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Original Article

Clinical application of platelet rich plasma to promote healing of open hand injury with skin defect

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A B S T R A C T

Background: Skin defects caused by open hand trauma are difficult to treat clinically and severely affect the recovery of hand function. Autologous platelet-rich plasma (PRP) has been widely used in the treatment of refractory chronic wounds, but its use in hand trauma skin defects remains scarce.
Methods: This study compared the outcomes of 27 patients treated with PRP to 31 patients undergoing skin flap transplantation for hand wounds. We assessed several parameters, including healing times, duration of surgery, postoperative pain (VAS score), intraoperative amputation length, finger function, sensation restoration, nail bed preservation, and hospitalization expenses.
Results: PRP-treated patients showed a mean healing time of 21.59 ± 3.17 days. Surgical times were significantly shorter in the PRP group (22.04 ± 7.04 min) compared to the flap group (57.45 ± 8.15 min, $P < 0.0001$). PRP patients experienced longer postoperative healing times (20.15 ± 2.16 days) than those in the skin flap group (12.84 ± 1.08 days, $P < 0.0001$), but reported lower pain scores (1.3 ± 1.44 vs 2.55 ± 2.06, $P = 0.0119$). Range of Motion (ROM) at the proximal interphalangeal joint was better in the PRP group (96.26° ± 6.69) compared to the flap group (86.16° ± 15.24, $P = 0.0028$). Sensory outcomes favored the PRP group, with a two-point discrimination of 2.37 ± 1.34 mm versus 2.52 ± 1.27 mm in the flap group ($P = 0.0274$). Costs were lower in the PRP group ($2081.6 ± 258.14 vs $2680.18 ± 481.15, $P < 0.0001$).
Conclusion: PRP treatment for skin defects from hand trauma is effective, offering advantages in terms of reduced surgical time, pain, and cost, with comparable or superior functional outcomes to flap transplantation. Despite longer healing times, PRP may represent a preferable option for open hand injuries, preserving more nail beds and resulting in better sensation and joint motion.

1. Introduction

Orthopaedic trauma, encompassing a spectrum of injuries ranging from fractures to soft tissue damage, poses significant challenges to patients and clinicians alike. Among the diverse array of traumatic injuries, those affecting the hand present unique complexities due to the intricate anatomy and essential functional role of this body part [1].

The management of traumatic hand injuries poses several challenges, primarily stemming from the intricate anatomical structures and functional demands of the hand [2]. Unlike other body parts, the hand exhibits a remarkable degree of dexterity and sensitivity, making restoration of function paramount in treatment

Abbreviations: (PRP), platelet-rich plasma; (VAS), visual analogue scale; (ROM), range of motion; (PDGF), platelet-derived growth factor; (TGF-β), transforming growth factor-beta; (VEGF), vascular endothelial growth factor.

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planning. Furthermore, hand injuries frequently involve complex soft tissue damage, including lacerations, avulsions, and degloving injuries, which can compromise vascularity and impede healing [3]. Traditional surgical approaches, while effective in stabilizing fractures and restoring alignment, often fall short in addressing the soft tissue component of hand injuries, leading to delayed healing, impaired function, and increased risk of complications such as infection and stiffness [4].

Moreover, the conventional paradigm of managing traumatic hand injuries, particularly in the context of soft tissue defects, relies heavily on techniques such as skin grafting and flap reconstruction [5]. While these methods have proven efficacy in promoting wound closure and preserving tissue viability, they still have many limitations [6]. Skin grafts, for instance, may exhibit poor adherence and limited durability, especially in areas of high tension or mobility such as the hand [7]. Similarly, flap reconstruction, while providing solid vascular tissue coverage, is accompanied by a high rate of necrosis and therefore requires meticulous surgical skill support [8]. Moreover, both skin grafts and flaps may result in donor site morbidity and aesthetic concerns, further complicating the treatment landscape.

In light of these shortcomings, there exists a compelling need for alternative approaches that can address the multifaceted nature of traumatic hand injuries while minimizing morbidity and optimizing outcomes. PRP therapy has emerged as a promising adjunctive treatment modality in orthopaedic trauma, offering the potential to accelerate tissue repair and promote regeneration [9,10]. PRP harnesses the body's natural healing mechanisms by delivering a concentrated dose of platelets and growth factors to the site of injury, thereby stimulating cellular proliferation and extracellular matrix synthesis [11]. Initially promoted in sports medicine for its purported ability to accelerate recovery from musculoskeletal injuries, PRP has gradually expanded its application to a wide range of orthopaedic conditions, including repair of chronic wounds in the extremities, such as the treatment of skin defects in the diabetic foot [12,13]. However, there is still a lack of research on its application to skin soft tissue defects caused by hand trauma.

PRP therapy has great potential for the treatment of skin defects in hand trauma based on its strong potential for tissue repair, modulating inflammation and promoting wound healing. By harnessing the regenerative potential of autologous platelets and growth factors, PRP therapy may accelerate healing and improve functional outcomes of post-traumatic skin defects in the hand. Therefore, the aim of this study was to explore the efficacy of PRP in open hand trauma combined with skin defects and to provide a new clinical treatment modality for the clinical management of hand trauma.

2. Methods

2.1. Patients

Observational and retrospective studies were conducted independently, with eligible cases gathered accordingly. Inclusion criteria for the observational study included [1]: patients aged 18 to 65 [2], open hand trauma, and [3] informed consent with complete clinical data. Exclusion criteria comprised [1]: incomplete clinical data, and [2] poor compliance or interrupted follow-up in patients. Inclusion criteria for the retrospective study included [1]: patients aged 18 to 65 [2], open trauma involving the distal and middle phalanges with skin defects, and [3] informed consent alongside complete clinical data. Exclusion criteria included [1]: trauma to the proximal phalanges [2], additional hand injury sites [3], concurrent nerve, tendon injuries, or fractures at the proximal end of affected fingers [4], any past medical history impacting hand function, and [5] poor patient compliance or disrupted follow-up.

2.2. Clinical information and grouping

Between June and December 2023, an observational study recruited 22 patients with open hand injuries from the Department of Traumatology and Orthopaedics at the First Affiliated Hospital of Shihezi University. The cohort consisted of 10 males and 12 females, ranging in age from 21 to 65. Of these patients, 13 presented with combined hand fractures, 11 had nerve injuries, 12 suffered from ligament injuries, and 5 were diagnosed with type 2 diabetes mellitus. Each patient underwent PRP treatment following thorough debridement, accompanied by regular dressing changes and documentation of the time until complete wound healing.

From January to December 2023, a retrospective study collected data on 58 trauma patients with distal finger defects treated at the previously mentioned healthcare facility. The participants included 27 males and 31 females, aged 19 to 65. Each patient received PRP treatment following thorough debridement, with regular dressing changes and wound healing times recorded. Patients were randomly assigned to either the PRP group (27) or the skin flap transplantation group (31), and their baseline data were compared. No statistically significant differences were found between the groups ($P > 0.05$, Table 1). The study received approval from the Medical Ethics Committee of the First Affiliated Hospital of Shihezi University (KJ2023-1301).

2.3. PRP preparation

All PRP preparations are meticulously performed during the surgical procedure within the confines of the operating room. For this study, between 8 and 50 mL of venous blood were drawn from patients using the Langtai PRP Preparation Unit (Hubei Langtai Biotechnology Co.). The procedure is executed as follows: Firstly, once the whole blood is collected, the PRP tube is gently inverted between 5 and 10 times to ensure thorough mixing. Secondly, the blood is subjected to centrifugation in a centrifuge calibrated to 1500 g and 8000 rpm for 6 min, ensuring that the tubes are perfectly leveled. Following centrifugation, the blood components separate: red blood cells settle firmly below the separation gel, while the platelets collect above it. Subsequently, approximately 2 mL of the upper layer, which is platelet-poor plasma, is carefully withdrawn using a syringe. The PRP tubes are then inverted again between 5 and 10 times to effectively resuspend the platelets in the remaining plasma, ultimately yielding 1 mL–2 mL of highly concentrated platelet-rich plasma. The platelet concentration within the PRP is rigorously measured using a haemocytometer to confirm that it surpasses the threshold of 1×10^{12}/L.

2.4. Surgical methods

2.4.1. Treatment of hand wounds

Following brachial plexus anesthesia, the wound was meticulously debrided under stringent aseptic conditions. Subsequently, autologous PRP gel was uniformly applied and covered with an appropriately sized oil-sand dressing, then wrapped in dry gauze (Fig. 1). The PRP gel dressing was changed weekly (see Fig. 2).

2.4.2. Treatment of distal finger wounds

Following brachial plexus anesthesia, the surgical principles for the PRP treatment group were outlined as described earlier. For the flap transplantation group, initial steps involved determining the location and size of the distal finger defect, followed by designing a flap of suitable dimensions accordingly. Subsequently, a flap of

Table 1
Patient demographics.

Patient	Age (y)	Gender	Union time(day)	Fracture	Maximum horizontal diameter (cm)	Maximum longitudinal diameter (cm)	Nerve damage	Ligament injury	Initial PRP volume	Diabetes
1	21	M	21	Y	2.6	4.3	Y	Y	4.2	N
2	45	M	18	Y	1.2	1.4	N	N	1.3	N
3	48	F	23	N	1.6	2.1	N	Y	2.1	N
4	38	M	29	Y	0.8	1.7	N	N	1.3	N
5	63	F	19	Y	2.1	3.8	Y	N	3.1	Y
6	33	F	19	N	3.2	1.2	Y	N	2.2	N
7	28	M	21	N	1.6	1.7	N	Y	1.5	N
8	26	M	22	N	4.6	5.8	Y	Y	8.9	N
9	48	F	22	N	10.4	7.3	Y	Y	10.6	Y
10	39	F	22	Y	3.6	5.4	Y	N	6.4	N
11	30	M	19	N	1.4	1.6	N	Y	1.1	N
12	45	F	20	Y	1.8	2.1	N	N	2.5	N
13	60	M	26	Y	3.7	5.3	Y	Y	7.3	Y
14	56	F	25	Y	5.7	3.6	N	Y	8.2	Y
15	59	F	17	Y	6.8	7.3	Y	Y	9.7	N
16	49	F	19	Y	5.3	3.8	Y	N	5.5	N
17	37	M	22	N	4.6	3.1	N	N	3.9	N
18	25	F	25	N	1.5	1.8	N	Y	1.3	N
19	53	M	20	Y	1.5	1.7	N	N	1.5	N
20	42	M	21	N	2.6	4.3	N	Y	4.8	Y
21	30	F	20	Y	3.7	4	Y	N	4.3	N
22	65	F	21	Y	3.9	5.8	Y	Y	7.0	N

Abbreviations: M, male; F, female; Y, yes; N, no.

suitable dimensions was dissected from the proximal phalanx of the injured finger, followed by serrated incisions extending towards the fingertip. Caution was exercised to prevent damage to nerves and blood vessels. Once the flap was dissected, repair of the subcutaneous adipose tissue was performed, followed by wound closure.

2.4.3. Postoperative treatment and follow-up

Following surgery, patients received routine postoperative treatment including anti-infective, haemostatic, and oral decongestive medications. Analgesia was only administered if the patient's postoperative VAS score exceeded 6. PRP treatment necessitated weekly preparation of PRP gel and regular dressing changes. In the flap transplantation group, anticoagulant treatment was administered alongside standard care, with daily monitoring of flap color, skin temperature, and peripheral blood perfusion. Dressings were initially changed on the 4th postoperative day and subsequently every 3 days thereafter. If flap necrosis occurred, stump revision surgery was performed to close the wound. Each patient was monitored until the wound fully healed.

2.4.4. Effectiveness observation

In the retrospective study, data collected included time to wound healing post-PRP treatment (days), intraoperative finger amputation length (mm), operative time (min), incidence of postoperative infections, and occurrences of distal tissue or flap necrosis in both the PRP treatment and flap grafting groups. Additionally, VAS scores were recorded after complete wound healing, while assessment of affected finger function involved testing flexor and extensor muscle strength (0-V), range of motion (ROM) of proximal interphalangeal joints, two-point sensory discrimination test of distal healing skin (mm), presence or absence of a nailbed, and total treatment cost (US dollars).

2.5. Statistical analysis

SPSS 26.0 software was used for data analysis. Measurement information was expressed as ($\bar{x}$±s), and *t*-test was used for comparison between groups. Count data were expressed as (n), and corrected χ^2 test was used for comparison between groups. The difference was considered statistically significant at $P < 0.05$.

3. Results

In the observational study, all 22 patients achieved complete healing of hand wounds within a mean duration of 21.59 ± 3.17 days (Table 1). When comparing the PRP treatment and flap transplantation groups, all 27 PRP-treated patients experienced healing of distal finger wounds. In term of demographic characteristics, no significant differences were observed in age, maximum horizontal and maximum longitudinal diameter between the two groups ($P > 0.05$) (Table 2). In contrast, 6 patients in the flap transplantation group developed necrosis of the transferred flap and subsequently required stump revision surgery (Table 3).

3.1. Comparison of trauma healing

The mean surgical duration in the PRP group (22.04 ± 7.04 min) was substantially shorter compared to the skin flap transplantation group (57.45 ± 8.15 min), with a statistically significant difference ($P < 0.0001$) (Table 2). Postoperative healing time in the PRP group (20.15 ± 2.16 days) exceeded that of the skin flap group (12.84 ± 1.08 days) ($P < 0.0001$). Regarding postoperative VAS scores, the PRP group achieved a lower score (1.3 ± 1.44) compared to the skin flap group (2.55 ± 2.06) ($P = 0.0119$). In comparing intraoperative amputation length, the PRP group exhibited significantly shorter length (8.88 ± 3.24 mm) compared to the skin flap group (13.13 ± 4.92 mm), with a statistically significant difference ($P = 0.0005$).

3.2. Comparison of postoperative function of affected fingers

Comparing finger function between the two groups after complete trauma healing revealed significantly higher range of motion (ROM) in the proximal interphalangeal joint of the PRP treatment group (96.26° ± 6.69) compared to the skin flap group (86.16° ± 15.24), with a statistically significant difference ($P = 0.0028$). Regarding muscle strength, values were 4.44 ± 0.74 in

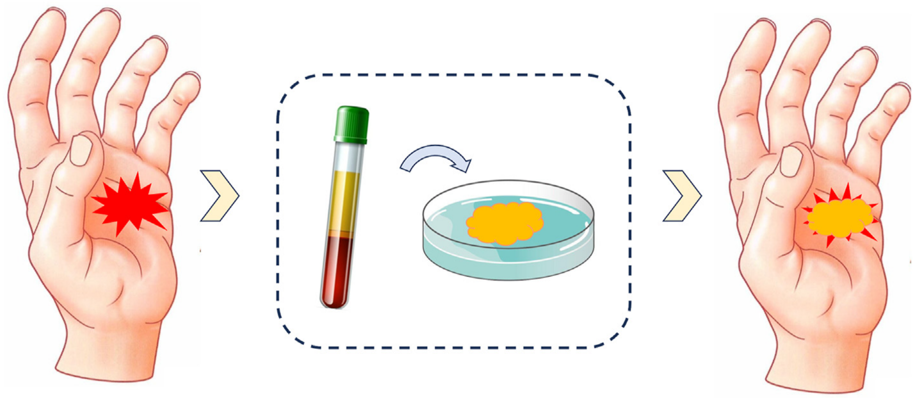

Fig. 1. Schematic diagram of PRP gel preparation and application.

the PRP group compared to 4.48 ± 0.67 in the skin flap group, with no statistically significant difference ($P = 0.8342$). Regarding restoration of sensation at the fingertip, the two-point sensory discrimination test following PRP treatment yielded a result of 2.37 ± 1.34 mm, compared to 2.52 ± 1.27 mm in the flap group, indicating poorer terminal sensation in the flap group ($P = 0.0274$). In the PRP treatment group, 19 patients retained the nail bed, whereas in the flap group, only 2 patients did so (Table 3).

3.3. Comparison of hospitalization expenses

In terms of treatment expenditure (Table 3), the PRP group incurred costs of $2081.6 ± 258.14, which were significantly lower than those of the flap group ($2680.18 ± 481.15), with a statistically significant difference ($P < 0.0001$).

3.4. Typical case 1

A 48-year-old man sustained a significant retrograde avulsion injury to the palm skin after being caught by a machine at work (Fig. 3A). The trauma had maximum horizontal and longitudinal diameters of 10.4 and 7.3 cm, respectively, accompanied by ligamentous and neurological injuries to the palm, along with loss of the distal phalanx of the middle finger. The patient had a medical history of type 2 diabetes mellitus. Following stage 1 debridement, the avulsed skin was sutured in place to cover the trauma. By postoperative day 7, the epidermis had become completely necrotic (Fig. 3B). Subsequent excision of the necrotic tissue (Fig. 3C) was followed by withdrawing 40 mL of venous blood for centrifugation to isolate 8 mL of PRP (Fig. 3D–E), which was then used to uniformly cover the trauma and wrap the hand. Subsequent to PRP treatment, dressing changes were performed on postoperative days 7 (Fig. 3F) and 14 (Fig. 3G), resulting in complete wound healing by day 22 (Fig. 3H).

3.5. Typical case 2

A 47-year-old man suffered accidental strangulation of the distal phalanx of her left index finger at work, resulting in a combined fracture of the distal phalanx. Following debridement, she underwent flap transfer treatment, resulting in wound healing by the 13th postoperative day (Fig. 4A–B). Subsequent to surgery, the affected finger exhibited poor function, characterized by a two-point sensory discrimination test result of 3 mm, grade 3 finger muscle strength, and a proximal interphalangeal joint range of motion (ROM) of only 55°. Two years later, the patient sustained a work-related reinjury to her right index finger, resulting in a ventral skin defect of the distal phalanx combined with a phalangeal fracture. Following debridement, the wound was treated with PRP gel. Subsequently, after two follow-up changes of PRP dressing, complete wound healing occurred by day 17 (Fig. 4C–D). The two-point sensory discrimination test result for the regenerated skin was 2 mm, accompanied by grade 5 finger muscle strength and a proximal interphalangeal joint range of motion (ROM) of 100°.

4. Discussion

The rationale behind PRP therapy lies in its ability to deliver a concentrated cocktail of bioactive molecules directly to the site of injury, thereby creating an optimal microenvironment for tissue regeneration [14]. Platelets, rich in growth factors such as platelet-derived growth factor (PDGF), transforming growth factor-beta (TGF-β), and vascular endothelial growth factor (VEGF), play a pivotal role in orchestrating various stages of wound healing, including inflammation, proliferation, and remodeling [15,16]. By amplifying these endogenous signaling pathways, PRP therapy aims to accelerate tissue repair, promote angiogenesis, and reduce fibrosis, ultimately facilitating the restoration of normal tissue architecture and function [17,18].

Table 2
Demographic data analysis.

Parameters	PRP	Flap	*t*	*P*
Patient	27	31	–	–
Age (y)	46.6 ± 12.49	43.8 ± 11.61	0.904	0.37
Gender	10M;17F	17M;14F	–	–
Fracture (phalangeal)	23	27	–	–
Maximum horizontal diameter (cm)	1.71 ± 0.26	1.42 ± 0.22	1.274	0.2079
Maximum longitudinal diameter (cm)	1.8 ± 0.12	1.37 ± 0.14	1.492	0.1412
First OT (min)	22.04 ± 7.04	57.45 ± 8.15	17.28	<0.0001

Abbreviations: M, male; F, female; OT, operation time.

Table 3
Clinical data analysis.

Parameters	PRP	Flap	*t*	*P*
Union time (day)	20.15 ± 2.16	12.84 ± 1.08	14.97	<0.0001
Infection	2	3	–	–
VAS score	1.3 ± 1.44	2.55 ± 2.06	2.601	0.0119
Necrosis	0	6		
Amputation length (mm)	8.88 ± 3.24	13.13 ± 4.92	3.717	0.0005
ROM (proximal interphalangeal joint)	96.26° ± 6.69	86.16° ± 15.24	3.13	0.0028
Muscle strength	4.44 ± 0.74	4.48 ± 0.67	0.2103	0.8342
Two points discrimination (mm)	2.37 ± 1.34	2.52 ± 1.27	0.266	0.0274
Nail retention	19	2	–	–
Cost (dollar)	2081.6 ± 258.14	2680.18 ± 481.15	5.58	<0.0001

Abbreviations: ROM, Range of motion.

In recent years, PRP has been used in the treatment of accelerated fracture healing, bone defect repair, osteochondral repair, ligament reconstruction, and degenerative joint diseases [19–21]. Its effective principle lies in its ability to deliver concentrated bioactive molecules directly to the site of injury, thus creating an optimal microenvironment for tissue regeneration. These include active substances such as platelet-rich platelet-derived growth factor (PDGF), transforming growth factor-β (TGF-β) and vascular endothelial growth factor (VEGF) [22,23]. And for the repair of chronic wound healing, PRP orchestrates the various stages of wound healing (including inflammation, proliferation and remodeling) by amplifying these endogenous signalling pathways [24]. Given PRP's broad therapeutic areas and stable therapeutic effects, we believe that it also holds great promise for the repair of skin defects combined with hand trauma.

Surprisingly, our study found that hand wounds incubated with PRP gel gradually healed in a short period of time, with the defective tissue being replaced by new epidermis, dermis and subcutaneous tissue. And unlike scar tissue, the new skin surprisingly contains normal texture, which is more prominent in the treatment of large defects on the hand. In the observed study population, healing of the wound was achieved in all patients, which proves the effectiveness and stability of PRP in this treatment. In the case of distal finger defects, we verified the advantages of PRP treatment in the restoration of the appearance and function of the finger by means of a control of flap grafting styles. In terms of economic cost, the PPR treatment appeared to be more economical because it only required debridement surgery and preparation of PPR gel, whereas the flap group added the cost of flap grafting surgery and secondary surgery after necrosis.

In clinical practice, many cases are combined with fractures of the metacarpophalangeal bones and ligament damage. In more serious cases, the combination of vascular and nerve damage poses a great challenge to the recovery of patients' hand function. However, PRP has demonstrated outstanding repair ability in previous studies and applications. It can not only promote the healing of fractures, but also has a significant effect on the repair of tendons and ligaments. Although there is a lack of direct evidence in the regeneration of nerves and blood vessels, we have carried out basic research on minimally invasive reimplantation after arteriovenous injury. In our animal experiments in rabbits, we demonstrated that PRP gel accelerated physiologic healing of vascular breaks and reduced scarring and fibroblast infiltration. Related results will be published in the future.

However, several factors should be considered when evaluating the promise of PRP therapy in the repair of hand trauma. Firstly, the heterogeneity of hand wounds and patient populations may affect the outcome of the treatment, and therefore the injury needs to be

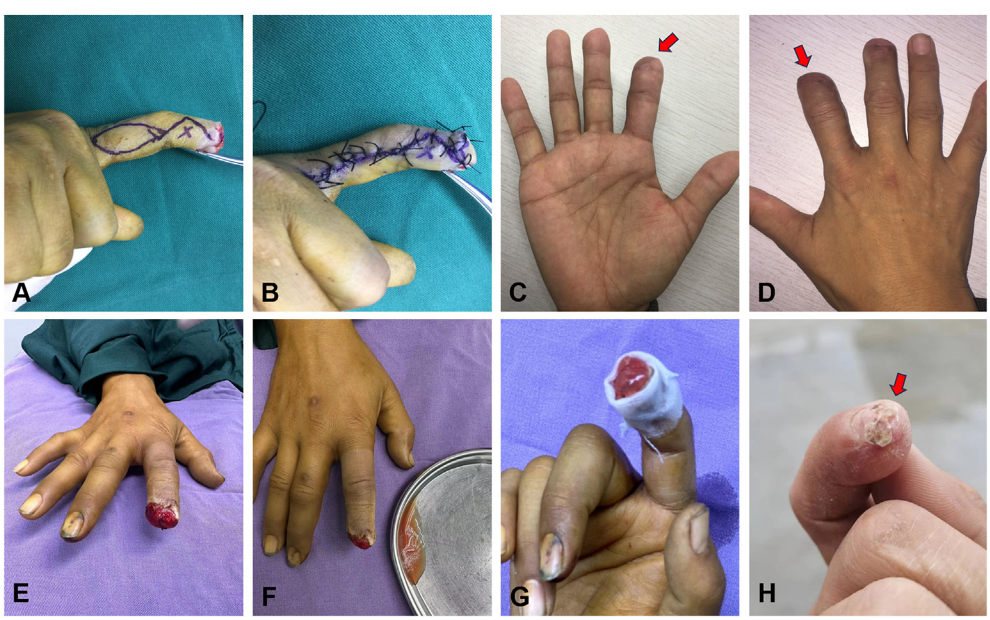

Fig. 2. Comparison of PRP and flap grafting in the treatment of distal finger skin defects. (A) Design of flap donor area. (B) Suturing of the incision after flap grafting. (C–D) Palmar and posterior images of wound healing after surgery (Red arrows indicate the affected finger). (E) Debridement of the wound before PRP treatment. (F) PRP gel preparation. (E) Cover the wound with PRP and dress with oil gauze. (F) Pictures of healed wounds after PRP treatment (Red arrows pointed at the fingernail).

Fig. 3. A 48-year-old man received PRP treatment after severe tearing of her palm skin. (A) The picture of the preoperative wound. (B) 7 days after debridement and suturing, the damaged skin was necrotic. (C) Removal of necrotic skin and subcutaneous tissue prior to PRP treatment. (D) Peripheral blood after centrifugation. (E) PPR treatment for the first time. (F) PPR treatment for the second time. (G) PPR treatment for the third time. (H) Wound healing after PRP treatment.

evaluated before adopting PRP therapy. We suggest that defective wounds must retain relatively intact subcutaneous tissue after debridement, and that large areas of bone exposure can severely affect soft tissue regeneration. In addition, the frequency of PRP treatment in trauma repair and the dose and method of administration can still be further optimised. We extracted the appropriate volume of PRP gel according to the size of the trauma (1 mL of PRP was prepared for every 2 cm2 defect), and changed the PRP gel once a week. Healing can be achieved in most cases in about 3 weeks.

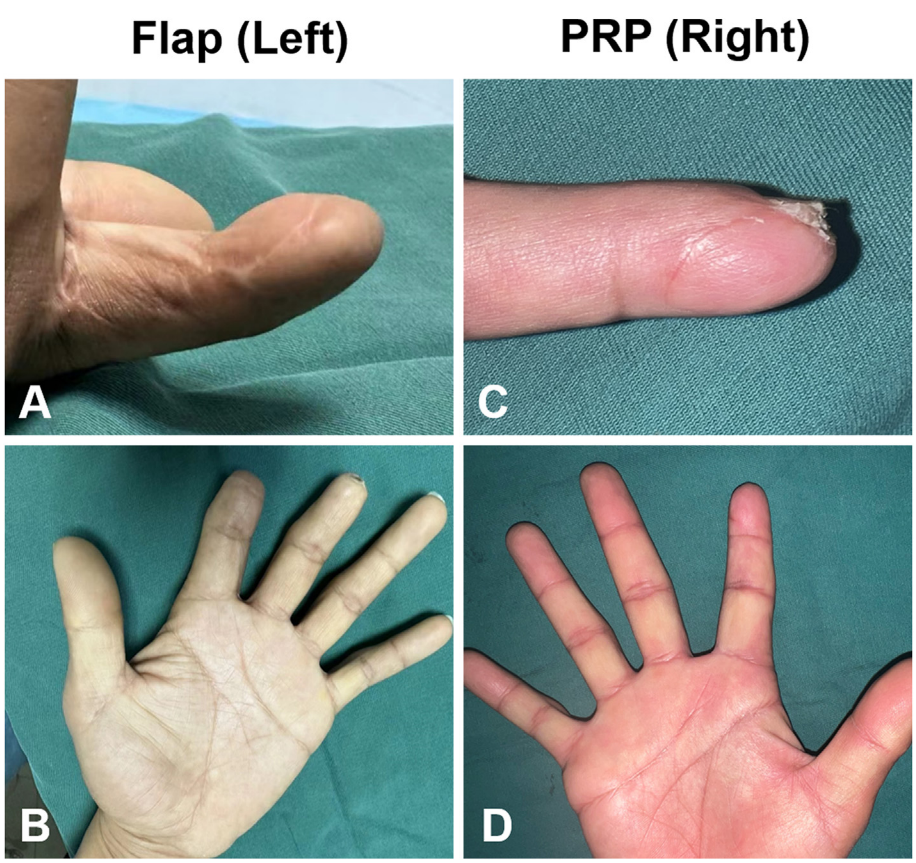

Fig. 4. A 47-year-old man treated with PRP and flap grafts respectively after experiencing trauma to bilateral index fingers. (A–B) Picture of the affected finger after flap grafting. (C–D) Picture of the affected finger after PRP therapy.

5. Conclusion

PRP therapy promises to be a potential adjunctive treatment modality for the repair of defective trauma to the hand. It preserves more finger function than traditional flap grafting and offers significant advantages for the repair of hand appearance. However, the optimal timing, frequency and delivery method of PRP treatment still needs to be further optimised. This requires rigorous study designs, standardised protocols and multidisciplinary collaboration, and future studies have the potential to advance our understanding of PRP therapy and improve outcomes for patients with hand trauma.

Author contribution

Xinhui Du: Writing – original draft, **Jiarui Zhao:** Methodology, **Qian Ren:** Data curation, **Yibo Ma:** Formal analysis, **Pengxia Duan:** Writing – review & editing, **Yansheng Huang:** Investigation, Validation, **Sibo Wang:** Conceptualization, Project administration.

Declaration of competing interest

The authors declare that they have no competing interests.

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None.

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