What is the most durable construct for a forefoot amputation, traditional transmetatarsal amputation or a medial ray sparing procedure?

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Comment on: Suh YC, Kushida-Contreras BH, Suh HP, *et al.* Is Reconstruction Preserving the First Ray or First Two Rays Better Than Full Transmetatarsal Amputation in Diabetic Foot? Plast Reconstr Surg 2019;143:294-305.

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This discussion is prompted by a recent paper from Suh and colleagues from Seoul, South Korea that evaluates clinical outcomes from a retrospective cohort of 59 patients with either a traditional transmetatarsal amputation (TMA) (n=27) or first or first and second ray sparing amputation (n=32) that all required follow-up free flap coverage (1). Evaluating the function of different amputation constructs in the diabetic foot is an important issue because recurrent events are very common in patients with diabetes and a history of diabetic foot ulcer or amputation. The medial column of the foot is essential for ambulation and balance. If we can maintain the function of the first ray (the great toe, first metatarsophalangeal joint, first metatarsal and metatarsocuneiform joint complex) we may be able to create a more durable amputation with improved function. However, when adjacent toes and metatarsophalangeal joints are amputated, the foot compensates. Often the remaining first and second toe and metatarsophalangeal joints deform, the toes hammer, the toes deviate laterally, and the metatarsophalangeal joints dislocate. As the metatarsophalangeal joints dislocate, the metatarsal heads are often literally pushed through the sole of the foot. A midfoot amputation clearly changes the way our patients walk. There is very little power generation across the ankle joint, so the hip becomes the primary source for propulsion. It makes sense that people with residual toes require more surgery, just as Suh reports (1).

Ideally, there would be more information about the biomechanical consequences of the two approaches. There are likely to be adaptive changes to the forefoot after amputation (2,3). The authors indicate there are more minor surgeries, but they do not provide enough information to explain exactly why the procedures were done. The structural changes after amputation are most likely the reason for the additional surgical procedures. We realize that in a small cohort study it is difficult to do any analysis with smaller and smaller subgroups within the cohort.

First of all, it is likely that there is selection bias in this study. Suh and colleagues may have a very different patient population and a different level of surgical expertise compared to most community plastic surgeons. The Korean population with diabetes is probably less obese than diabetic patients from the Middle East, Europe or America. Nutrition, tobacco use, activity, social constructs and other factors may also be different. The expertise of the surgeons in this study are also probably different than the plastic surgeons in many communities. Suh and colleagues would fit into the category of super microvascular surgeons. They do very challenging cases, and they have a large volume of cases of high-risk people with diabetes. This group has a well-organized system with good continuity of care, that

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is the exception rather than the rule in diabetic foot care. Because of this group's experience, they have internal inclusion and exclusion criteria for patient selection. Unfortunately, their criteria were not clear from the paper.

The devil is in the detail. Every surgeon wants to understand if the study population looks like their patients. Some important operational definitions for this population are not stated while other important variables are not reported at all. The authors do provide information about the prevalence of peripheral sensory neuropathy, residual osteomyelitis, BMI, equinus deformity, long term glucose control, or nutrition parameters such as albumin and pre-albumin.

Peripheral vascular disease is reported to be present in 52% of TMA patients and 47% of ray amputation patients. However, the criteria used to define PVD is not stated. Mönckeberg's sclerosis is very common in this high-risk segment of the population that renders traditional ankle brachial indices, systolic pressures, and waveforms unreliable. The authors relate that all patients ultimately had good flow after angioplasty, but there is no objective measure of flow or functional perfusion to help the reader understand baseline PVD and post angioplasty perfusion. Patients with neuro-ischemic wounds and severe PVD could be expected to have worse long-term outcomes. One of the unmet needs in the diabetic foot is tools to evaluate functional perfusion that can be used to predict wound healing and amputation level. Traditional arterial doppler studies are often unreliable because of arterial classification. New technology like Skin Perfusion Pressure measurements (Sensilase, Vasamed, MN) and hyperspectral imaging technology are promising techniques to measure functional perfusion to the skin.

Nutrition assessment using albumin and pre-albumin as surrogate markers is a point of discussion in many studies that address surgical outcomes and wound healing in people with diabetes, the elderly, and other high-risk populations. Dickhaut and Pinzur reported the association of low albumin and amputation failure in people with diabetes more than 30 years ago (4,5). Other studies have focused on albumin <3.0 as a predictor of failure (6). Low albumin and prealbumin has been associated with higher rates of complications in orthopaedic surgery (7,8), abdominal wall reconstruction (9), and trauma (10,11). However, some studies have not found a relationship with albumin and pre-albumin in surgical complications (12-14). It would have been interesting to see if low nutritional parameters were traditional exclusion criteria for Dr. Suh's group or if failure was more common if albumin and prealbumin were low. Albumin and prealbumin levels are a consideration in patient selection in our institution. There is only one study we identified that suggests a nutritional intervention improves diabetic foot wound healing in patients with albumin <4.0 (15). Are these parameters measures of nutrition or surrogate markers for something else that are associated with poor clinical outcomes?

The type of initial surgery is only part of providing a functional amputation and preventing re-ulceration, re-infection, re-admission and minor and major surgical procedures. The type and quality of follow-up care and prevention service after surgery is the other part of the equation. The importance of these services is often lost on the surgeon that does not work as part of a multidisciplinary team. Most diabetic foot ulcers occur on the sole of the foot and are related to abnormal foot biomechanics in patients with sensory neuropathy; so repetitive injuries are not recognized. After amputation, the underlying co-morbidities are still present (sensory neuropathy, vascular disease, immunopathy) and abnormal biomechanics are often worse because of the amputation, so the risk of another ulcer is very high (16). Long term success and failure depends on the availability and quality of preventive care. Bespoke shoes and insoles, regular foot care and diabetic foot specific education are important components to prevent re-current ulcers and their sequelae. When prevention services are not provided, re-ulceration is 50–62% a year (17-19). When prevention services are provided re-ulceration is cut in half. Unfortunately, Suh and colleagues do not report re-ulceration, re-infection, or re-admission to hospital. Neither do they report the type of prevention services that were provided. This is an important part of treatment, but it is rarely reported in studies that discuss the success of amputation procedures in the diabetic foot.

Other studies that evaluate outcomes after midfoot amputation suffer the same methodological issues as Suh and colleagues (1). There is very little detail about the reason for the amputation, (infection, gangrene, vascular disease), the quality of post-operative preventative care, or risk factors such as glucose control, dialysis, nutrition, and perfusion. Multiple surgical processes are common after amputation. For instance, Dillingham and colleagues reported the results of 379 foot or ankle amputations in dysvascular patients and reported that 29% required ≥1 re-amputation, and 11% required ≥2 additional procedures (20). Pollard *et al.* reported that 31% of 101 patients with TMAs failed at this level and required a more proximal amputation (21).

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A team approach in high risk patients with diabetes and foot complications has been demonstrated to have impressive outcomes (17,22,23). Surgeons are a central part of the team. Just as this investigation by Suh and colleagues demonstrates, selecting the most functional amputation is an important part of the process. Re-ulceration and re-amputation are 50% lower when a team of specialists perform the amputation and provide amputation aftercare including bespoke shoes, insoles, bracing, foot specific education and regular foot assessment (24-26).

Suh and colleagues reported that there were few differences in the two types of amputations except for more minor surgical procedures in subjects that did not have the traditional transmetatarsal amputation. From these results, there does not seem to be an advantage to keep one or two toes compared to the traditional transmetatarsal amputation construct. Suh's results are better than most of the published work on this topic. All of the literature suffers from poor documentation about after care and poor objective measures of perfusion and nutrition.

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Footnote

Conflicts of Interest: The authors have no conflicts of interest to declare.

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