Rate and Location of Reulceration and Reamputation After Partial First-Ray Amputation versus Hallux Amputation in Diabetic and Nondiabetic Populations

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Background: We sought to determine the rates of reulceration and reamputation in individuals who underwent partial first-ray amputations versus hallux amputations in diabetic and nondiabetic populations.

Methods: Eighty-four amputations were reviewed in a retrospective fashion. A retrospective medical record review was performed to determine patients who underwent a hallux amputation, both partial and complete, and patients who underwent a partial first-ray amputation. Only patients from 2007 to 2019 were reviewed. The reulceration rate of hallux amputations was 61% compared with a partial first-ray amputation reulceration rate of 74%.

Results: The reamputation rate of hallux amputation versus partial first-ray amputation was 43% versus 51%. At final follow-up, it was statistically significant that patients who underwent hallux amputation were more likely to be healed than those who underwent partial first-ray amputation, regardless of reulceration or reamputation. In addition, patients who underwent hallux amputation went on to digital amputation, and those who underwent partial first-ray amputation went on to transmetatarsal amputation.

Conclusions: Comparing partial first-ray amputation to hallux amputation, hallux amputation patients are more prone to subsequent digital ulceration. Patients who initially undergo hallux amputation have variable subsequent amputations, often digital. Reulceration primarily occurs at the incision site for partial first-ray amputations, with a higher likelihood of subsequent transmetatarsal amputation. Patients with a medical history of diabetes and staged procedures are more likely to receive partial first-ray amputations. However, hallux amputation patients have a lower risk of reulceration and reamputation, regardless of subsequent events. These findings underscore the importance of discussing risks and preventive measures with patients undergoing such amputations, emphasizing postoperative examinations for specific areas of concern. Hallux amputation appears to offer greater protection against reulceration and reamputation for both diabetic and nondiabetic populations. (J Am Podiatr Med Assoc 114(2), 2024; doi:10.7547/22-029)

The first ray consists of three bones and spans two joints. The bones that are involved include the first metatarsal, the proximal phalanx, and the distal phalanx of the hallux. These bones articulate to form the metatarsophalangeal joint and the interphalangeal joint. During gait, the foot resupinates during the propulsion phase, leading the first ray and medial column to become a rigid beam, allowing forces to be transmitted through the first metatarsophalangeal joint. Due to circumstances such as equines, foot architecture, and peripheral neuropathy, an increase in pressure in other locations during propulsion can result in hyperkeratosis or ulceration formation.[1] Complications such as infection or osteomyelitis then can result in the need for amputation.[2,3,4] Any amputation may lead to an increase in pressure and the possibility of reulceration, or worse, reamputation. Many physicians believe that amputations involving solely the

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Table 1. Patient Demographics

Characteristic	Hallux Amputation (n = 49)	Partial First-Ray Amputation (n = 35)	*P* Value
Sex (No. [%])			
Male	42 (86)	27 (77)	.8383
Female	7 (14)	8 (23)	.1617
Age (mean ± SD [years])	58.57 ± 15.11	62.2 ± 11.65	.2374
Follow-up (mean [mo])	20.46	25.94	.2452
Diabetes (No. [%])	35 (71)	31 (89)	.0206[a]
Neuropathy (No. [%])	41 (84)	33 (94)	.0534
Developed ulceration (No. [%])	30 (61)	26 (74)	.0991
Need for further amputation (No. [%])	21 (43)	18 (51)	.2183
No ulceration at last follow-up (No. [%])	43 (88)	21 (60)	.0018[a]
Deceased (No. [%])	19 (39)	12 (34)	.6637

[a]Significance between patients who underwent hallux amputation versus partial first-ray amputation ($P < .05$).

hallux maintain a long lever arm of the medial column, thus a decrease in transfer lesions, resulting in a decreased need for reamputation. We compared hallux amputations versus partial first-ray amputations for factors that may predispose patients to reulceration or reamputation in the diabetic and nondiabetic populations.

Methods

Research Design

A retrospective medical record review was performed of patients seen and treated by the primary surgeon (P.R.B.). The purpose was to determine the rates of reulceration and reamputation in individuals who underwent partial first-ray amputations versus hallux amputations. This study will help determine the University of Pittsburgh Medical Center's reulceration and reamputation rates for these two procedures and compare which would be more beneficial for a patient.

Approval was obtained from the University of Pittsburgh Institutional Review Board (Pittsburgh, Pennsylvania). Records of the primary surgeon (P. R.B.) were reviewed to identify patients undergoing either hallux amputation or partial first-ray amputation between January 1, 2007, and December 31, 2019. Patients were included who were older than 18 years, underwent partial first-ray amputation or hallux amputation, and had 1 year of follow-up after the index procedure. Patients who underwent amputation before hallux or partial first-ray amputation on the ipsilateral limb and patients with open ulceration not involved with the index procedure were excluded. Medical records were reviewed to obtain demographic information and outcomes. Eighty-four amputations were reviewed in a retrospective fashion. After this, we determined when patients developed an ulceration through medical record review and when patients, if needed, underwent an amputation via operative report.

Data and Resource Availability

The data sets generated or analyzed during the present study are not publicly available due to protection on the University of Pittsburgh Medical Center server but are available from the corresponding author on reasonable request. The tables and figures generated or analyzed during the present study are also available from the corresponding author on reasonable request.

Results

There were 49 patients who underwent hallux amputation and 35 who underwent partial first-ray amputation who met the inclusion and exclusion criteria. Mean follow-up was 20.46 months in the hallux amputation group and 25.94 months in the partial first-ray amputation group. In the hallux amputation group, 86% of patients (n = 42) were male and 14% (n = 7) were female. In the partial first-ray amputation group, 77% of patients (n = 27) were male and 23% (n = 8) female. It was noted that 84% of patients (n = 41) in the hallux amputation group and 94% (n = 33) in the partial first-ray amputation group were diagnosed as having peripheral neuropathy. In the hallux amputation and partial first-ray amputation groups, 71% (n = 35) and 89% (n = 31), respectively, were diagnosed as having diabetes (Table 1).

Diabetes

Comparing the amputation groups demographically revealed several significant factors. Of note, it was

Table 2. Hallux Amputation Only versus Hallux Amputation with Reulceration/Reamputation

Characteristic	Hallux Amputation Only (n = 19)	Hallux Amputation with Reulceration/Reamputation (n = 30)	*P* Value
Age (mean ± SD [years])	56.37 ± 14.58	59.97 ± 15.52	.4223
Laboratory values at index procedure (mean ± SD)			
WBC count ($\times 10^9$/L)	9.60 ± 2.59	10.33 ± 3.93	.4777
ESR (mm/h)	58.43 ± 34.38	60.17 ± 37.36	.8707
CRP (mg/dL)	6.07 ± 4.28	7.39 ± 5.13	.3553
Creatinine (mg/dL)	1.33 ± 1.29	1.84 ± 1.80	.2895
Albumin (g/dL)	2.79 ± 0.67	3.03 ± 0.65	.2195
Hemoglobin A_{1c} (%)	9.33 ± 2.35	9.00 ± 3.16	.6974
Diabetes (No. [%])	13 (68)	22 (73)	.3567
Neuropathy (No. [%])	14 (74)	27 (90)	.0778
Staged index procedure (No. [%])	0	5 (17)	.0071[a]
Deceased (No. [%])	7 (37)	12 (40)	.4122

Abbreviations: CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; WBC, white blood cell.

[a]Significance between those who underwent a staged procedure in the hallux amputation only group versus the group with reulceration/reamputation ($P < .05$).

statistically significant that patients with a medical history of diabetes were more likely to undergo partial first-ray amputations. This is explained by a subset of the population that underwent hallux amputations secondary to trauma rather than from foot infection. In addition, in the diabetic patient, at follow-up, it was statistically significant to have a reulceration or reamputation in the partial first-ray amputation group versus the hallux amputation group ($P = .024$). There was no statistically significant difference, however, in patients with neuropathy between groups (Table 1).

Of the 30 patients in the hallux amputation group with reulceration or reamputation, 73% (n = 22) were diabetic and 90% (n = 27) were diagnosed with neuropathy; this was not found to be statistically significant (Table 2). For partial first-ray amputations, 92% of 26 patients (n = 24) who developed a reulceration or required reamputation were noted to be diabetic and 96% (n = 25) were diagnosed as having neuropathy. Similar to the hallux amputation group, there was no statistically significant difference (Table 3).

When evaluating relative risk in patients who underwent a hallux amputation, patients with diabetes were noted to have a relative risk for reulceration or reamputation of 7.18% (relative risk reduction [RRR] = 1.0718). Patients with neuropathy in the hallux amputation group had an increased risk of reulceration or reamputation of 22.14% (RRR = 1.2214). In the partial first-ray amputation group, patients with diabetes had a relative risk of 18.68% (RRR = 1.1868) of developing a new ulceration or undergoing a new amputation, and those diagnosed as having neuropathy had a relative risk of 8.17% (RRR = 1.08170) of developing a new ulceration or undergoing another amputation.

Table 3. Partial First-Ray Amputation Only versus Partial First-Ray Amputation with Reulceration/Reamputation

Characteristic	Partial First-Ray Amputation Only (n = 9)	Partial First-Ray Amputation with Reulceration/Reamputation (n = 26)	*P* Value
Age (mean ± SD [years])	64.78 ± 12.64	61.31 ± 11.41	.4494
Laboratory values at index procedure (mean ± SD)			
WBC count ($\times 10^9$/L)	10.14 ± 5.88	13.7 ± 5.83	.1247
ESR (mm/h)	75.86 ± 45.68	67 ± 33	.5343
CRP (mg/dL)	9.78 ± 8.36	11.79 ± 8.03	.5261
Creatinine (mg/dL)	1.96 ± 1.66	1.49 ± 0.88	.2858
Albumin (g/dL)	2.77 ± 1.10	2.6 ± 0.57	.5536
Hemoglobin A_{1c} (%)	8.55 ± 1.34	9.19 ± 2.54	.4783
Diabetes (No. [%])	7 (78)	24 (92)	.1633
Neuropathy (No. [%])	8 (89)	25 (96)	.257
Staged index procedure (No. [%])	6 (67)	15 (58)	.6866
Deceased (No. [%])	3 (33)	9 (35)	.472

Abbreviations: CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; WBC, white blood cell.

Patients with diabetes who underwent a partial first-ray amputation were 23.17% more likely to develop a reulceration or undergo a reamputation (RRR = 1.217) compared with patients who underwent a hallux amputation as their initial index procedure.

Reulceration

In the hallux amputation group, 61% of patients (n = 30) developed an ulceration during follow-up (Table 1). In the partial first-ray amputation group, 74% of patients (n = 26) were noted to develop an ulceration; compared with the hallux amputation group, this was not noted to be significant (P = .0991).

Patients who underwent hallux amputation were less likely to have an ulceration at final follow-up regardless of whether they had reamputation or reulceration compared to the partial first-ray amputation group (80% versus 60%; P = .0018). Furthermore, for patients who developed a reulceration or required a reamputation, those who underwent a hallux amputation as their index procedure were more likely to be healed at final follow-up (77% versus 46%; P = .0072).

When evaluating location of reulceration, it was significant that patients developed a subsequent digital amputation if they underwent a hallux amputation (P = .002). When calculating reulceration rates in patients who underwent partial first-ray amputation, it was significant for patients to have an ulceration at the site of the incision compared with other ulcerations (P = .014).

Patients who underwent partial first-ray amputation were 44% more likely to develop a reulceration compared with those who underwent hallux amputation (RRR = 1.444).

Reamputation

In the hallux amputation group, 21 patients (43%) underwent additional amputation (Table 1). Eighteen patients (51%) who underwent a partial first-ray amputation required reamputation. However, there was no significant difference between hallux reamputation rate and partial first-ray reamputation rate (P = .2183). The major amputation rate, defined as amputation at or proximal to the midtibia, was noted to be 8% for hallux amputation and 5% for partial first-ray amputation. There was no statistically significant difference in major amputations for the two groups. The total major amputation rate in this study was 5.3% (Table 4).

Patients who underwent a partial first-ray amputation were more likely to undergo a primary staged procedure at initial presentation (P = .0003) compared with those in the hallux amputation group. A staged amputation was defined as an amputation followed by a repeated incision and drainage or delayed primary closure. However, when evaluating patients who developed a reulceration or needed reamputation in the hallux amputation group, patients who underwent a staged hallux amputation were more likely to experience a reulceration or reamputation (P = .0071). There was no significant different in reamputation or reulceration in the partial first-ray amputation group if they underwent a staged index procedure (P = .686).

When evaluating reamputation, patients were more likely to undergo a transmetatarsal amputation after a first-ray amputation than after a hallux amputation (P = .0001). Regarding reamputation after a hallux amputation, there was no statistically significant difference in the type of amputation that was subsequently performed; however, digital amputation was the most common (Table 4). When looking at the relative risk of a reamputation, patients who underwent partial first-ray amputation were 20% more likely to undergo another amputation compared with the hallux amputation group (RRR = 1.2).

Discussion

Digital and partial ray amputations have been widely regarded as minor amputations compared with transtibial amputations. However, it is well documented that patients who undergo initial amputation are at higher risk for reamputation to the ipsilateral limb.[1,2,6] Due to changing biomechanics of the foot secondary to a hallux amputation or a partial first-ray amputation, this may be contributory to the development of new ulcerations or secondary amputations. This study, to our knowledge, is the first to directly compare partial first-ray amputations and hallux amputations in terms of reulceration and reamputation in patients with and without diabetes. There are several papers that investigate the reulceration rate of these amputations[6]. However, there is no research, to our knowledge, that compares these amputations, both partial first ray and hallux, at the same institution and with the same surgeon.

Hallux amputations at our institution had a reamputation rate of 43% in the follow-up period. This compares favorably with other studies in terms of

Table 4. Hallux Amputation with Reulceration/Reamputation vs Partial First-Ray Amputation with Reulceration/Reamputation

Characteristic	Hallux Amputation with Reamputation/Reulceration (n = 30)	First-Ray Amputation with Reamputation/Reulceration (n = 26)	*P* Value
Age (mean ± SD [years])	59.97 ± 15.52	61.31 ± 11.41	.7179
Laboratory values at index procedure (mean ± SD)			
WBC count ($\times 10^9$/L)	10.33 ± 3.93	13.7 ± 5.83	.0131
ESR (mm/h)	60.17 ± 37.36	67 ± 33	.4747
CRP (mg/dL)	7.39 ± 5.13	11.79 ± 8.03	.0165
Creatinine (mg/dL)	1.84 ± 1.80	1.49 ± 0.88	.3712
Albumin (g/dL)	3.03 ± 0.65	2.6 ± 0.57	.0116
Hemoglobin A_{1c} (%)	9.00 ± 3.16	9.19 ± 2.54	.8071
Time between amputation (mean ± SD [mo])	9.70 ± 9.54	6.26 ± 7.39	.1418
Diabetes (No. [%])	22 (73)	24 (92)	.0242[a]
Neuropathy (No. [%])	27 (90)	25 (96)	0.1774
Staged procedure (No. [%])	5 (17)	15 (58)	0.0003[a]
Deceased (No. [%])	12 (40)	9 (35)	.6615
	Location of ulceration (No. [%]) (n = 36)	Location of ulceration (No. [%]) (n = 30)	
Digit	16 (44)	3 (10)	.002[a]
Incision site	9 (25)	16 (52)	.0104[a]
Heel	1 (3)	2 (6)	.6806
Ankle	3 (8)	NA	
Lesser metatarsal head	2 (6)	NA	
First metatarsal head	4 (11)	NA	
Second metatarsal head	NA	4 (13)	
Plantar midfoot	NA	4 (13)	
Dorsal midfoot	1 (3)	4 (13)	
	Reamputation site (No. [%]) (n = 26)	Reamputation site (No. [%]) (n = 20)	
Transmetatarsal amputation	6 (23)	16 (80)	<.001[a]
Digit	8 (31)	2 (10)	.9674
First ray	7 (27)	NA	
First-ray revision	NA	1 (5)	
Hallux	2 (7)	NA	
Major amputation	2 (8)	1 (5)	
Metatarsal head	1 (4)	NA	
No ulceration/healed at final follow-up (No. [%])	23 (77)	12 (46)	.0072[a]

Abbreviations: CRP, C-reactive protein; ESR, erythrocyte sedimentation rate; NA, not applicable; WBC, white blood cell.

[a]Significance between patients who developed a reulceration or required reamputation in the hallux amputation group versus the partial first-ray amputation group ($P < .05$).

hallux amputations, as Vassallo et al[8] noted a reamputation rate of 59% after single or multiple toe amputations. This also compares with studies by Littman et al[9] in hallux/ray amputation in the US veteran population. Their reamputation rate was 34%; however, they did not delineate between ray and hallux amputation in the study.

In the present study, the reulceration rate after hallux amputation was 61%. This is noted to be higher than that of Vassallo et al[8] of 43.2%. However, similar to that same study, the present study showed a high rate of hallux amputations healed at final follow-up (80%).

Borkosky and Roukis[6] in 2013 performed a systematic review of partial first-ray amputations and stated that 42.4% of patients underwent a more proximal amputation. As with the previous studies, this finding does not show any comparison of a partial or complete hallux amputation. The present study has a higher reamputation rate compared with this systematic review: 51% of patients required a reamputation. Also, in terms of reulceration, Borkosky and Roukis[6] noted a reulceration rate of 69% in a 3-month period. This compares with the present study in which 74% of patients developed an additional ulceration; however, in the

present study this was reported during the 24-month follow-up. The present study did not delineate the specific time to ulceration.

More diabetic patients were noted to undergo a partial first-ray amputation versus a hallux amputation. This may be explained secondary to traumatic hallux amputations in the general population. In the present study, comparing patients with and without diabetes, patients who developed a reulceration or required a reamputation were diabetic in 73% of the hallux amputations and in 90% of the partial first-ray amputations. Also, in the hallux amputation group, patients with diabetes had a relative risk of 7.18% of reulceration or reamputation, and those with diabetes who underwent a partial first-ray amputation had a relative risk of reulceration or reamputation of 18.68%. In the diabetic population, patients who underwent partial first-ray amputation had a relative risk of 23.17% of reamputation or reulceration compared with the hallux amputation group. One of the most glaring findings is in terms of reulceration. It was found that if patients underwent a partial first-ray amputation as their initial index procedure, they had a 44% relative risk of reulceration compared with patients who underwent hallux amputation as their initial procedure.

It was statistically significant that patients who underwent a hallux amputation were more likely to be healed at final follow-up compared with those who underwent partial first-ray amputation, regardless of diabetic or nondiabetic status. Compared with a study by Murdoch et al,[10] the present study shows a favorable outcome of 80% of patients who underwent hallux amputations healed at final follow-up. Murdoch et al[10] noted that 17% of patients required below-the-knee amputation in a 3-year span, which is grossly higher than the 8% major amputation rate in the present study.

With any study, there are noted limitations. First, all of the patients who did not have 1-year follow-up were excluded. All of the patients who underwent a reamputation from an outside physician (not P.R.B.) were also excluded unless amputation was noted to be transtibial or proximal. In terms of the 1-year follow-up as a limitation, there may be a subset of patients who did well with their amputation and therefore did not follow up. This may show that some patients with extensive follow-up may be those who had issues with reulceration and reamputation. Another limitation was that the consequences to the contralateral limb were not explored unless a contralateral hallux or partial first-ray amputation was found. This article focused on the changing biomechanics of one lower extremity after removal of a portion of the first ray. We felt that including ulcerations to the contralateral limb would change the findings as the ulcerations may have been caused by other reasons and not secondary to the previous amputation. We also were limited in patients' quality of life. The study looked at only reulceration, reamputation, and the status of the ulcer-free foot. We did not have scoring systems in place to inquire about quality of life after amputation or secondary to continually caring for ulcerations with dressings and offloading.

Conclusions

Comparing partial first-ray amputation versus hallux amputation, patients are more likely to develop subsequent digital ulceration with hallux amputation. Furthermore, if patients undergo hallux amputation, the subsequent amputation was variable, with the most common being digital. For partial first-ray amputations, the reulceration was most noted to be at the area of the incision. Patients, if in need of further amputation, are more likely to undergo transmetatarsal amputation if they underwent a partial first-ray amputation initially. A medical history of diabetes and undergoing a staged procedure were more likely for patients who received a partial first-ray amputation.

Patients are more at risk for reulceration and reamputation if they undergo a partial first-ray amputation initially compared with a hallux amputation. As well, patients are more likely to be healed at final follow-up if they undergo hallux amputation compared with first-ray amputation, regardless of whether they developed a reulceration or underwent reamputation.

Overall, this information will help patients to better understand the risks they face when undergoing a partial first-ray amputation or hallux amputation. This information can be discussed with patients about future preventive options and areas to ensure are examined at follow-up. For patients with hallux amputations, examination of other digits is critical, and for those who undergo partial first-ray amputations, the value is in evaluating the incision. This will allow us as physicians to better understand sequential problems and hopefully prevent them from occurring. These findings indicate that hallux amputations are protective from the development

of reulceration and reamputation in both the diabetic and nondiabetic populations.

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