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ARTICLE

Recent strategic approach in postburn extremity scars and contractures

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ABSTRACT

This study aims to present the outcomes from current alternative treatment modalities combined with the conventional techniques used in the treatment of burn contractures. Twenty-nine patients were included in the study. Patients were divided into three groups according to the severity of contractures: 1- mild, 2- moderate, and 3- severe. Skin defects that occurred following the incision and scar contracture release were closed with a collagen-elastin acellular dermal matrix (ADM). The split-thickness skin graft was evenly placed on the ADM and fixed with absorbable sutures. The grafts were closed with NPWT (negative pressure wound therapy system) dressings. In platelet-rich plasma (PRP) mild cases as well as moderate and severe PRP cases, stem cell and fat injection were applied. PRP injection was applied to the scar base before the contracture; fat injection and stem cells were applied at the 3rd and 6th months. Preoperative and postoperative range of motion (ROM), Patient and Observer Scars Evaluation Scale (POSAS), and histopathological scores were evaluated. There was a statistically significant decrease in postoperative POSAS scores ($p < .05$) and a significant increase in the ROM score ($p < .05$). Histopathological examination revealed an increased postoperative collagen accumulation and organization, increased vascularization, decreased scar tissue thickness and increased subcutaneous tissue thickness. There was no difference in treatment outcomes between the groups.

Based on the current findings, we conclude that ADM, stem cell-rich fat grafting, and PRP therapies combined with conventional methods could satisfactorily improve functional outcomes in the repair of burn contractures.

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Introduction

With recent advances, survival in the treatment of acute burn injuries has significantly improved. However, we should highlight that there are ongoing studies to achieve desirable and permanent functional outcomes with burn cases in the long term [1]. Severe functional insufficiency may occur in patients with severe burn scars; particularly those located in the upper extremities [2]. The contractures tend to persist at various rates and are dependent on the surgical method employed. Therefore, opting for reconstructive surgery should improve functionality, while decreasing the risk of recurrence [3]. Recent studies have focused on improving long-term outcomes and combining modern methods with conventional treatment modalities.

With this purpose, dermis equivalents, platelet-rich plasma (PRP) injections, stem cells, fat grafting, and the combination of negative-pressure wound therapy (NPWT; Renasys®, Smith&Nephew Medical Ltd, Hull, England, UK), conventional flap reconstruction, and other graft applications have become increasingly popular. Dermal scaffolds (DS) and split-thickness skin grafts (STSG) are options that increase skin quality and flexibility. NPWT has been used for more than a decade and has been the first choice for deep wounds following debridement. The concept of NPWT has been used as an alternative for traditional dressing methods. This technique provides a near-perfect buffer between the graft and the recipient wound bed [4,5]. Seroma, hematoma, and infections within the graft base are the most common causes of skin graft loss. NPWT holds the skin graft in the desired position and prevents shearing, hematoma, seroma, and infection. Besides helping to prevent contamination, NPWT is used to increase granulation formation, facilitate revascularization, and attachment of the graft to the recipient site [6–11]. NPWT can also maximize graft take rates of FTSGs [12].

ADM is a single-layer dermal component that contains bovine collagen and hydrolyzed elastin. This material is transformed into an intense, functionally and morphologically live neodermis that facilitates adhesion between the skin epidermis and the underlying bony tissue [13]. Previous reports have described a one-step procedure of ADM grafting combined with a STSG overlay. The minimally invasive procedure has delivered close to excellent or comparable results with that of complex skin or fasciocutaneous flaps without the donor site morbidity.

PRP is a product derived from autologous blood and is rich in platelets, growth factors, and chemo/cytokines in a concentrated volume of plasma. PRP has been used in tissue repair and regeneration since the 1970s [14]. PRP injections, stem cell injections, and NPWT contribute to tissue regeneration and integration in the recipient area.

The aims of this study were to evaluate the outcomes of alternative treatment methods used in burn contractures and to establish a protocol that combines conventional treatment modalities with modern methods.

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Materials and methods

Twenty-nine patients (19 male and 10 female), between May 2012 and September 2015, were evaluated following admittance to our clinic due to scarring and contractures in the upper extremities. In all patients, scar contractures affected joint mobility and functionality to various degrees. The mean age of patients was 15.4 years (2–44 years). The patients were divided into three groups according to the severity of contractures as 1- mild, 2- moderate, and 3- severe. 1- mild: patients with minimally affected functions [range of motion (ROM); 90–135°] and poor aesthetic appearance; 2- moderate: patients with restricted functioning (ROM; 45–90°) but with active motions; and 3- severe: patients with completely restricted functioning (ROM $<$ 45°). There were mild contractures in 3 patients, moderate contractures in 6 patients, and severe contractures in 20 patients. ROM values of all patients were also measured before and after surgery.

All defects were recorded by photographing in the preoperative and postoperative control visits. Scar assessment scales were used to evaluate the appearance of scars. The Patient and Observer Scar Assessment Scale (POSAS) offered a suitable, reliable, and complete scar evaluation tool [15]. The POSAS including factors of scar vascularity, pigmentation, thickness, relief, pliability, and surface area was used to assess the scar surface [16,17]. A numerical 10-point scale, where 1- represents a scar comparable with ‘normal skin’ and 10- represents the ‘worst scar imaginable’ was used for all POSAS factors. The observer assessment was carried out by a physician, nurse, or researcher.

Preparation of PRP

PRP, using a PRP kit (gloprp®, Biotrend, Istanbul, Turkey), was prepared in accordance with the manufacturer’s instructions. Briefly, blood was drawn from the patient and collected in a tube containing an anticoagulant citrate dextrose solution. The tubes were then centrifuged at 1200 × *g* for 5 min. The plasma layer was separated from the red blood cells, removed, and centrifuged again 1200 × g for 10 min. After the graft was inset, 2 mL of PRP was injected under the graft and around the wound at the end of the operation. As mentioned in the literature, we evaluated the efficacy of cellular therapy on the 7th day, 3rd month, and 6th month after the treatment.

Preparation of thrombin

Nine milliliters of blood was taken from the patients into tubes containing 1 mL of anticoagulant citrate. 1.7 mL of calcium was added to 8 mL of blood taken from the mixture obtained and kept at room temperature for 40 min. Then it was centrifuged at 1200 g for 5 min. Thrombin was obtained from the supernatants in the upper section.

Preparation of stem cell concentrate

Cell concentration was obtained by SVF (Stromal Vascular Fraction) separation method from adipose tissue using Stempia kit (ADIMARKET, Miami Fl. United States). The kit contains a cell-permeable filter and the resulting cell concentration is completely injectable and separated from macromolecules. The main purpose of the cells obtained with Stempia is to enrich the fat, increase angiogenesis, and increase the fat viability. Stempia is mostly used for neovascularization.

Bone marrow aspirate, stem cell concentrate recovered from the iliac crest by bone marrow aspiration, was centrifuged at 1200 × *g* for 5 min. The plasma layer separated from the red blood cells was removed and centrifuged again 1200 × *g* for 10 min.

Figure 1. View of PRP-enriched fat injection.

Surgical procedures

Patients and their families were provided with detailed information about the procedures and informed consent was obtained. Surgical procedures were performed under general anesthesia. Hypertrophic scars were marked with a skin marker to the outer margin of the scar. Before surgery, specimens were obtained from the scars for histopathological examination and sent to the laboratory for analysis. PRP injections were planned for the base of the scar before or after the release of the contracture. This was planned to help promote adaptation and vascularization of the graft in cases with an extremely fibrotic and hypovascular wound base. PRP was activated with thrombin and applied beneath the scar (Figure 1). Then, the scar contractures were incised from the marked areas and released until reaching the subcutaneous tissue. Staged excision was performed until complete release was achieved while preserving the superficial veins during excision. Meticulous hemostasis was achieved with electrocautery. The dimensions of the resulting defect were measured after contracture release. A 0.2-mm thick STSG was harvested from the thigh using an Electrical Dermatome (Aesculap®, Acculan, B. Braun Meslungen AG, Germany). The defects were closed with a dermal collagen-elastin dermal matrix (ADM/Matriderm®, MedSkin Solutions Dr. Suwelack AG, Germany) in layers of 74 × 52 × 1-mm and fixed with absorbable sutures (Figure 2). The skin graft placed on the ADM was meshed to prevent fluid collection under the graft (Figure 3). The grafts were covered with chlorhexidine acetate tulle gras (Bactigras®, Smith&Nephew Medical Ltd, Hull,

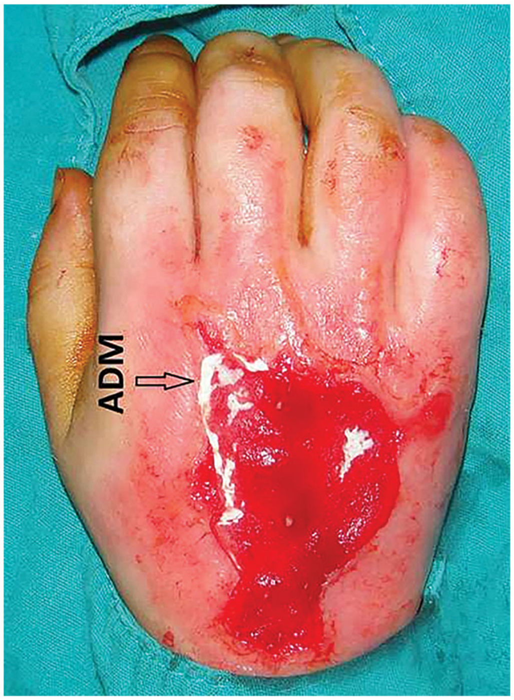

Figure 2. Intraoperative view of ADM application.

Figure 3. Intraoperative view of STSG application.

England, UK) and NPWT dressings (Renasys®, Smith&Nephew Medical Ltd, Hull, England, UK) that were applied at 50 mmHg of pressure (Figure 4). This constant pressure was provided by setting the continuous mode on the VAC device. A white VAC sponge was chosen for the skin graft.

Upper extremities were immobilized with a splint and donor sites were closed with nonadhesive dressings (Epigard®, Biovision GmbH, Wiesbaden, Germany). The NPWT dressings were removed at postoperative day 3, and re-dressing was performed by changing the closure apparatus. On postoperative day 6, the grafts were covered with chlorhexidine acetate tulle gras dressings (Bactigras®, Smith&Nephew Medical Ltd, Hull, England, UK) and saline-soaked sponges. The splints were left in place for two weeks following the surgery.

Patients with irregularity, depression, or firmness on the reconstructed site at postoperative follow-up periods (3rd and 6th month) were scheduled to receive fat injections mixed in a 1:1 ratio with PRP and thrombin concentrate. Fat grafts were obtained with aspiration and centrifuged at 2,400 rpm for 3 min to remove cellular components and injected into the reconstructed site (Figure 5).

In cases with a high rate of fibrosis and moderate or severe contractures, the stem cell concentrate recovered by bone marrow aspiration from the iliac crest (BMAC-2; Bone Marrow Aspirate Concentrate, Harvest® Technologies GmbH, Munich, Germany)

Figure 4. Intraoperative view of VAC placement over the meshed STSG.

Figure 5. View of postoperative fat grafting to the scar area.

(Figure 6) was injected to the sites of scarring, alone or in a mixture with fat graft. Scar tissue samples were obtained during the same session using a punch biopsy. PRP, thrombin, stem cell injection, and lipoinjection were repeated at 6-month intervals as required.

Histopathological analysis

Specimens were examined histopathologically followed by staining with hematoxyline & eosine (H&E) and Masson's trichrome stains. Histopathological characteristics of collagen deposition and

Figure 6. View of harvesting of bone marrow from the iliac crest.

organization, vascularization, hyperkeratinization and melanocytic activity were evaluated under magnification before and after surgery.

Statistical analysis

Preoperative and postoperative scores for ROM, POSAS factors and histopathological characteristics were analyzed using IBM SPSS Statistics for Windows, v22 (IBM Corp., Armonk, N.Y., USA). The Paired Samples t-test in SPSS was used to compare the means of preoperative and postoperative scores for ROM, POSAS factors, and histopathological characteristics. Also, effects of gender, age, and severity of contractures of patients on the difference between preoperative and postoperative scores for POSAS factors and histopathological characteristics were examined by using the univariate linear model in the General Linear Model (GLM) procedure in SPSS. After significant effects were identified, differences between least-square means were considered significant at 0.05 based on the Least Significant Difference (LSD).

Table 1. Size of defects (cm^2) and ADM (cm^2) measured for all patients.

Case no	Size of defects (cm^2)	Size of ADM (cm^2)
1	40	38
2	77	58
3	83	64
4	192	112
5	105	84
6	111	98
7	133	124
8	143	105
9	111	86
10	104	94
11	173	95
12	204	134
13	223	154
14	214	154
15	234	162
16	190	114
17	178	106
18	137	62
19	121	55
20	280	269
21	184	114
22	225	154
23	194	169
24	157	114
25	205	165
26	224	180
27	151	126
28	144	118
29	178	156
Mean	162.6	119.5

Table 2. Mean and standard errors of preoperative and postoperative ROM, POSAS factors, and histopathological characteristics.

	Preoperative*	Postoperative*
ROM	36.14 ± 5.91^a	74.31 ± 6.96^b
POSAS Factors		
Vascularity	6.55 ± 0.20^a	3.93 ± 0.24^b
Pigmentation	6.62 ± 0.21^a	3.66 ± 0.23^b
Thickness	6.55 ± 0.21^a	3.55 ± 0.23^b
Relief	6.72 ± 0.22^a	3.62 ± 0.30^b
Pliability	7.17 ± 0.23^a	3.34 ± 0.24^b
Surface area	6.72 ± 0.21^a	3.55 ± 0.24^b
Histopathological Characteristics		
Collagen deposition and organization	2.21 ± 0.15^a	3.69 ± 0.19^b
Vascularization	2.28 ± 0.15^a	3.97 ± 0.18^b
Hyperkeratinization	2.03 ± 0.17^a	3.79 ± 0.14^b
Melanocytic activity	2.14 ± 0.18^a	3.69 ± 0.21^b

*Different lowercase letters in the same row indicate statistically significant difference between preoperative and postoperative means at $p < .05$.

Results

Twenty-nine patients with contractures were followed up for the study. The duration of follow-up for patients in this study ranged between 6 and 33 months with a mean of 17.2 months. The size of defects after contracture release and the size of ADM applied for defects were measured and given in Table 1. As seen in Table 1, the patient defects were of different sizes with a mean of 162.6 cm^2 and a range between 40 and 280 cm^2. However, the size of ADM applied for defects with a mean of 119.5 cm^2 and a range between 38 and 269 cm^2 was found smaller than the size of defects.

The means and standard errors of preoperative and postoperative scores for ROM, POSAS, and histopathological characteristics are given in Table 2. Preoperative and postoperative ROM mean and standard error values were 36.14 ± 5.91 (range 0–120°) and 74.31 ± 6.96 (range 30–170°), respectively. The statistically significant increase ($p < .05$) in the postoperative ROM values resulted in an improvement in quality and elasticity of the skin and a decrease in hypertrophic scar formation in all patients (Figures 7(a,b)).

The means and standard errors of preoperative and postoperative POSAS factors were 6.55 ± 0.20 and 3.93 ± 0.24 for vascularity; 6.62 ± 0.21 and 3.66 ± 0.23 for pigmentation; 6.55 ± 0.21 and 3.55 ± 0.23 for thickness; 6.72 ± 0.22 and 3.62 ± 0.30 for relief; 7.17 ± 0.23 and 3.34 ± 0.24 for pliability; and 6.72 ± 0.21 and 3.55 ± 0.24 for surface area, respectively. All POSAS factors were evaluated on numeric rating scales ranging from 1 (normal skin) to 10 (worst scar imaginable). Statistically significant decreases ($p < .05$) between the means of preoperative and postoperative POSAS factors (Table 2) indicated that there were significant improvement and statisfaction in the output of scars after postoperative evaluation.

Figure 7. (a/b) Sample cases (a; preoperative/b; postoperative).

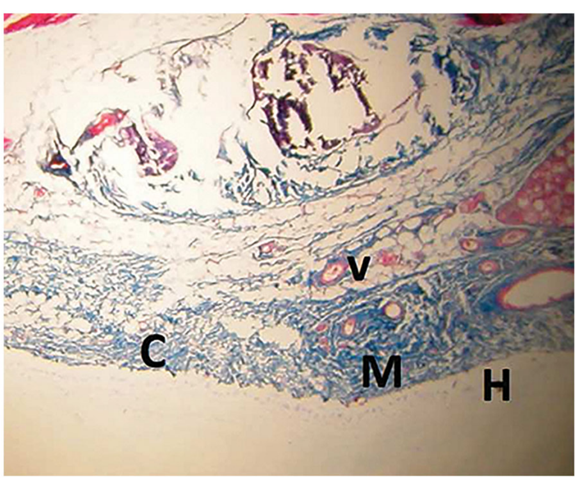

Figure 8. Histopathological findings (C; Collagen, V; Vascularization, H; Hyperkeratinization, M; Melanocyte) (40x).

Table 2 also showed the means and standard errors of preoperative and postoperative histopathological characteristics of collagen deposition and organization (2.21 ± 0.15 and 3.69 ± 0.19), vascularization (2.28 ± 0.15 and 3.97 ± 0.18), hyperkeratinization (2.03 ± 0.17 and 3.79 ± 0.14) and melanocytic activity (2.14 ± 0.18 and 3.69 ± 0.21), respectively. As seen in Table 2, preoperative and postoperative histopathological examination of the scar tissue samples revealed an increased collagen deposition and organization as well as increased vascularization, keratinization and melanocytic activity. There was also a decrease in scar tissue thickness and an increase in the thickness of subcutaneous tissues ($p < .05$) (Figure 8).

Table 3. Mean and standard errors of differences between preoperative and postoperative scores of POSAS factors and histopathological characteristics by gender of patients.

	Male*	Female*
Patient and Observer Scar Assessment Scale (POSAS) Factors		
Vascularity	-2.60 ± 0.55^{a}	2.12 ± 0.70^{a}
Pigmentation	-3.31 ± 0.38^{a}	-2.59 ± 0.49^{a}
Thickness	-3.59 ± 0.33^{a}	-2.81 ± 0.43^{a}
Relief	-3.81 ± 0.49^{a}	-2.87 ± 0.62^{a}
Pliability	-4.25 ± 0.44^{a}	-3.99 ± 0.56^{a}
Surface area	-2.60 ± 0.44^{a}	-2.74 ± 0.56^{a}
Histopathological Characteristics		
Collagen deposition and organization	1.75 ± 0.41^{a}	1.62 ± 0.52^{a}
Vascularization	1.80 ± 0.38^{a}	1.40 ± 0.49^{a}
Hyperkeratinization	1.90 ± 0.31^{a}	1.31 ± 0.39^{a}
Melanocytic activity	1.77 ± 0.40^{a}	0.93 ± 0.51^{a}

*Different lowercase letters in the same row indicate statistically significant difference between preoperative and postoperative means at $p < .05$.

Table 4. Mean and standard errors of differences between preoperative and postoperative scores of POSAS factors and histopathological characteristics by severity of contractures of patients.

	Mild*	Moderate*	Severe*
Patient and Observer Scar Assessment Scale (POSAS) Factors			
Vascularity	-1.61 ± 1.14^{a}	-2.88 ± 0.82^{a}	-2.59 ± 0.45^{a}
Pigmentation	-2.86 ± 0.80^{a}	-3.24 ± 0.57^{a}	-2.74 ± 0.32^{a}
Thickness	-3.83 ± 0.69^{a}	-3.10 ± 0.50^{a}	-2.67 ± 0.28^{a}
Relief	-4.47 ± 1.01^{a}	-2.74 ± 0.73^{a}	-2.80 ± 0.40^{a}
Pliability	-5.53 ± 0.91^{a}	-3.12 ± 0.65^{a}	-3.73 ± 0.36^{a}
Surface area	-1.98 ± 0.92^{a}	-2.44 ± 0.66^{a}	-3.61 ± 0.36^{a}
Histopathological Characteristics			
Collagen deposition and organization	2.65 ± 0.86^{a}	0.98 ± 0.62^{a}	1.43 ± 0.34^{a}
Vascularization	2.34 ± 0.80^{a}	0.65 ± 0.58^{a}	1.81 ± 0.32^{a}
Hyperkeratinization	1.17 ± 0.64^{a}	2.01 ± 0.46^{a}	1.64 ± 0.25^{a}
Melanocytic activity	2.22 ± 0.83^{a}	0.16 ± 0.60^{a}	1.68 ± 0.33^{a}

*Different lowercase letters in the same row indicate statistically significant difference between preoperative and postoperative means at $p < .05$.

The effects of gender, age, and severity of contractures of patients on the difference between preoperative and postoperative scores for POSAS factors and histopathological characteristics were analyzed and the results for effects of gender and severity of contractures were given in Table 3 and 4.

The age of patients was used as a covariate in the linear model. The results of analyses indicated that there was no age effect on the difference between preoperative and postoperative scores for POSAS factors and histopathological characteristics ($p > .05$). Also, Tables 3 and 4 showed that gender and severity of contractures of patients did not affect the difference significantly between preoperative and postoperative scores for POSAS factors and histopathological characteristics ($p > .05$).

As a result of the applications, we encountered only a few minor complications. Scaffold failure and hematoma were observed in only 2 cases. When opened on the 3rd day, the pore was opened and emptied for small drainage and the graft was adhered using Vacuum-Assisted Closure (VAC). The most important complication was graft loss, but there was no major graft loss. We did not see any complications as we used a closed system during fat injection. Skin viability, on the other hand, appeared as minimal epidermolysis in 2 patients with very adherent post-injection contractures. We did not encounter any skin necrosis when applied to the appropriate level.

Discussion

Standstill in progress for 2 months with the therapy for contracture is an indication for surgical intervention. Surgical management may be delayed until scar tissue matures [18]. Contracture release is usually performed by incising the scar at its maximal tension point. These incisions are usually extended to healthy tissues to achieve full release. Sometimes the muscle fascia is also included for the release process to achieve full gain [19]. Tissue defects usually occur after full contracture release. Since reconstruction of these defects is complex and includes step-by-step multilayered repair, it should be planned before the surgery. However, defects can be much bigger than desired. In such cases, temporary wound closure with epidermal equivalents or NPWT is an alternative approach before final reconstruction. In our practice, we usually prefer to excise the whole scar area restricting the motion of the joint instead of just incising and releasing it.

Common problems we have to face in burn reconstruction are high recurrence rate, insufficient skin thickness and elasticity, and failure to provide adequate passive and active ROM. Difficulty using local or regional flaps are also problematic in wide extremity burns with hypertrophic scars. For these patients, treatment options are limited to two ends of the reconstructive ladder-free flaps or STSG's [20]. Free flaps provide adequate skin thickness and elasticity. On other hand, factors like long procedure time, hospitalization, and donor site morbidity have limited their usage. STSGs only increase recurrence rates with a low patient satisfaction ratio. Therefore, STSGs are used in combination with dermal matrix components, which support the dermal layer and increase skin elasticity; thus, patient satisfaction and decrease recurrence.

Due to its surface structure and texture, ADM offers superior outcomes. Various studies have demonstrated the beneficial effects of increased skin quality in the long term [13,21,22]. The first clinical study on this dermal material was reported in the treatment of acute postburn scar in 2000. This comparative study evaluated ADM and STSG combination versus STSG alone between the groups. The researchers observed that autograft survival was not affected in wound reconstructed with ADM. However, there was no increase in the rate of graft loss or the need for regrafting in the ADM-reconstructed group compared to the reconstructed without ADM group [22]. In recent studies, 1 mm ADM's were used with STSG in one-stage reconstruction. We used 2 mm ADM with NPWT in one-staged reconstruction to achieve better dermis quality. The combined use of PRP provides acceleration of tissue regeneration and graft-host integration. Similarly, micro fat-graft injections can increase the thickness of the subcutaneous tissue and skin quality. We used ADM in a one-step surgical procedure in combination with cellular therapies for lower complication rates. A significant increase in skin elasticity was observed in scar tissue at three months following the application of ADM. In addition, we found superiority in recovery time and hospital stay in our clinical series.

Objective and subjective analyses are available to evaluate scar surfaces, which include the measurement of elasticity, colorimetry, and the Vancouver Scar Scale. The POSAS can be used to subjectively assess acute and reconstructed postburn scars and indicate surface differences in repaired scar tissue statistically [15,17,23]. When the wounds were treated with meshed STSGs, a significantly higher elasticity was observed for the ADM area. This finding is clinically significant because the application of ADM is particularly needed in severely burned patients when donor sites are sparse and widely expanded grafts are inevitable. Meshed STSGs were used in all our cases and demonstrated a statistically significant difference in POSAS scores, which is consistent with the literature [23]. These results suggest that ADM and cellular therapy applications are highly beneficial in increasing elasticity in the graft site.

Hur et al. [24] measured scar tissue dimensions at the end of the maturation phase and compared them with original wound dimensions. Their study showed that the grafts undergo contracture formation and remodelling 3–6 months following the procedure. The same study also observed a higher rate of contractures in acute burn defects than the defects that occurred following reconstructive surgery. However, ADM usage reduced contracture rates and increased elasticity; although contracture rates could not be eliminated totally by applying dermal product [24,25]. Many other studies have been reported on acute burns and scar management. The most interesting finding was observed in the category of acute burn wounds. At first view, no benefit of the ADM could be noted in the acute burn group. But, most of the reports obtained a positive effect of ADM [26–28]. ADM has been mostly used and assessed specifically for acute hand burns and reconstructions in this area with affirmative results [29–32]. Demircan et al. [33] showed that the use of ADM provided moderately good aesthetic and functional outcomes in the pediatric age group. The results encouraged clinicians about using ADM in such case. Before the bioengineering era, we had to reconstruct the wrist with a flap to achieve better result. Recently, our first choice in the pediatric patient group was to use ADM in acute and late deep burn cases.

Hypertrophic scars and contractures often occur in conditions where 1:3 or higher proportion of the skin graft is meshed. In a clinical report, they used ADM for 1:3–6 meshed autograft as a one-stage reconstruction method [34]. In other studies comparing non-ADM graft only with 1:1.5 meshed skin graft and ADM graft with 1:1.5 mesh autograft, skin elasticity was twice as high with the ADM group in postoperative day 60. Better cosmesis without hypertrophic scarring in postoperative day 90 was also observed [35]. We did not perform a comparative study evaluating the use of meshed and unmeshed grafts and ADM given that these studies already exist in the literature [34,35].

Platelets stimulate wound healing cascade in the defect site. Degranulated platelets release protein compounds that contain various growth factors into the wound site. These compounds promote cellular mitosis and angiogenesis. Platelets, therefore, have an important role in wound healing [36,37]. The activation of platelets with thrombin is a commonly used method for platelet degranulation. PRP obtained after concentration of platelets contains 4–5-fold higher amounts of growth factors than the platelets in the circulation. Therefore, the wound healing process is superior when applied to the wound site [38–40]. In the present study, PRP was used to increase skin and fat graft viability in fibrotic and hypovascular defects. In light of the current data, the authors have concluded that PRP may be preferred as a modern and significantly useful treatment option in cases with resistant and fibrotic contractures.

Stem cell applications involve the preparation of a concentrated compound that contains high rates of various growth factors for implantation to the defect. This method also provides significant benefits in conditions where wound healing and vascularization is problematic [41,42]. Stem cell therapy is recommended for such conditions as well as wound site ischemia and the formation of contractures. Stem cell applications are contemporary modern treatment options for promoting an optimal wound healing process in the presence of ischemia and fibrosis. Another indication, owing to its angiogenic and growth factor content, is to prepare a mixture with fat-graft at a certain ratio and implant the mixture to the tissue to increase the viability of

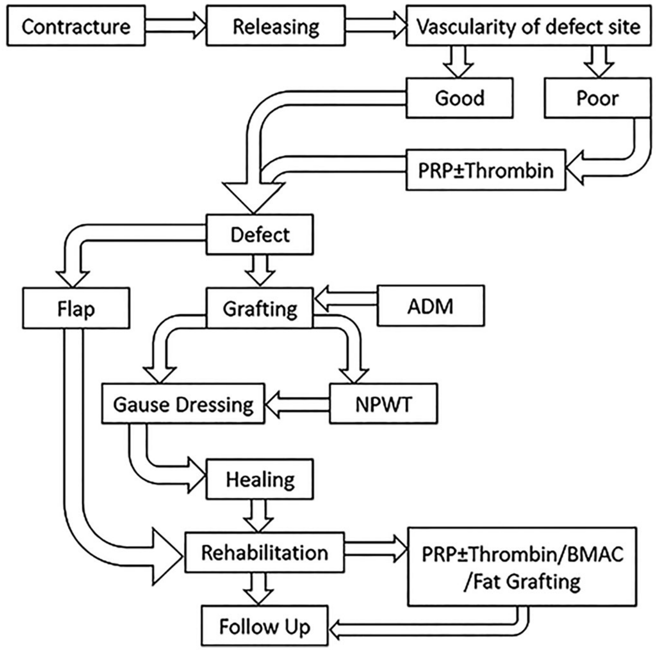

Figure 9. Burn reconstruction algorithm.

fat-graft [43,44]. As a result of these two indications, stem cell applications were added to the treatment algorithm in our cases, and more favorable outcomes were achieved. As stem cells contained higher amounts of growth factors than PRP, they were used as an option in combination with fat-graft in the long term, particularly for extremely fibrotic scar tissue. The authors suggested that this method could reduce the risk of hypertrophic scar and contracture formation in selected cases.

In the practice of plastic surgery, fat-grafting is a method used for both cosmetic and reconstructive purposes. Fat-grafts are very important components for correcting contour defects as well as contributing to the healing process in the wound bed [45–48]. Another important advantage of fat-grafts is their ability to aid in smoothing fibrotic tissues. Particularly, they can be used to complement therapy and facilitate the rehabilitation process in the early and late periods in the repair of contractures located on the joint sites. Decreased joint stiffness in the long term, increased soft tissue plasticity, and decreased pain in cases for which this method has been used suggests that fat grafting could be used more often in the repair of contractures.

NPWT allows a one-step reconstructive procedure with ADM and skin-graft combination. One-stage grafting saves time and effort for both the surgeon and patient by reducing operation time and dressing change. There are numerous clinical studies showing the successful use of NPWT in the management of skin and biomatrix grafts [6,8,49]. A prospective study of 47 cases with skin defects treated by one-stage allodermis combined STSGs with NPWT reported that 97.8% of grafts take at day 5. In addition, good aesthetic and functional result mimicks a FTSG obtained at the end of treatment [50]. Two-stage operation is another common reconstructive consideration for wound coverage with ADM and skin graft. In most cases, ADM usage is followed by definitive coverage with skin graft at the second stage after ADM adaptation [3].

In a randomized, multicenter, controlled study, Bloemen et al. reported on cases with deep defects requiring skin grafting [51]. In their study, they divided STSG applications into patients with and without ADM, and further divided these patients into subgroups as those with and without NPWT, creating a total of 4 groups [51]. The graft survival rate of more than 90% was found in all categories. The dermal component of ADM also reduced trans-epidermal water loss compared with STSG only group. An improved effectiveness of the ADM was obtained when combined with NPWT. NPWT helps ADM and STSGs to easily clench on subcutaneous tissues. However, the study by Moiemen et al. could not demonstrate increased neovascularization rates by NPWT [52].

The most common problems encountered in the repair of burn contractures are the tendency to relapse and the inability to satisfactorily correct joint stiffness. Despite the use of strict rehabilitation programs for this purpose, conventional methods may not always achieve the desired outcomes in the long term. Particularly in the pediatric age group, practical application of rehabilitation programs is challenging and may be complicated by patient compliance. Surgical methods to decrease the risk of contractures are still under research to overcome these problems. Methods, such as dermal matrix, cellular therapies and fat grafting, in addition to the surgical release and repair techniques used for this purpose, are effective with therapies that could be used to improve the outcomes of conventional methods. In light of results from current data, the authors suggest that the above-reported modern treatment methods will find their place in the standard treatment algorithm for burn reconstruction in parallel to the advances (Figure 9).

Conclusion

Despite the use of effective burn reconstruction methods, conventional therapies may result in recurrence and failure in cases with severe contractures. The advances in cellular therapies, the introduction of dermal scaffolds and alternative therapies in wound management have resulted in the emergence of various options. Such combination therapies could gradually replace conventional methods. It must be kept in mind that extremity functions may be further affected by hypertrophic scars. In particular, pediatric patients and these alternative therapies must be considered in the planning of treatment.

Informed consent

Informed consent was not sought for the present study.

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Ethical approval

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Disclosure statement

The authors declare no potential conflicts of interest with respect to the research, authorship, and publication of this article.

Contributorship

Not Applicable.

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