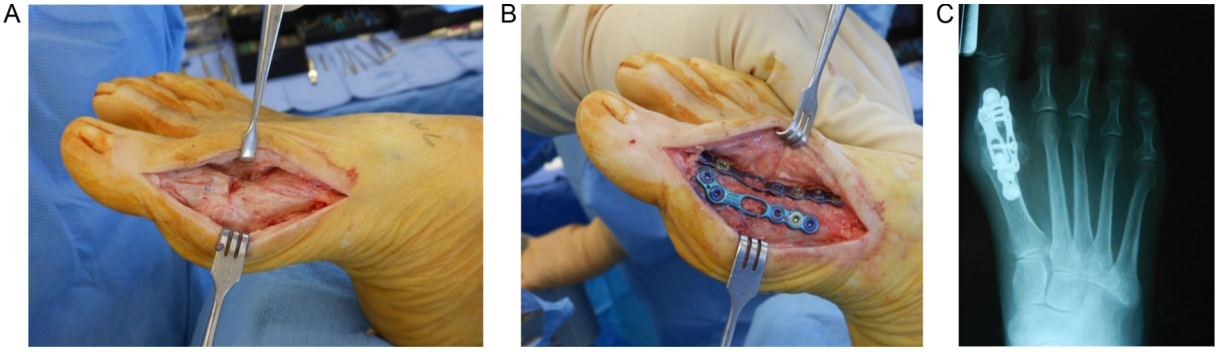

Fig. 1. (a) Intraoperative clinical picture before revision of the first metatarsophalangeal joint arthrodesis in a diabetic patient, (b) intraoperative clinical picture after revision, and (c) postoperative anteroposterior radiograph demonstrating the double plate fixation technique.

in 5.3%. Metatarsalgia was indicated in 5.3%. Hallux interphalangeal arthritis was noticed radiographically in 12 (15.8%) patients, which was found to be significant ($p = 0.029$) in patients with peripheral neuropathy.

Discussion

After reviewing the results it was found that approximately two-thirds of patients had no complications (64.5%) and went on to a successful postoperative course. No severe complications were observed including amputation, limb loss, ischemia, or osteomyelitis. One of three (35.5%) of the study's diabetic patients that had a first MTPJ arthrodesis had one or more mild to moderate complications but only a small number of those required revision surgery. Approximately two of three (68%) of the study's diabetic patients with peripheral neuropathy had one or more mild to moderate complications. This is significantly higher than the results of non-diabetic patients who had approximately 10% of complications (2–5, 35, 39). Mal-position, hardware failure, superficial infection, dehiscence, metatarsalgia, and interphalangeal arthritis can all be considered mild complications, and made up the majority of the study's total complications (68.8%). The moderate complications of mal-union and non-union were 31.3% of complications, of which only two required revision surgery.

Bone healing complications in diabetic patients with neuropathy that have had a first MTPJ arthrodesis seem to be at an increased risk than non-diabetic patients. Non-union and mal-union occurred in 19.7% of the diabetic patients and in 73% of the diabetic patients with peripheral neuropathy. Non-union has been found in the literature to be as low as 5.4% and mal-union as low as 6.1% (6). These findings are comparable with the current literature that has compared fusion rates in patients with diabetic neuropathy (40). Mal-position and hardware complications were found to be 7.9 and 5.3%, respectively. All of these complications occurred in patients with peripheral neuropathy. These findings did not vary from the ranges found in non-diabetics (30). Although unfortunate bone healing, mal-position, and hardware complications occurred, these patients were satisfied with their results, and had a successful outcome based on deformity correction and pain relief.

Infection and wound complication rates were consistent with the literature (51); 9.2% of patients had a wound healing complication. A correlation could not be found in these findings with the hemoglobin A1c because 25 of the 76 patients were not documented. None of the wound healing complications were noted to be in diabetic patients with neuropathy. No deep infections, seromas, or hematomas occurred in the study group of patients, and only mild superficial infections and dehiscence were noted.

Metatarsalgia has been consistently less than the 20% in studies reviewed (30). The results showed it occurring in 5.3% of patients. With the stability of the arthrodesis and the possibility of restoring the length of the first metatarsal with bone graft placement, arthrodesis has even successfully relieved metatarsalgia (30).

It was found that of the patients that had a complication of mal-position, 50% of them also had a complication of hallux interphalangeal arthritis. This complication of arthritis ranges from 10–25%, and was found to be 15.8% in the study (30). It is understood that interphalangeal arthritis and mild to moderate hallux extensus are both low-grade complications.

There are limitations and shortcomings to this study. One limitation is the lack of description of different methods in which the arthrodesis was fixated. Also, not all patients received bone grafts at the time of arthrodesis. Another limitation was to rely on the surgeons' progress notes for tobacco use, bone graft use, hemoglobin A1c, and other significant medical comorbidities.

In conclusion, two-thirds of the diabetic patients who had a first MTPJ arthrodesis had no complications and experienced successful outcomes. Complication rates in diabetic patients were higher than non-diabetic patients. Diabetic patients with peripheral neuropathy appeared to have an increased risk for complications from this procedure compared to non-diabetic patients

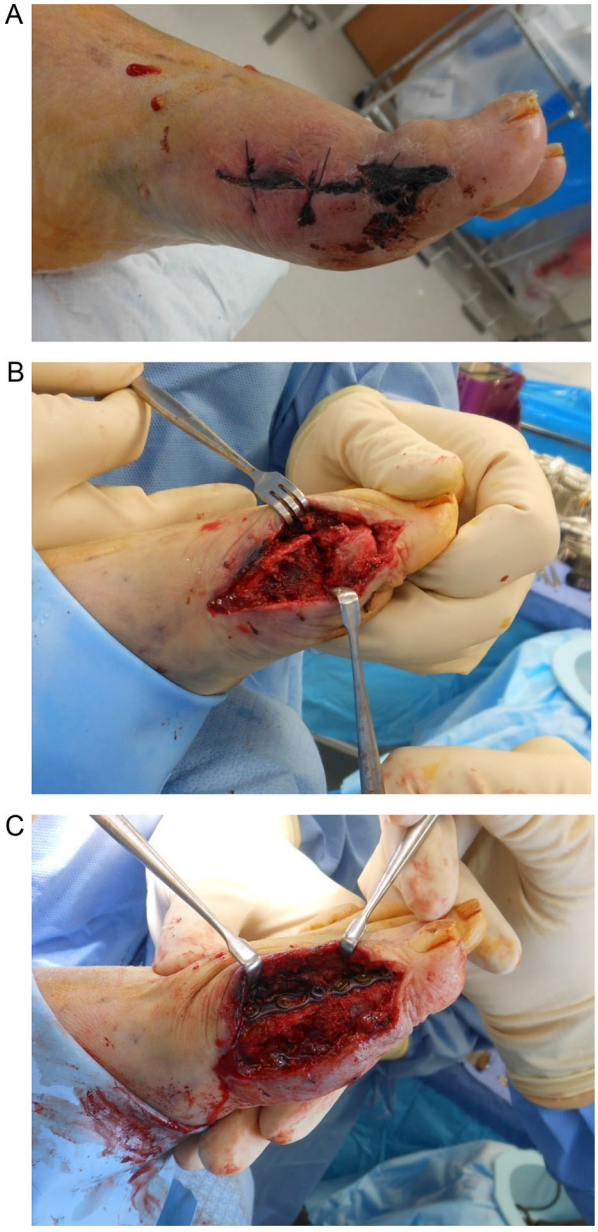

Fig. 2. (a) Preoperative clinical picture showing the wound dehiscence at the first metatarsophalangeal joint, (b) intraoperative clinical picture showing the non-union, and (c) intraoperative clinical picture demonstrating the revision of non-union.

and diabetic patients without peripheral neuropathy. Postoperative complications were either mild or moderate and fell within the normal ranges as compared with non-diabetic patients, and no severe complications occurred. In our retrospective study, diabetic patients with peripheral neuropathy did have an increased risk for mild to moderate complications, but only a small number of those did need revision surgery.

Conflict of interest and funding

There are no known conflicts of interest or any funding provided associated with this paper.

References

1. Castro MD, Klaue K. Revisiting an alternative method of fixation for first MTP joint arthrodesis. Foot Ankle Int 2001; 22: 687–8.
2. Kumar S, Pradhan R, Rosenfeld PF. First metatarsophalangeal arthrodesis using a dorsal plate and a compression screw. Foot Ankle Int 2010; 31: 797–801.
3. Bennett G, Sabetta J. First metatarsophalangeal joint arthrodesis: evaluation of plate and screw fixation. Foot Ankle Int 2006; 30: 752–7.
4. Choudhary RK, Theruvil B, Taylor GR. First metatarsophalangeal joint arthrodesis: a new technique of internal fixation by using memory compression staples. J Foot Ankle Surg 2004; 43: 312–17.
5. Lombardi CM, Silhanek AD, Connolly FG, Dennis LN, Keslonsky AJ. First metatarsophalangeal arthrodesis for treatment of hallux rigidus: a retrospective study. J Foot Ankle Surg 2001; 40: 137–43.
6. Roukis TS. Nonunion after arthrodesis of the first metatarsophalangeal joint: a systematic review. J Foot Ankle Surg 2011; 50: 710–13.
7. Sung W, Kluesner AJ, Irrgang J, Burns P, Wukich DK. Radiographic outcomes following primary arthrodesis of the first metatarsophalangeal joint in hallux abductovalgus deformity. J Foot Ankle Surg 2010; 49: 446–51.
8. Dayton P, McCall A. Early weightbearing after first metatarsophalangeal joint arthrodesis: a retrospective observational case analysis. J Foot Ankle Surg 2004; 43: 156–9.
9. Wassink S, van der Oever M. Arthrodesis of the first metatarsophalangeal joint using a single screw: retrospective analysis of 109 feet. J Foot Ankle Surg 2009; 48: 675–61.
10. Denning J, van Erve RHGP. Arthrodesis of the first metatarsophalangeal joint: a retrospective analysis of plate versus screw fixation. J Foot Ankle Surg 2012; 51: 172–5.
11. Kim PJ, Hatch D, DiDomenico LA, Lee MS, Kaczander B, Count G, et al. A multicenter retrospective review of outcomes for arthrodesis, hemi-metallic joint implant, and resectional arthroplasty in the surgical treatment of end-stage hallux rigidus. J Foot Ankle Surg 2012; 51: 50–6.
12. Mah CD, Banks AS. Immediate weight bearing following first metatarsophalangeal joint fusion with Kirschner wire fixation. J Foot Ankle Surg 2009; 48: 3–8.
13. Moon JL, McGlamry MC. First metatarsophalangeal joint arthrodesis: current fixation options. Clin Podiatr Med Surg 2011; 28: 405–19.
14. Peace RA, Hamilton GA. End-stage hallux rigidus: cheilectomy, implant, or arthrodesis? Clin Podiatr Med Surg 2012; 29: 341–53.
15. Beeson P. The surgical treatment of hallux limitus/rigidus: a critical review of the literature. Foot 2004; 14: 6–22.
16. Sharma H, Bhagat S, DeLeeuw J, Denolf F. In vivo comparison of screw versus plate and screw fixation for first metatarsophalangeal arthrodesis: does augmentation of internal compression screw fixation using a semi-tubular plate shorten time to clinical and radiologic fusion of the first metatarsophalangeal joint (MTPJ)? J Foot Ankle Surg 2007; 47: 1–7.
17. Aas M, Johnsen TM, Finsen V. Arthrodesis of the first metatarsophalangeal joint for hallux rigidus: optimal position of fusion. Foot 2008; 18: 131–5.
18. Agoropoulos Z, Efstathopoulos N, Mataliotakis J, Kokoroghiannisx C, Karachalios GG, Karras K, et al. Long-term results of first metatarsophalangeal joint fusion for severe hallux valgus deformity. J Foot Ankle Surg 2001; 7: 9–13.

Citation: Diabetic Foot & Ankle 2014, **5**: 24649 - http://dx.doi.org/10.3402/dfa.v5.24649

19. Groucher NR, Coughlin MJ. Hallux metatarsophalangeal joint arthrodesis using dome-shaped reamers and dorsal plate fixation: a prospective study. Foot Ankle Int 2006; 27: 869–76.
20. Grondal L, Stark A. Fusion of the first metatarsophalangeal joint, a review of techniques and considerations: presentation of our results in 22 cases. Foot 2005; 15: 86–90.
21. Shereff MJ, Baumhauer JF. Hallux rigidus and osteoarthrosis of the first metatarsophalangeal joint. J Bone Joint Surg 1998; 80: 898–908.
22. Machacek F, Easey ME, Gruber F, Ritschl P, Trnka HJ. Salvage of failed Keller resection arthroplasty. J Bone Joint Surg 2004; 86: 1132–8.
23. Bayomy AF, Aubin PM, Sangeorzan BJ, Ledoux WR. Arthrodesis of the first metatarsophalangeal joint: a robotic cadaver study of the dorsiflexion angle. J Bone Joint Surg 2010; 92: 1754–64.
24. Mankovecky MR, Prissel MA, Roukis TS. Incidence of nonunion of first metarsal-phalangeal joint arthrodesis with autogenous iliac crest bone graft after failed Keller-Brandes arthroplasty: a systematic review. J Foot Ankle Surg 2013; 52: 53–5.
25. Vanore JV, Christensen JC, Kravitz SR, Schuberth JM, Thomas JL, Weil LS, et al. Diagnosis and treatment of first metatarsophalangeal joint disorders. Section 2: Hallux Rigidus. J Foot Ankle Surg 2003; 42: 124–36.
26. Nicolas C, Silhanek AD, Connolly FG, Lombardi CM. The effect of first metatarsophalangeal arthrodesis on transverse plane deviation of the second toe: a retrospective radiographic study. J Foot Ankle Surg 2005; 44: 365–76.
27. Beertema W, Draijer WF, van Os JJ, Pilot P. A retrospective analysis of surgical treatment in patients with symptomatic hallux rigidus: long-term follow-up. J Foot Ankle Surg 2006; 45: 244–51.
28. Buranosky DJ, Taylor DT, Sage RA, Sartori M, Patwardhan A, Phelan M, et al. First metatarsophalangeal joint arthrodesis: quantitative mechanical testing of six-hole dorsal plate versus crossed screw fixation in cadaveric specimens. J Foot Ankle Surg 2001; 40: 208–13.
29. Rajczy RM, McDonald PR, Shapiro HS, Boc SF. First metatarsophalangeal joint arthrodesis. Clin Podiatr Med Surg 2012; 29: 41–9.
30. Fadel GE, Rowley DI, Abboud RJ. Hallux metatarsophalangeal joint arthrodesis: various techniques. Foot 2002; 12: 88–96.
31. Giannini S, Cecarelli F, Faldini C, Bevoni R, Grandi G, Vannini F. What's new in surgical options for hallux rigidus? J Bone Joint Surg 2004; 2: 72–83.
32. McNeil DS, Baumhaumer JF, Glazebrook MA. Evidence-based analysis of the efficacy for operative treatment of hallux rigidus. Foot Ankle Int 2013; 34: 15–32.
33. DeOrio JK. Technique tip: arthrodesis of the first metatarsophalangeal joint–prevention of excessive dorsiflexion. Foot Ankle Int 2007; 28: 746–7.
34. Hunt KJ, Ellington JK, Anderson RB, Cohen BE, Davis WH, Jones CP. Locked versus non-locked plate fixation for hallux MTP arthrodesis. Foot Ankle Int 2011; 32: 704–9.
35. Yu GV, Gorby PO. First metatarsophalangeal joint arthrodesis. Clin Podiatr Med Surg 2004; 21: 65–96.
36. Sharma V, Geary NPJ. Long term retrospective analysis of the first metatarsophalangeal joint arthrodesis with two crossed screws. Foot 2002; 11: 199–204.
37. Harisboure A, Joveniaux P, Madi K, Dehoux E. The Valenti technique in the treatment of hallux rigidus. Orthop Traumatol Surg Res 2009; 95: 202–9.
38. Coughlin MJ, Shurnas PS. Hallux rigidus. grading and long-term results of operative treatment. J Bone Joint Surg 2003; 85: 2072–88.
39. Schnirring-Judge M. Technique and pearls in performing the first metatarsophalangeal joint arthrodesis. Clin Podiatr Med Surg 2011; 28: 345–59.
40. Shibuya N, Humphers JM, Fluhman BL, Juniper DC. Factors associated with nonunion, delayed union, and malunion in foot and ankle surgery in diabetic patients. J Foot Ankle Surg 2013; 52: 53–5.
41. Acott AA, Theus SA, Kim LT. Long-term glucose control and risk of perioperative complications. Am J Surg 2009; 198: 596–9.
42. Golden SH, Peart-Vigilance C, Kao L, Brancati FL. Perioperative glycemic control and the risk of infectious complications in a cohort of adults with diabetes. Diabetes Care 1999; 22: 1408–14.
43. Marchant MH, Veins NA, Cook C, Vail TP, Bolognesi MP. The impact of glycemic control and diabetes mellitus on perioperative outcomes after total joint arthroplasty. J Bone Joint Surg 2009; 91: 1621–9.
44. Myers TG, Lowery NJ, Frykberg RG, Wukich DK. Ankle and hindfoot fusions: comparison of outcomes in patients with and without diabetes. Foot Ankle Int 2012; 33: 20–8.
45. Perlman MH, Thordarson DB. Ankle fusion in a high risk population: an assessment of nonunion risk factors. Foot Ankle Int 1999; 20: 491–6.
46. Wukich DK, Belczyk RJ, Burns PR, Frykberg RG. Complications encountered with circular ring fixation in persons with diabetes mellitus. Foot Ankle Int 2008; 29: 994–1000.
47. Wukich DK, Shen JY, Ramirez CP, Irrgang JJ. Retrograde ankle arthrodesis using an intramedullary nail: a comparison of patients with and without diabetes mellitus. J Foot Ankle Surg 2011; 50: 299–306.
48. Santana RB, Xu L, Chase HB, Amar S, Graves DT, Trackman PC. A role for advanced glycation end products in diminished bone healing in type 1 diabetes. Diabetes 2003; 52: 1502–10.
49. Blotter RH, Connolly E, Wasan A, Chapman MW. Acute complications in the operative treatment of isolated ankle fractures in patients with diabetes mellitus. Foot Ankle Int 1999; 20: 678–94.
50. Jones KB, Maiers-Yelden KA, Marsh JL, Zimmerman MB, Estin M, Saltzman CL. Ankle fractures in patients with diabetes mellitus. J Bone Joint Surg 2005; 87: 489–95.
51. Mehta SK, Breitbart EA, Berberian WS, Liporace FA, Lin SS. Bone and wound healing in the diabetic patient. Foot Ankle Clin 2010; 15: 411–37.
52. Ghirlanda G, Mancini L. Current perioperative treatment of patients with type 1 and type 2 diabetes. Clin Podiatr Med Surg 2007; 24: 365–82.
53. Tao LS, MacKenzie CR, Charlson ME. Predictors of postoperative complications in the patient with diabetes mellitus. J Diabetes Complications 2008; 22: 24–8.
54. Giurini JM, Cook EA, Cook JJ. Diabetes: the latest trends in glycemic control. Clin Pod Med Surg 2007; 24: 159–89.
55. Bevilacqua NJ, Stapleton JJ. Advanced foot and ankle fixation techniques in patients with diabetes. Clin Podiatr Med Surg 2011; 28: 661–71.
56. Chuah LL, Papamargaritis D, Pillai D, Krishnamoorthy A, le Roux CD. Morbidity and mortality of diabetes with surgery. Nutr Hosp 2013; 28S: 47–52.
57. Anderson J, Jeppesen N, Hansen M, Brady C, Gough A, Fowler Z. First metatarsophalangeal joint arthrodesis: comparison of mesenchymal stem cell allograft versus autogenous bone graft fusion rates. Surg Sci 2013; 4: 263–7.