Below-the-ankle angioplasty: early and mid-term outcome

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Aim
The aim of the study was to investigate the clinical effect of additional below-the-ankle angioplasty in patients with critical limb ischemia (CLI) attributed to pedal artery occlusion with insufficient wound blushing after conventional above-the-ankle percutaneous revascularization regarding the wound healing, amputation survival-free rate, limb salvage, and quality of life.
Patients and methods
This is a prospective observational study conducted over a period of 1 year including 21 patients who underwent below-the-ankle angioplasty.
Results
A total of 21 patients were included in the study; successful recanalization of the pedal-plantar arch was achieved in 19 (90.5%) patients, and complete wound healing was achieved in all patients. Primary and secondary patency rates after 1 year were 84.2 and 89.4%, respectively. Limb amputation rate at 1 year was 5.3%.
Conclusion
With the rapid advancement in the endovascular tools and equipment, angioplasty of the pedal arch can be a valuable revascularization strategy for adequate wound healing and limb salvage which in turn add an extra therapeutic option for patients with CLI to avoid major limb amputation.

Keywords:
limb salvage, pedal arch angioplasty, peripheral vascular disease

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Introduction

The pedal arch is the communication between the anterior and posterior circulation of the foot 'lateral plantar branch of the posterior tibial artery and dorsalis pedis.' Keeping in mind the anatomical description of the pedal arch and its multiple connections is quite important to increase procedural success [1].

Arterial revascularization is a helpful measure for limb salvage, and by which patient's quality of life gets improved, and endovascular therapy can be a first-line treatment in high-risk populations [2–4].

Some studies reported that in diabetic patients, the distribution of atherosclerosis usually involves the tibial vessels and tends to leave foot arteries spared [5]; however, extension of the atherosclerotic disease down to the foot arteries is associated with increased rate of major limb amputation [6], increased need for re-intervention [7], and decreased chances for healing of the wound [8,9].

Successful revascularization of the pedal arch can improve the outcomes of patients with critical limb ischemia (CLI) [10,11].

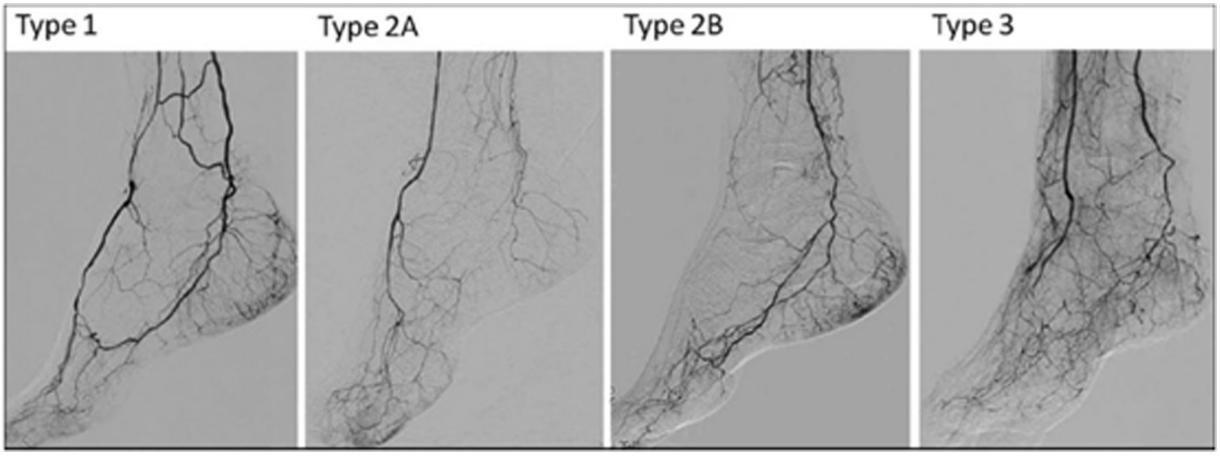
Kawarada *et al*. [8] described three types of pedal arch disease: type 1, both dorsal and lateral plantar arteries were patent; type 2, either the dorsal (2A) or lateral plantar (2B) artery was opened; and type 3, both the dorsal and lateral plantar arteries were occluded (Fig. 1).

An angiosome-directed revascularization strategy, however, has clearly been shown to improve wound healing and limb salvage rates in both surgical and endovascular series [11,12]. Pedal arch interventions should therefore be considered in patients with advanced tissue loss, with a goal of restoring inline flow to the corresponding angiosomes.

The two available strategies for foot revascularization are 'complete revascularization' and 'specific wound artery revascularization.'

Complete revascularization strategy is based on that healing of the wounds is mainly dependent on providing adequate blood flow especially in cases with extensive foot infection and tissue loss, where the problem was not confined to single arterial

Figure 1



Kawarada classification for pedal artery disease.

territorial distribution but it usually spreads to involve more than one angiosome [13].

Limb salvage rate eventually correlates with the possibility to re-establish adequate blood flow to the area of tissue loss, and it was ~73, 80, and 83% with only single patent, two patent, or three patent tibial vessels, respectively [13].

Hence, the 'complete revascularization' strategy is concerned with re-establishment of the best possible blood flow to the foot by restoring patency of the lumen of as many of the tibial vessels as possible [13].

Specific wound revascularization strategy or the angiosome-oriented revascularization has been proved to be effective in the past decade, because restoring the blood flow to the territorial artery has been associated with increased wound healing and limb salvage [14–18].

Patients and methods

This is a prospective observational study over a period of 1 year, in which a special predetermined protocol was applied in all patients aiming to successfully revascularize the pedal-plantar arch with subsequent healing of the wounds, and this protocol consists of the following steps. Ethical committee approved for this study.

Dual antiplatelet therapy of 'aspirin' (100 mg/day) and 'clopidogrel' (75 mg/day) was given to the patient before the procedure; antibiotics were administered in presence of infection, and all procedures were performed using local anesthesia.

Access was achieved through an ipsilateral common femoral artery using 6 Fr sheath, and intravenous bolus administration of 5000 IU of unfractionated heparin was given into the sheath.

Diagnostic angiography through a selective catheter placed at the lower popliteal segment and digital subtraction angiography of the foot should be done in at least two views with prolonged imaging time to allow adequate filling of the collateral circulation. A contralateral oblique view was first obtained to allow for the optimum visualization of the common plantar artery and its bifurcation, as well as the dorsalis pedis and its connection to the pedal arch through the deep perforating artery. The second view should be obtained as an ipsilateral cranial view to get a better view for the course of the dorsalis pedis artery and the deep plantar arch of the foot, and also a high frame rate of 4 fps is recommended to get the best view of the filling of the collaterals and to easily discriminate between the overlapping vessels through their differential filling time. Adequate time interval should be given to ensure adequate wash of the contrast from the slowly filling collateral vessels [19].

Wire traversal through the pedal arch can be quite challenging especially in case of marked tortuosity of the vessel, even if the arch is patent but diseased. Moreover, the numerous side branches of the arch can add much more difficulty for wire traversal.

Wire choices will be based according to anatomical characteristics of the target vessel. At the proximal part of the foot, the vessels usually have a straight course, for which a hydrophilic 0.018-inch guide wire is useful to cannulate the lesion. A low-weight 0.018-inch chronic total occlusion (CTO) guide wire can be helpful if there is a side branch just at the beginning of occlusion that can make the passage of the hydrophilic wire quite difficult.

All wire traversal trials of the arch lesions should be done under road mapping to make it easier [19].

Failure to achieve antegrade crossing of the lesion increases the possibility to use a retrograde cannulation, and a trial to lesion traversal in a retrograde fashion was done in addition to the antegrade wire 'by the aid of duplex guided cannulation of the posterior tibial artery if the antegrade wire was placed in the anterior tibial artery and vice versa,' which is known as controlled antegrade and retrograde subintimal tracking (CART) [19].

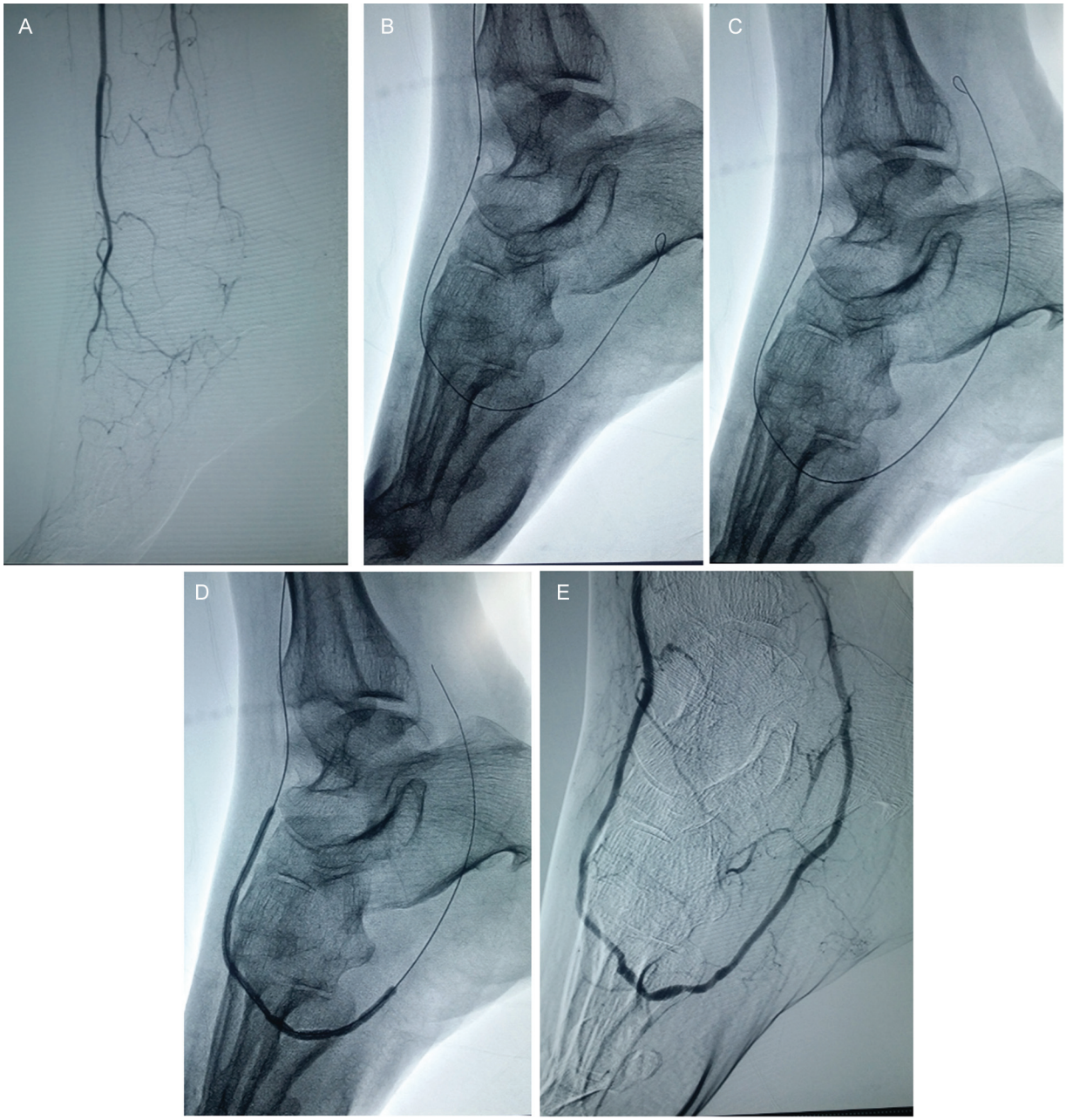
Table 1 Patient demographics

Age (mean±SD) (years)	45–80 (59±4)
Sex [*n* (%)]	
Male	9 (42.8)
Female	12 (57.2)

Table 2 Risk factors

Risk factor	*N* (%)
Hypertension	9 (42.8)
Diabetes	18 (85.6)
Smoking	14 (66.6)
Hyperlipidemia	8 (38.1)
Renal impairment	14 (66.6)

Figure 2



Patient with critical limb ischemia (CLI) and extensive pedal-plantar arch disease, successful crossing of the lesion and balloon dilatation with good angiographic appearance of the pedal-plantar arch.

After successful crossing of the lesion, the pedal-plantar arch vessels are dilated using a low-profile balloon of 2.0–2.5 mm with an inflation pressure ranging between 6 and 8 atm and inflation time between 1 and 3 min.

After balloon dilatation, 100–300 mcg of 'nitroglycrine' was administrated through the sheath, and completion angiogram should be performed in two views (contralateral oblique and cranial views) for proper assessment of any residual lesions and patency of the arch.

The patients were assessed clinically for the retrieved distal pulsation post procedural and by duplex evaluation after 1, 6, and 12 months.

Results

In this study, 21 patients (21 limbs) were included, and pedal arch angioplasty was performed according to the aforementioned protocol.

The clinical characteristics and patient demographics are given in Tables 1 and 2.

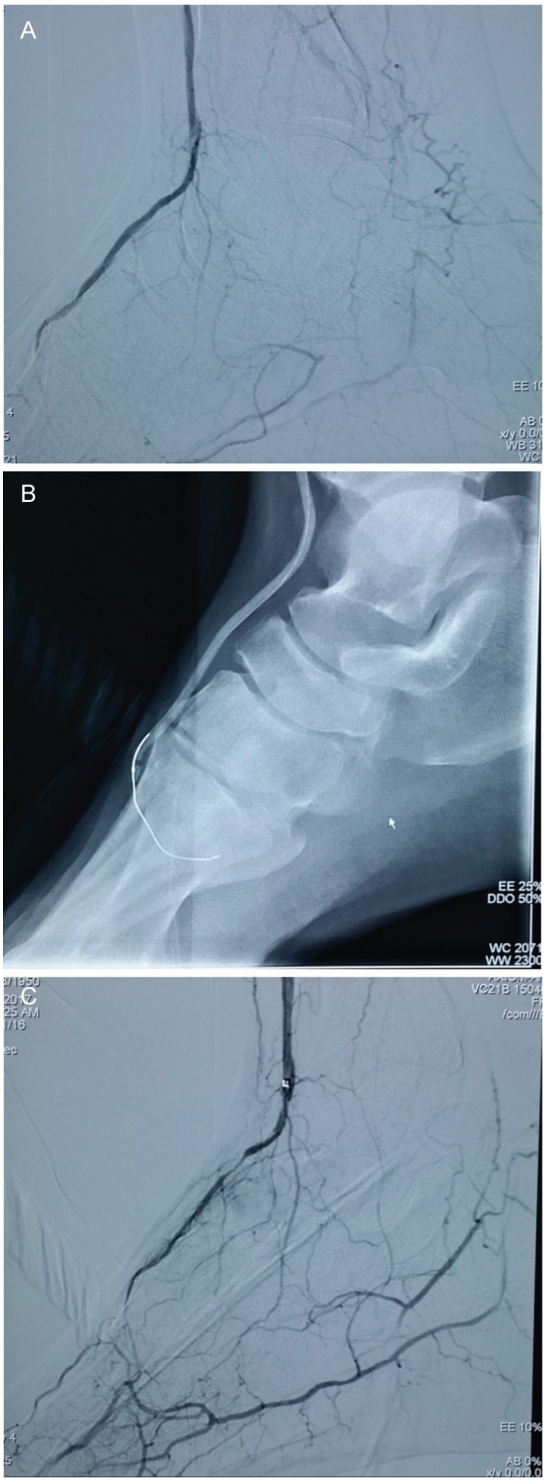
The patients were presented clinically by dry gangrene in six (28.6%) patients, infection or infective gangrene involving the toes and the forefoot in 13 (61.9%) patients, and indolent ulcer and/or nonhealing wounds in seven (33.3%) patients (Figs 2–5).

By applying the aforementioned protocol, we successfully managed to cross the pedal-plantar arch lesions in 19 (90.5%) patients, which was associated with adequate wound blushing with contrast during the procedure and with retrieval of dorsalis and/or posterior tibial artery pulsations, and failed to cross the pedal-plantar arch lesions in two (9.5%) patients and unfortunately they ended up in below-the-knee amputation owing to an associated extensive tibial artery disease and aggressive foot infection.

Regarding the follow-up, one patient was lost during the follow-up periodic assessment, and after exclusion of the two patients who underwent limb amputation, all the remaining patients retained the retrieved distal peripheral pulsations at 1 and 3 months, with complete wound healing, that is, complete epithelialization of the wound.'

At 6-month evaluation, only one patient has lost the previously retrieved distal pulse by clinical examination and by duplex evaluation that documented recoil of the pedal-plantar arch, but the patient was asymptomatic, and she was managed conservatively by medical treatment.

Figure 3



Patient with critical limb ischemia (CLI) and extensive pedal-plantar arch disease, with unsuccessful crossing of the pedal-plantar arch lesion and poor final angiographic appearance.

At 1 year, another two patients lost the retrieved distal pulse by clinical examination and duplex assessment that documented occlusion of the previously dilated pedal-plantar arch (primary patency rate at 1 year was 89.4%). One patient started to develop infective gangrene of the toes which was treated by endovascular dilatation of the pedal-plantar arch followed by drug-coated balloon, and

Figure 4

Successful crossing of the pedal arch with good angiographic results.

then the patient underwent surgical debridement for the infective toes (secondary patency rate at 1 year was 87.5%). The other patient developed extensive foot and leg infection and gangrene that required major limb amputation.

Discussion

Through the development and continuous understanding of the endovascular concepts, providing a 'direct' blood flow to the target area has became much more important than the number of opened infrapopliteal arteries [16,20].

Revascularization based on angiosome concept has become more popular strategy over the past decade [21]. However, in patients with pedal-plantar arch disease, the blood supply to the wound depends on collateral channels. Hence, below-the-ankle revascularization is quite important to re-establish blood flow to the target wounds [12].

Pedal-plantar arch angioplasty should be considered for patient who do not show adequate wound blushing during conventional above-the-ankle angioplasty. Moreover, this concept has been thoroughly tested over several studies comparing the results between above-the-ankle and below-the-ankle angioplasty [22].

Utsunomiya and colleagues documented that wound blushing with opacification of the contrast around the wound after angioplasty is quite important for proper wound healing and consequently improving the prognosis for limb salvage.

Pedal-plantar arch angioplasty was successful if at least one (either dorsal or lateral plantar) artery was recanalized and complete if both dorsal and lateral plantar arteries were opened. Re-intervention could be in the form of re-do angioplasty or even bypass surgery [22].

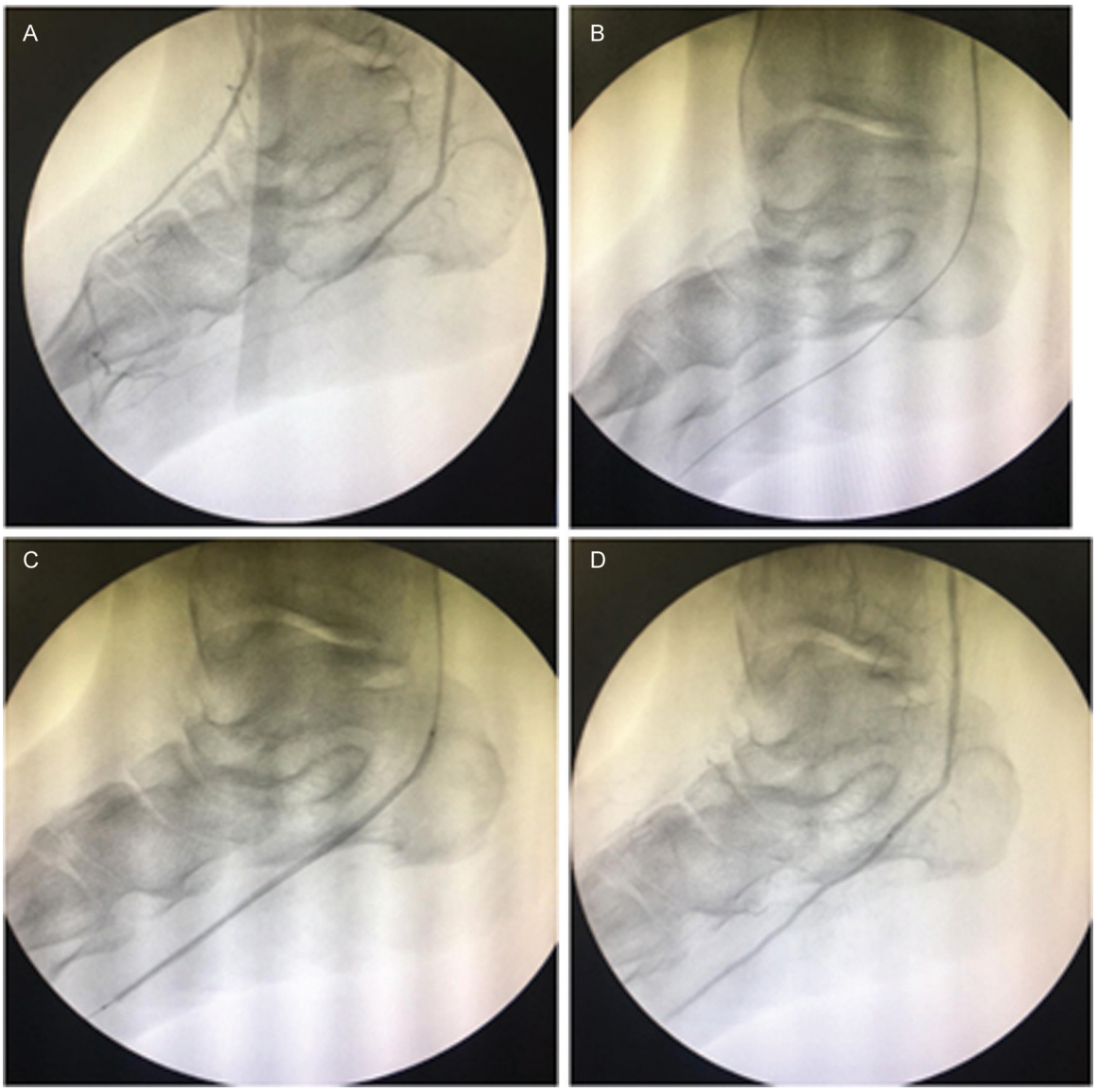
In the current study, we successfully managed to provide a direct blood flow to the target wound in 19 (90.5%) patients, and during the follow-up period, they got their wounds completely healed. So, we conclude that pedal-plantar arch angioplasty may have the potential to increase limb salvage, complete wound healing, amputation-free rate, and decrease the need for re-intervention, and these coincide with the current published data.

Khalil *et al*. [23] documented primary patency rates of 67% and 1-year amputation-free survival of 85%.

Utsunomiya *et al*. [12] showed in their study that patient provided with a direct flow to the target wound had a superior limb salvage and amputation-free survival in comparison with the patients with above-the-ankle angioplasty only (82.1, 73.2, and 69.6% vs. 56.8, 45.9, and 37.3%, respectively, at 1, 2, and 3 years).

In the current study, during the follow-up period, three patients lost the previously retrieved pulse after the intervention, and only one patient required re-intervention (6.25%) with regaining of the disappeared pulse, with secondary patency rate of 87.5% at 1 year. Two patients underwent major

Figure 5



Only plantar arch angioplasty.

amputation from the start owing to failed crossing of the pedal-plantar arch and only one (6.25%) patient underwent limb amputation after one year.

Khalil. *et al*. [23] highlighted similar results where primary assisted and secondary patency rates were 83 and 86% respectively, and the major limb amputation at one year was 4%.

Iida *et al*. [7,16] also reported that the angiosome-oriented revascularization was superior to indirect revascularization regarding the limb salvage (86 vs. 69%, respectively; P=0.029) over 1 year (Table 3).

Using the pedal-plantar arch could be an alternative pathway in case of failure of antegrade crossing of an occluded tibial vessel, where a wire is maneuvered from the anterior tibial artery into the dorsalis pedis artery and then across the plantar arch into the lateral plantar artery passing upwards to the posterior tibial artery or vice versa [1].

Table 3 Comparison between different studies

	Khalil *et al*. [23]	Utsunomiya *et al*. [12]	Iida *et al*.[7]	Current study
Primary patency	67	81.4	79.9	84.2
Secondary patency	83	82.9	82.8	89.4
Amputation-free survival	85	82.1	86	94.7
Limb amputation	4	5.1	4.9	5.3

On the contrary, even with sufficient wound blushing in patients who underwent above-the-ankle angioplasty only, the clinical outcomes of these patients were not

satisfactory. It should be kept in mind that infected wounds may get 'contrast opacification' as a part of the inflammatory reaction, for which it was called 'wound blushing like finding.'

Conclusion

Endovascular treatment for the pedal-plantar arch angioplasty in situation with extensive arterial disease below the ankle in patients with CLI is an adjunctive technique that can help achieve target vessel perfusion and subsequently accelerate the wound healing and decrease the risk of limb amputation.

Below-the-ankle angioplasty can improve the clinical outcomes with accelerated wound healing in patients with CLI, along with limb salvage and amputation-free survival rates, especially when compared with above-the-ankle angioplasty alone.

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Conflicts of interest

There are no conflicts of interest.

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