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Tissue expanders; review of indications, results and outcome during 15 years' experience

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ABSTRACT

Background: Tissue expanders (TE) are frequently used worldwide.
In this study we surveyed outcome of our patients retrospectively during 15 years.
Materials and Methods: We had 1105 patients for whom 3059 TEs have been used. Demographic data, age, sex, indications, type of tissue expander devices, volume of devices, site of scar and site TE insertion, our technique for tissue expander insertion and flap design, complications and outcome were gathered. A complete and through technical points and tips will be discussed.
Results: In 91% of patients overexpansion was done. (Expansion ratio=2.1–4.5). Re-expansion has been done in about 12% of patients. Complications were perforation of skin of pocket (11%) or exposure, infection (6%), dehiscence of the wound (1.5%), perforation of the port or disconnection of the tubes (2.1%), expansion of the scar itself (1%), saggy flap (3%), dog ear (5%), lack of adhesions of flap to its new site (4%).
Outcome: In 93% of the patients we could totally remove the scar. Around 9.1% of our patients had two sessions of expansion in the same area and 2.9% had three sessions of expansion. 51% of our patients were highly satisfied and 42% were satisfied of the results of expansion.
Conclusion: Our patients were satisfied with the results. In 12% cases we have done re-expansion. Re-expansion is possible as long as you have enough thickness of dermis in the skin. More than 50% of our patients were optimistic for 2nd or 3rd session of re-expansion.

1. Introduction

Tissue expander devices have been used over more than 38 years in Plastic and reconstructive surgeries. The expansion is a technique that cause different tissues in the body to grow and expand; such as skin, muscles, bone and other tissues [1–6].

Radovan in 1978 for the first time used a tissue expander device for reconstruction of scar in face [7]. And after him, many surgeons used different types and volumes of tissue expanders to treat their patients. In this method, the surgeon uses a subcutaneous silicon inflatable balloon and by gradual inflation of the balloon, the skin grow due to controlled mechanical overstretch [8–14].

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The extra skin is from the same area and matches the color, texture and thickness of the surrounding skin. So it is the best option for replacement of scar in the same area with minimal scarring and very low (if any) risk of rejection [15,16]. The remaining skin of expansion will cover the donor area, therefore there is no donor scar or deficit and in other words, there is no donor for this reconstruction. The expanded skin has the same sensation, so it has a good protective effect for the reconstructive area [16,17].

In this article we will share our experiences over 15 years with more than 3000 expanders that we used for different part of the body (Figs. 1–7).

2. Materials & methods

In more than 15 years we used different types of tissue expanders in over 1100 patients for treatment of their scars or for reconstructive purposes. All demographic data, age, sex, type of tissue expander devices, volume of devices, site of scar and site TE insertion, type of TE, indications, results, complications and outcome have been reviewed retrospectively.

All of the TE were hard base, with remote port, not self-filling. And we only used them for chronic scars.

Some guidelines and tips for proper technique of insertion, flap design and usage of TE have been provided below. The way that we used for using and insertion of TE, is the way that we reached after 15 year experience with a large number of patients.

We believe that this is the best way to suggest usage of TE for the patients.

By using this way we had not much complications and failure,

So we recommend our method to other colleagues. As you can see in our photos, this method has many advantages and can treat even difficult cases.

With using our method, the surgeon can be sure that he will not have much complications and easily he can reach to the proper treatment results. This is against the complication rates of other centers.

All data have been gathered in a special questionnaire and Statistical analysis has been done by SPSS 21 software.

P value less than 0.05 was considered significant.

2.1. *Operative technique*

At first and second consultation with the patients, we tried to completely discussed the technique and provide full information to the patients and family about advantages and disadvantages of the TE.

Then, in third visit, the normal tissue (skin) around the scar will be examined and we tried to find the best option for expansion and skin replacement in the place of the scar. The chosen skin measured to find the best size for the TE. The length and width of the skin can guide us to find the best type and the best size for expander. In most of the cases a rectangular TE is the ideal one. And the height of the expander is not an important issue in selection of the size of the expander i.e. the important measures are length and width of the TE. In some cases the normal skin around the scar have not big sizes. And we don't want to put the TE below the scar. We recommend to only place the TE beneath the normal skin. We don't recommend to place the TE beneath the scar, as you will have more complications. Expansion of TE beneath the scar would result in skin necrosis, exposure of the TE and eventually extrusion of the TE.

Therefore for these cases we use small size TEs and over-expand them.

During insertion surgery, after anesthesia, the site of TE will be marked by a waterproof pen and is injected with normal saline + 1/100000 epinephrine. Then the patient is prepped and draped. (It is important to inject epinephrine first, so after prep and drape, the needed time has passed and the site of surgery is bloodless and ready for dissection. If you inject the epinephrine after prep, you have to wait for 10–15 min for the site to be ready for clean and bloodless dissection. And the time of the surgery will be longer.)

Then the incision is made tangentially, just in the border between normal skin and scar. Usually incision with the length of half of the length of TE is enough for complete dissection of the pocket. We usually used metzenbaum scissors for blunt dissection of the pocket, usually there is no need for sharp dissection and the pocket can be easily dissected. Then TE inserted and checked if the pocket is of proper size. Then TE removed and a gauze with 1/100000 epinephrine is placed in the pocket for further hemostasis. The TE is placed in normal saline with Antibiotics. A tunnel is made for insertion of the port. We never use a second incision for insertion of the port.

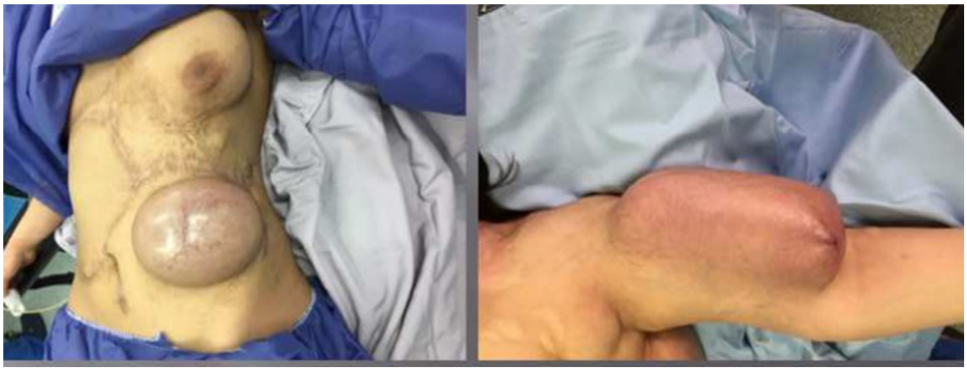

Fig. 1 – Examples of one TE in different parts of body.

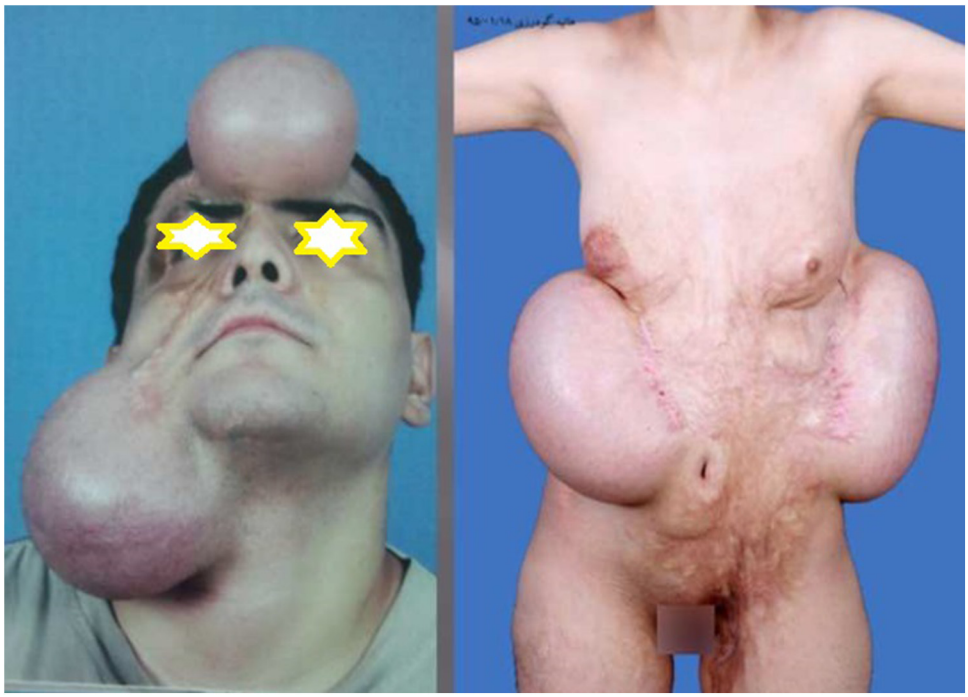

Fig. 2 – Examples of usage of two TEs for one scar in different parts of body.

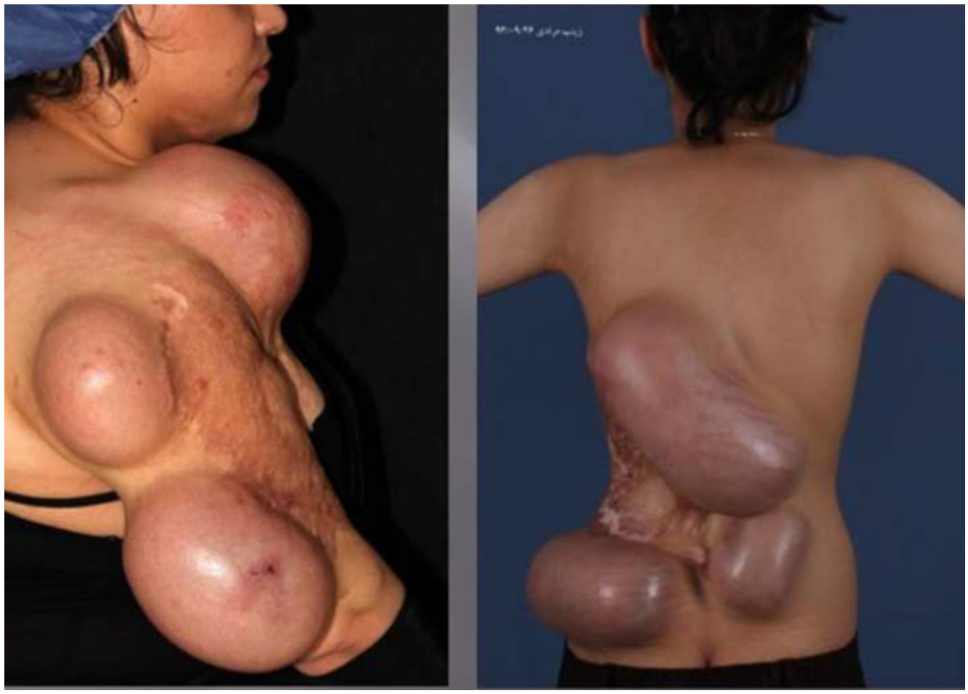

Fig. 3 – Examples of usage of three TEs for one scar in different parts of body.

The port should be in the far place to the pocket, at least in 5 centimeters distance. And it should be placed in such a way that after full expansion, the TE would not cover the port and injection can be easily preformed during the last stages.

Then the gauze is removed and a vacuum drain is inserted and fixed. TE is irrigated with normal saline and Antibiotics (Cephalothin+Gentamicin). The TE is inserted in the place and we make sure that all of the tubes and drains are placed beneath the TE. Then TE is compressed and all of the air is removed then it is connected to the port by the help of a connector. The port and TE is tested by a few millimeter injection of normal saline to be sure that everything is secure and water tight. The TE and port are placed in their sites and incision is closed in two layers with vicryl sutures separately and continuous monocryl (or nylon) sutures. After closure of wound, the bag of hemovac drain connected and vacuumed.

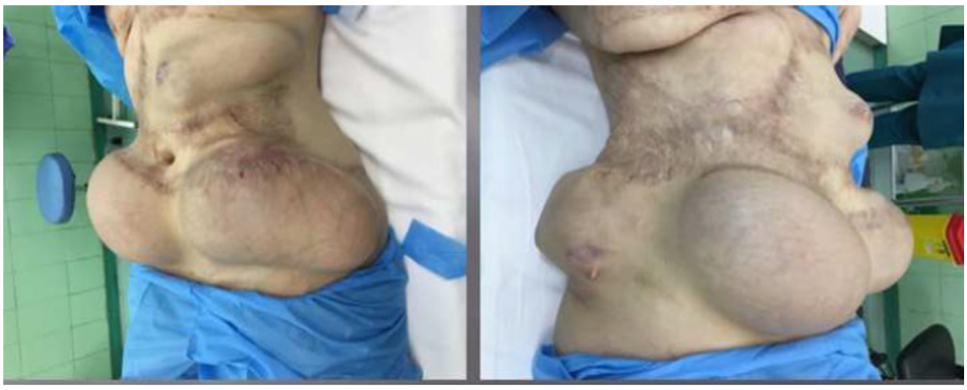

Fig. 4 – Examples of usage of four TEs for one scar in different parts of body.

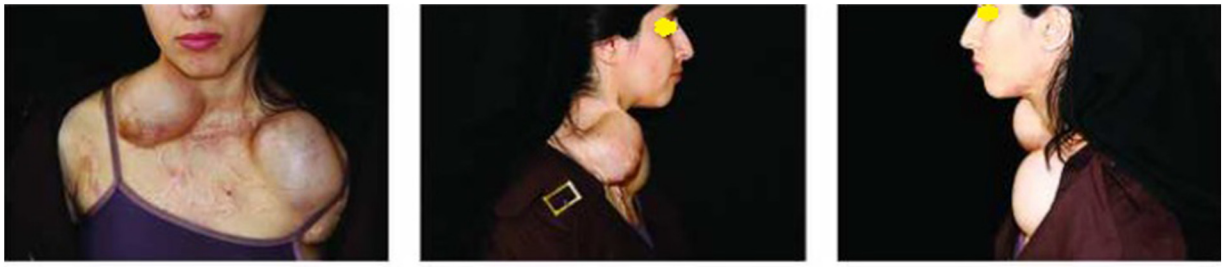

Fig. 5 – A 26 years old girl with different scars and using of 6 TEs in many parts of body for reconstruction of scars.

Then by a small needle (24 gauge needle or blue butterfly), normal saline is injected into the TE through the skin. Normally the saline is injected until the dead space is completely filled with TE (around 1/10 of the volume of the TE). In this way you will be sure that by the help of drain, seroma or hematoma will not be develop in the pocket and around the TE. A very loose dressing will be applied over the incision and the site.

After 3 weeks the sutures are removed and injection will be begin weekly. Although it is said that you can start on 8-10 days later, we usually wait until 3 weeks, as the wound in the first 3 weeks, is in its weakest point and any extra injection may disrupt the healing and results in dehiscence of the wound.

During 4-6 months, the injection of the TE will continue and when it is reach to desire size, the second operation will be performed. Our desire size is usually 2cm more than the needed length of the flap, to be in safe side that if anything happens during the second surgery, the surgeon always can use this 2cm extra tissue to solve the problem. And all of the scar can be removed completely.

In second operation, after prep and drape, the needed flap is designed and the incision site is marked with a waterproof pen. Then the whole scar is injected with normal saline +1/100000 epinephrine. In this way during removal of TE and preparing of a new flap, the required time will be passed and the scar will be bloodless and ready for excision.

The incision for removal of the TE, is the same incision for insertion of it. It is a very important point. The surgeon must decide during first operation that what incision he will need for the second operation and what type of flap he is going to use for reconstruction. With TE, advancement flap, rotational flap, bi-lob flap, prefabricated flap and Trans-positional flap can be made. The selection of the flap is based on the type of the scar and the amount of normal tissue that is available around the scar and pliability of the normal tissue that is going to be transferred. Normally transposition flap will give a longer flap

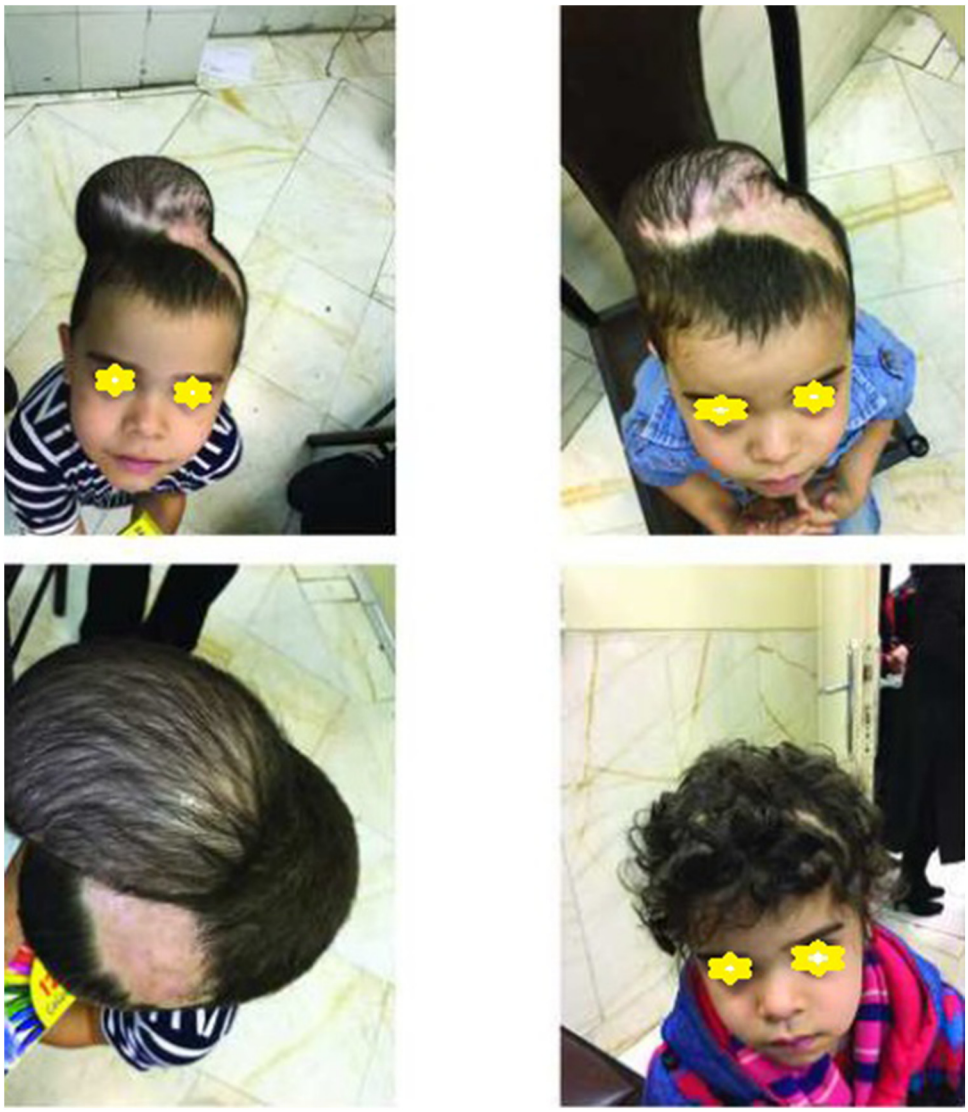

Fig. 6 – TE in head of a 3 years old boy for reconstruction of burn scar and the result after one year.

than advancement flap. And we can remove a longer scar with it. Although we do not remove all of the capsule in most of our patients, but in some cases a partial release in the middle of flap can help for better arc of rotation or advancement.

And in some other cases, over-expansion can cover this issue, and without partial release, the flap can reach to the desire length.

Then the desire flap is designed and cut from the expanded tissue and the flap transferred to the scar area. The flap is fixed with staples. Then surrounding of the flap is marked with a pen and staples removed. And flap returned back into its place. The scar tissue that is marked will be resected and after hemostasis, the flap again inserted into its new place and sutured in two layers with vicryl and monocryl (or nylon) sutures. In most of the cases a vacuum drain in needed. After checking the circulation of the flap, the loose dressing will be applied. During first and second days after the surgery, the flap frequently monitored for the circulation and any sign of bad circulation or necrosis. If anything suspicious happened, the surgeon will remove the stitches and reduce the tension over the flap. And the site will dressed for 2–3 days, during this time the flap will be tolerated to the ischemia and new circulation. After 2–3 days, the flap can be re-sutured again to the site. In this stage no necrosis will occur since the flap is now adapted to the new circulation. The drain will be removed once there is less than 10–15 cc discharge per day, usually after 1–2 days. And the sutures will be removed after 7–8 days, if needed.

The flap will be rather reddish for a few weeks and sometimes there is a chance for seroma accumulation. But in most of the cases, the flap will go smoothly and without any complications. If any seroma happens, it will respond well to drainage.

3. Results

During more than 15 years, we had 1105 patients, for them 3059 TEs were inserted and used.

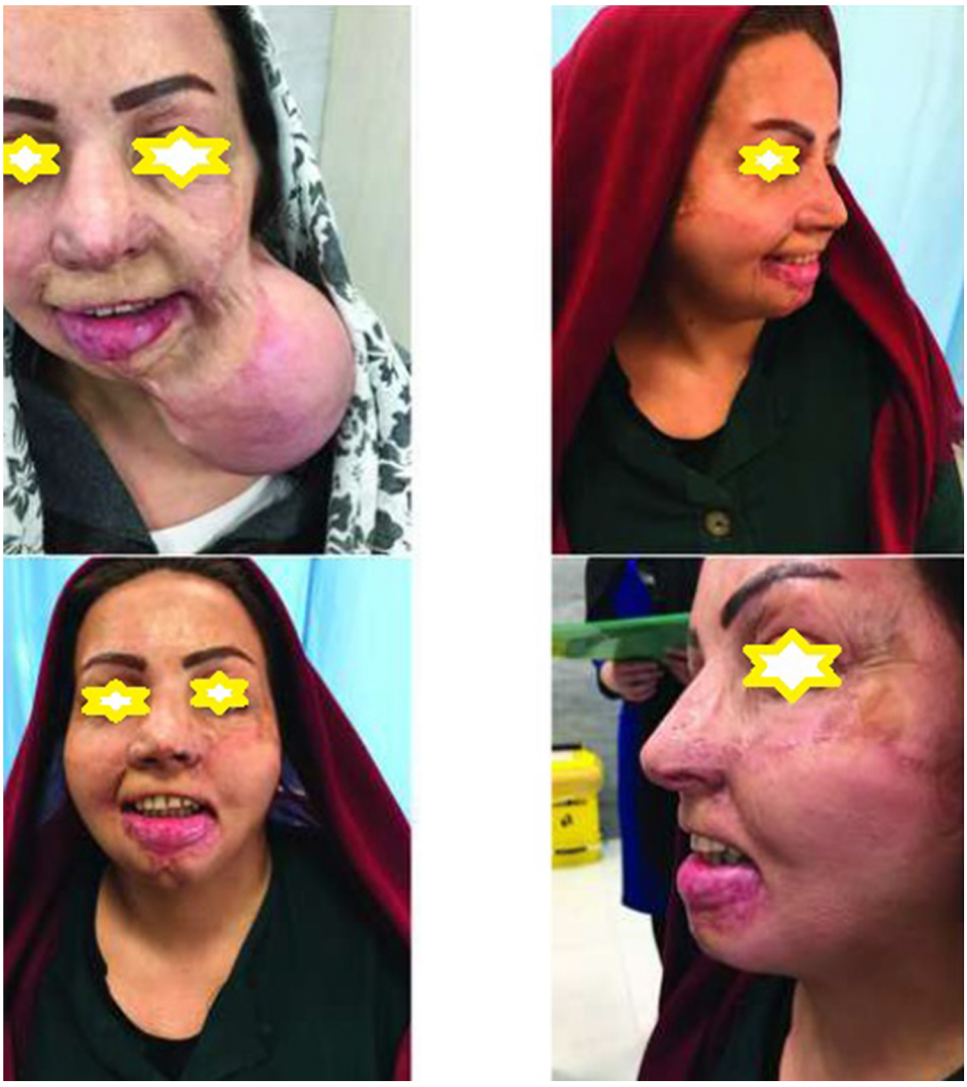

Fig. 7 – A 32 years old woman with scar in her cheek. We used TE in neck for removal of scar. Lower row shows her photos after 1.5 year.

791 were female and 314 were male. 94 were below 15 years old, 68 female and 26 male.

Table 1 shows the site of insertion of TE in the body.

Indications for TE insertion were: scar, traumatic scar, atrophic scar, scar revision, burn scar, alopecia, mammary aplasia, giant congenital melanocytic nevus (GCMN) and microtia Table 2.

Due to the size of scar, site of scar and availability of normal tissue around the scar or defect and the number of flaps that were needed for reconstruction, from one to four TE have been used for treatment of a defect or scar (Figs. 1–4).

[Examples of one TE are in supplementary file 1; Examples of two TEs are in supplementary file 2; Examples of three TEs are in supplementary file 3; Examples of four TEs are in supplementary file 4]. All of the TE were used after the acute wound is healed and the scar is matured (that is at least more than 6 months after the injury) (Fig. 5).

From one to six TE have been inserted for the patient in various parts of the body (in multiple sessions) according to the

Table 1 – Frequency of TEs in different sites of the body.

Site of TE	Frequency	Percentage
Scalp	581	19%
Forehead	184	6%
Cheek	489	16%
Neck	820	26.8%
Upper chest	153	5%
Scars over the breasts	61	2%
Shoulder	315	10.3%
Arm	171	5.6%
Forearm	31	1%
Belly	0	0%
Lateral belly and lumbar area	61	2%
Upper back	61	2%
Lower back	49	1.6%
Thigh	83	2.7%
Leg	0	0%
Total	3059	100%

Table 2 – Indications of TEs in our patients.

Indication	Percentage	Number of TEs
Scar, traumatic scar, atrophic scar, scar revision, burn scar	71.9%	2198
Hypertrophic scar	13%	398
Alopecia, scalp reconstruction	9.9%	303
Breast area scar reconstruction	0.8%	25
Mammary aplasia	0.6%	21
Giant congenital melanocytic nevus (GCMN)	1.3%	41
Microtia	2.2%	68
Nose reconstruction	0.1%	3
Hemangioma	0.06%	2
Total	**100%**	**3059**

Table 3 – The percentage of complications of TE in our patients.

Perforation of skin of pocket	11%
Infection	6%
Dog ear	5%
Lack of adhesions of flap in its new site	4%
Saggy flap	3%
Perforation of the port or disconnection of the tubes	2.1%
Dehiscence of the wound	1.5%
Leakage of the fluid or perforation of the TE	0.5%
Expansion of the scar itself	1%
Retraction of the flap or necrosis in the distal part of the flap	0.8%
Skull bone depression specially in the children below 4 years old	0.7%
Exposure of port	0.7%
Exposure of the tube	0.3%
Kinking of the TE	0.2%
Placement of the tube over TE	0.1%
Exposure of the edges of the TE due to local necrosis of skin over it	0.2%
Migration of the TE	0.1%
Hypertrophic scar in the repaired site	0.1%
Ectropion of the lower eyelid	0.1%
Hematoma	0.08%
Seroma	0.05%
Development of wide scar around the flap after reconstruction	0.01%
Permanent decrease in sensation of the flap	0.01%

desire of the patients, type and location of scars and the number of flaps that were needed for the repair.

The most of TE that were used, were rectangular shape and some minority of them were round shape. Other shapes of the TE were indicated rarely and their use should be individualized depending to the reconstruction method and treatment plan.

For insertion of TEs, the tangential incisions were used and redial incisions have not been used.

After 21 days, the expansion began and continued weekly. In most of our patients overexpansion were done for the patients (91% of the patients). The expansion ratio (volume inflated/volume of TE) were around 2.1 to 4.5 .In most of our patients, the capsule were remained intact and in some patients it was used as a bulk of tissue for camouflage of deformities below them. In some uncommon cases the capsules were removed specially in those cases for reconstruction of skin over cartilage framework in ear reconstruction or nasal tip reconstruction. Removal of capsule allow better adhesion of flap to the cartilage and better definition of the cartilage framework.

Re-expansion have been done in about 12% of patients due to lack of enough normal tissue for coverage of the defects in one session or complications that happened after insertion of the TE [Supplementary file 5].

Complications were perforation of skin of pocket (11%) or exposure, infection (6%), dehiscence of the wound (1.5%), leakage of the fluid or perforation of the TE (0.5%), perforation of the port or disconnection of the tubes (2.1%), expansion of the scar itself (1%), exposure of port (0.7%), exposure of the tube (0.3%), kinking of the TE (0.2%), placement of the tube over TE (0.1%), exposure of the edges of the TE due to local necrosis of skin over it (0.2%), migration of the TE (0.1%), skull bone depression specially in the children below 4 years old (0.7%), hypertrophic scar in the repaired site (0.1%), retraction of the flap or necrosis in the distal part of the flap (0.8%), seroma (0.05%), hematoma (0.08), development of wide scar around the flap after reconstruction (0.01%), ectropion of the lower eyelid (0.1%), permanent decrease in sensation of the flap (0.01%), saggy flap (3%), dog ear (5%), lack of adhesions of flap in its new site (4%) Table 3.

3.1. *Outcome*

Regarding to outcome, in 93% of the patients we could totally remove the scar and cover it with flap(s) (Fig. 6,7). In those who had complications some part of scar remained and needed a re-expansion. Around 9.1% of our patients had two sessions of expansion in the same area and 2.9% had three sessions of expansion.

51% of our patients were highly satisfied with the results of TE and 42% were satisfied. Only 8 patients were completely disappointed with the results of the expansion and these were patients who had unrealistic expectations about the results of the surgery. With complete explanation and detailed discussion of the technique and what are the real expectations of the surgery, the number of unsatisfied patients were decreased.

The surgeons were highly satisfied in 59% and satisfied in 45% of the cases. There were some cases that we could not remove all of the scars and some cases who did not want to continue the expansion and treatment.

4. Discussion

The tissue expander devices have opened a very new and promising area for reconstruction of the tissues in the different parts of the body. The idea that we can reconstruct the defective tissue with the same tissue was brilliant and brought a lot of hopes for our patients.

Since 1978, several plastic surgeons have used TE for reconstruction of defects in their patients. Especially for the scars in the face and neck, TE is a suitable option [7,17–31]. The scars in the face has been classified into four groups:

Type I: Single partial unit defect

Type II: Partial but two unit defects or total one unit defect

Type III: Multiunit defect

Type IV: Total/subtotal defects in face [32].

For type II–IV and some of type I the only option for reconstruction with the similar skin is TE. It is recommended that if the defect is more than 50% of a unit, or more than one third of forehead, or more than 6 cm in scalp, it is better to use TE [53]. The TEs can provide many options of flaps to the surgeon in order to cover the defects.

They can also be multiple, so in difficult cases, the surgeon can use multiple flaps to have the best and proper result.

In most of the cases the TE should be inserted beneath the skin and hypoderm or over the fascia [18]. But in cases of defects in the midline of chest or defects in abdomen, the surgeon usually inserted the TE beneath the muscles and try to close the defect with musculo-cutaneous flaps [33–36].

Several indications for using the TE are shown in Table 4 such as:

Scars, Traumatic scars, burn scars, atrophic scars, revision of the scars, scar contractures, congenital nevus, hemangioma, alopecia, burn alopecia, congenital anomaly, sebaceous nevus, pigmented nevus, leishmaniosis, scalp reconstruction, cutis aplasia, congenital abdominal wall defects, incisional hernia in abdominal wall, mammary hypoplasia or aplasia, microtia reconstruction of auricle, nose reconstruction, eyelid reconstruction, tumor, scleroderma, Dermatofibrosarcoma protuberance (DFP), giant congenital melanocytic nevus, palatal fistula, hypospadias, scrotal reconstruction, repair of bed sores, alveolar ridge augmentation, treatment of hypertrophic scars and keloids, repair after resection of BCC and SCC in face, for better and effective radiotherapy of liposarcoma in retro peritoneum [7,33,37,38,34,39,19,20,40–45,17,46,35,47–51,21–23,52,24,53,25,54,55,26,56–64,72,73,65–67,36,68,31,69–74].

The TE always is placed beneath the normal skin and after expansion it will produce a superfluous skin that can be used as a rotational flap, advancement flap, trans-positional flap, bi-pedicle flap, prefabricated (pedicle or free) flap or even sometimes as skin graft for other part of the body [75–80]. In our study all of flaps and skin graft have been used as a reconstructive tool for treatment of our patients, although among rotational flaps, advancement flaps and trans-positional flaps, the best length can be achieved by trans-positional flaps.

Table 4 – Overall indications for using TEs in literature:.

Scars, traumatic scars, burn scars, atrophic scars, revision of the scars, scar contractures, treatment of hypertrophic scars and keloids	[7,33,37,38,34,39,19,20,40–45,17,46,35,47–51,21–23,52,24,53,25,54,55,26,56–64,72,73,65,66,67,36,68,31,69–74]
Congenital nevus, hemangioma, alopecia, burn alopecia, congenital anomaly	
Sebaceous nevus, pigmented nevus, leishmaniosis	
Scalp reconstruction, cutis aplasia, congenital abdominal wall defects, incisional hernia in abdominal wall	
Mammary hypoplasia or aplasia	
Microtia reconstruction of auricle, nose reconstruction, eyelid reconstruction	
Scleroderma, Dermatofibrosarcoma protuberance(DFP), giant congenital melanocytic nevus	
Palatal fistula, alveolar ridge augmentation	
Hypospadias	
Repair of bed sores	
Repair after resection of BCC and SCC in face	
For better and effective radiotherapy of liposarcoma in retro peritoneum	

The number of TEs is directly depending on the number of flaps that are needed for the reconstruction and the normal skin that are available around the scar. In our study from one to 4 TEs have been used for repair of a defect or scar for our patients (Figs. 1–4). It has been reported that using more than 2 TEs can increase the complications but this is not found in our study [81].

Regarding to placement of drains in the pocket, it is our experience that drains can prevent accumulation of the seroma and/or hematoma, and closed suction drain for one or two days can help a lot for prevention of complications, although some of the authors do not always recommend it [82].

The size of TE depends on mathematical measurements of the normal skin that is candidate for insertion of the TE. Usually height of the TE is not an important issue and only length and width are measured. And the volume of the TE will be selected according to them, e.g.: if the size of normal skin is about 10 by 7 cm, the selected volume for it is a TE with (length 9.6 cm by 6.0 cm) around 250–300 cc volume (depending to the manufacturer of the TE) [83].

During our study it was revealed that over-expansion from 2.1 to 4.5 times of the volume can be done and is rewarding. The TE can expand with gradual injection of the saline. So after achievement of enough excess skin, the expansion is stopped and the patient will be scheduled for the surgery, removal of the TE and flap reconstruction. It is recommended that around 30–50% over-expansion is a safe zone to be sure that the flap dimension is suitable for the reconstruction [27].

In order to stand in the safe zone, we recommend the surgeons to measure the extra skin and directly predict the width and length of the flap that can be used for the treatment. Two easy ways for measurement are:

1. Subtraction of the length of the base of the TE from the length of the skin over the dome of the TE (Dome-base).
2. Two times of the expanded height of the TE (2× height of the TE or height of expanded skin) [27].

But this is the calculation over the paper, and it is always better to consider the length of flap a 1–2 cm less than the calculation.

Therefore the two measurements are like this:

1. [(Dome-base) – (1 or 2)] = actual length of the flap.
2. [(2× expanded height of TE) – (1or 2)] = actual length of the flap.

[For example: if the dome is 18 cm, base is 7 cm, then actual length of flap that we would have is: (18–7)-(1–2) = 7–8 cm i.e.: the length of the flap will be around 7–8 cm]. In our experiences, the first calculation is much more precise and near to real achievement in the length.

Complications of the insertion of the TE during different stages of operations, are presented in Table 5 [30,31,84,85,87–90].

The risk factors for complications are: wrong technique of the surgeon, insertion of TE below the elbow(in forearm) and below the knee (in leg), tight dress, lying over the TE specially during the night, excessive injection of fluid in each session, non-cooperative patient, children between 3–8 years old, smokers, history of radiotherapy to the area, wrong measurement for volume and size of the TE, placement of a big TE in a small pocket, placement of TE below the scar and use of other tissues in the pocket such as use of ADM in breast reconstruction [33,91] Table 6.

In a report from USA, risk factors of complication for TE in breast reconstruction were: BMI >30, history of radiotherapy, age >50 and smoking in the first month [92]. In other report in 2015 risk factors were: radiotherapy and experience of surgeon [93]. In a study in China in 2014 risk factors were TE in lower limb, external port, small children, site of TE and number of TEs [94]. In a report from Germany in 2008, authors believed that only anatomical area and volume of TE are important risk factors [50]. In other report from USA in 2007 closed drain was not a risk factor for complication and the same was in our study [82]. In a report from USA in 2005 about using TE in children cervicofacial area, the most frequent complications were in the neck [22]. In another report in 2003, the authors mentioned that risk factors were re-expansion cases and TE in lower limb [52]. Although there is a report from Spain that complication of TEs in lower limb were not different with other part of the body [88].

There is another report in 2014 that the most frequent place of complication in children was scalp [89]. In a study from Austria in 2013, the risk factors of complications were lower limb and children below 10 years old [95].

In a report in 2012, Karagergou et al. mentioned that the risk factors were number of TE, lower limb and big scar tissues [85]. In a study in 2011, Yeong et al. reported that risk factors were higher age, volume of TE, PVP (volume that is injected during first operation, the more you inject, the less you have complications) and lower limb (43 times more) [96].

Total rate of complications has been reported among 10%–33% in different studies and in our study rate of complication were 11.6%. We believe that proper technique and good design for flaps are the key factors that decreased the rate of complications in our cases [90,87,49,21,22,7,81,29,30,88,89,95,84,31,85,96,97,74]. There is a report from Sweden that they had 24% minor complications and 13% major complications for which they had to do a corrective surgery [21]. Radovan in

Table 5 – Complications of TEs.

Complications of the insertion of the TE during the first operation	1. Accidental traumatization and perforation of the skin of the pocket 2. Trauma or laceration in the edge of the skin and incision 3. Placement of the port in vicinity of the bag, placement of the port beneath the TE bag, so the injection is not possible or may perforate the TE 4. Accidentally perforation of the TE bag or port by scissors or knife, trauma to important anatomical tissues for example nerves, veins, arteries, fascia or muscle. For example in the neck it is very frequent that the surgeon may traumatize the superficial jugular vein or accidentally injured the platysma muscle [22,27].
Complications of insertion of TE in early phase after the operation	1. Hematoma 2. Seroma 3. Infection 4. Dehiscence of the wound 5. Migration of TE 6. Necrosis of the a part of the wound or scar, necrosis of a part of skin due to excess tension or over-injection of the fluid during the surgery and infection [22,31,84]. (In a report from Tunisia in 2012, it was mentioned that early complications are not related to the volume of the TE and infection was the most frequent one [84]. This issue has not been evaluated in our study.)
Complications of TE during the injection period	1. Perforation of the TE bag 2. Perforation or traumatization of the port, so the port cannot hold the fluid inside the bag and TE gradually deflate 3. Infection 4. Perforation of the skin and exposure of a part of TE or tube or port 5. Migration of the TE to unwanted area 6. Rotation or kinking of the TE or connecting tube so the injection is no longer possible [21,22,49,85–89].
Complications of second surgery for removal of the TE	1. Oozing of blood and hematoma formation 2. Seroma formation in the capsule of the TE 3. Excessive resection of the scar, excessive tension in the flap, problems in circulation of the flap and necrosis of the distal part of the flap, excessive tension in the surrounding tissue 4. Deformity and contracture of the surrounding skin 5. Skin retraction 6. Post-expansion atrophy 7. Permanent decrement in sensation 8. Sagging of the flap, dog ear and widening of the scar and lower lid ectropion [30,31,84,85,87–90].

Table 6 – The risk factors of complications in TE.

Risk factors:	1. Wrong technique of the surgeon, insertion of TE below the elbow (in forearm) and below the knee (in leg), tight dress, lying over the TE specially during the night, excessive injection of fluid in each session 2. Non-cooperative patient, children between 3-8 years old, smokers 3. History of radiotherapy to the area 4. Wrong measurement for volume and size of the TE 5. Placement of a big TE in a small pocket, placement of TE below the scar and use of other tissues in the pocket such as use of ADM in breast reconstruction [33,91].

1978 reported 12% major complications and 32% minor complications that did not interfere with the expansion [7]. Complications of TE in children has been reported in a study from USA in 2014, Absolute complications were 14% and partial complications were 10%. It seems that overall complications in children is less than adults [89,36]. Overall the minor complications are more frequent, but fortunately they cannot prevent the process of expansion.

For selection of incision in the first operation for insertion of the TE, you can chose radial incision or tangential incision. Radial incision is in the scar and dissection of the pocket is more difficult but the expansion can be started in 2–3 days after surgery as there is no chance for dehiscence of the incision, but there is a chance for necrosis of the some part of scar tissue due to dissection and undermining. For tangential incision, it is placed in the border of the scar and normal tissue, dissection in much easier but it is better that injection of TE be started after 3 weeks as there is a chance for dehiscence of the wound. Also it is our recommendation that as the wound is not enough strong during 1–3 weeks after surgery, so remove the stitches during 3 weeks [18,44,16,17,21,27,98].

For treatment and repair of a scar 4 different method can be used: pre-suturing, skin stretching device, skin retraction with undermining and use of TE. According to the experience and interest of surgeon, he may chose TE for reconstruction of the scar [11].

For using expansion, five methods are exist: Table 7

1. Intraoperative expansion.
2. Short time intermittent expansion (for gentle subcutaneous mobilization). This method can increase microcirculation of the dermis.
3. Classic prolong intermittent expansion. Which usually last for 4–6 months to have enough tissue for reconstruction.
4. Chronic tissue expansion. For example for a breast aplasia, the surgeon can place a TE and inflate every 3–4 months in aplastic site for a girl around 14 years old, so with growth of the normal side, the patient will have balance and equal breast in a long time and usually when she reach to 19 years of age, the TE can be replaced with an implant [16,23,97–99].
5. The external skin expander (extender): which are not true tissue expander. They are used over skin. There are many types of devices for extension of skin externally. They can be inserted in the first operation with local anesthesia, without need for operating room. They have not histological changes as TE. The TE produces more tissues per one unit of skin than skin extenders [10].

4.1. *Machanobiology of expansion*

After expansion due to chronic stretching force, biochemical, biomechanical and physiologic changes will happen in the skin [100]. Depending on viscoelastic properties the skin, expansion will occur by four phenomenon: intrinsic extensibility of the skin, mobility of skin, mechanical creep and stress-relaxation phenomenon (for production of new tissue). The laxity of skin will produce a good rate for expansion such as cheek skin in face [18]. The mechanical strain will result in tissue remodeling. Skin over-stretching (beyond the physiological limits) will induce the mechanotransduction pathways. The stretch will open the stretch--induced ion channels and by transferring of the ions, second messengers will be produced and this will lead to cell proliferation.

At the same time stress will lead to change in morphology of the skin. Bundles of collagen fibers will be parallel and aligned. These bundles will get thicker with more bundle spacing. Similarly elastin fibers will be parallel with the line of stretch. The changes in collagen fibers will be fast and in the response to stress of expansion. With increase in the surface of the skin, the dermis will be thinner and there is decrease in tensile strength of the skin [13]. Actually expansion can be continued to the point that the dermis is very thin. In other words, if you

Table 7 – Different methods for expansion:.

1.	Intraoperative expansion.
2.	Classic prolong intermittent expansion. Which usually last for 4–6 months to have enough tissue for reconstruction.
3.	Classic prolong intermittent expansion. Which usually last for 4–6 months to have enough tissue for reconstruction.
4.	Chronic tissue expansion. For example for a breast aplasia, the surgeon can place a TE and inflate every 3–4 months in aplastic site for a girl around 14 years old, so with growth of the normal side, the patient will have balance and equal breast in a long time and usually when she reach to 19 years of age, the TE can be replaced with an implant [16,23,97–99].
5.	The external skin expander (extender): which are not true tissue expander. They are used over skin. There many types of devices for extension of skin externally. They can be inserted in the first operation locally, without need for operating room. They have not histological changes as TE. The TE will produce more tissues per one unit of skin than skin extenders [10].

Table 8 – Different types of TEs.

-Classical TE with a distant port and a connection tube.
-TE with magnetic port over the main bag.
-Osmotic TE (osmed, hydrogel) which is self-inflating and volume will reach to 65% of original volume.
-Tabbed TE that can be fixed by sutures to a fix tissue in order to have maximum expansion in a special anatomical part of the tissue.
-Aeroform TE; which is inflated by Co2, with less time for inflation period.
-Becker TE, or permanent for reconstruction of the breast.
-Double reservoir TE; for reconstruction of the breast.
-External TE (external tissue extender), that don't need first operation and is much cheaper.
[107,36,38,108,109,39,93,110,42,43,111,112,48,113,114,54,26,99,65,68,73,115].

have enough thickness in the dermis, still you can continue the expansion.

The increase in the skin is also accompanied by increase in vascularity of skin, production of highly vascular capsule and increase in survival of the future flap. In this way, skin expansion is seen as a kind of delay phenomenon for the flap, that help the surgeon to have bigger and longer flap(s) for reconstruction [100,14,8,9,11,12,10,98,13,99,101,71]. The new flap has good sensation, so it is a very good option for the reconstructing the neighbor areas [52]. The presence of sensation is a very good option in treatment of bed sores. One can put TE beneath the sensate skin and transpose new flap for coverage of the bed sore. In this way the site of the sore will have protective sensation to prevent any further bed sores in this area [58]. There are some reports that in expansion of myocutaneous flaps, injection of Botox can increase the velocity of expansion, reduce the pain and increase the blood flow of the flap [102,103,16,104].

Some authors believe that after the removal of TE, the flap will have small retraction and decrease in size and others did not mention that. On the other hand, there are reports from China that there was no decrease in the dimension of the flaps [28]. In our experience we have not seen any retraction of the flap after the second surgery. Besides after insertion of the flap there is no risk for recurrence of scar and we have seen no rejection of the flap [9,98,28,105,84,106,31,71,90].

There are some reports that after insertion of the flap, there would be some reduction in the sensation of the flap comparing to the skin sensation before expansion, but in our study we had not any decrement in the sensation of the flap [17,52,58,31].

There are several types of TEs that are presented in Table 8 [107,36,38,108,109,39,93,110,42,43,111,112,48,113,114,54,26,99,65,68,73,115].

Nowadays insertion of TE with endoscope has been introduced. Insertion of TE with endoscope is feasible, with a far enough incision (remote incision), smaller incision, incision in a more hidden area which is more acceptable aesthetically, remote port, reduces the length of stay, reduces the rate of dehiscence, reduces the rate of complications, the injection can be started sooner and total length time for injection is reduced. But it has longer operative time, more expensive and needs expertise [116,81,97,117].

We usually do not remove the capsule of TE, it is suitable for camouflage of the deformities in the recipient site (contour deformity), it has bulk for new area, it provides good vascularity for the flap and it can be used for fixation of the flap and for reduction in the tension of the flap [But we recommend to remove the capsule in two cases, reconstruction of auricle and reconstruction of the cartilage in the tip of the nose. By resecting the capsule, the flap will adhere to the cartilage framework and the definition of the cartilage can be visible beneath the flap [54,55,26,62,63,106,118–122].

We had 12% cases for re-expansion. We had 9.1% cases for second expansion and 2.9% cases for third expansion and results were very good. Re-expansion is possible as long as you have enough thickness of dermis in the skin [49,120,52,98] [Supplementary file 5]. There is a report from Greece that the authors used TE for burn scars and more than 50% of the patients ask for re-expansion. Their patients were highly satisfied with the results of the TEs [17,49,123].

5. Conclusions

Over-expansion from 2.1 to 4.5 times of the volume can be done and is rewarding. We had 12% cases for re-expansion. We had 9.1% cases for second expansion and 2.9% cases for third expansion and results were very good. Re-expansion is possible as long as you have enough thickness of dermis in the skin. More than 50% of our patients were optimistic for 2nd or 3rd session of re-expansion.

The complications are rare with proper technique. Some of them are:

Perforation of skin of pocket (11%) or exposure, infection (6%), dehiscence of the wound (1.5%), leakage of the fluid or perforation of the TE(0.5%), perforation of the port or disconnection of the tubes(2.1%), saggy flap (3%), dog ear (5%), lack of adhesions of flap in its new site (4%).

Conflict of interest

No conflict of interest.

Disclosure

No disclosure.

Appendix A. Supplementary data

[Examples of one TE are in supplementary file 1, Examples of two TEs are in supplementary file 2; Examples of three TEs are in supplementary file 3; Examples of four TEs are in

supplementary file 4] [Supplementary file 5 shows the results of re-expension]. Supplementary data associated with this article can be found, in the online version, at https://doi.org/10.1016/j.burns.2018.11.017.

REFERENCES

[1] Zöllner Alexander M, Buganza Tepole Adrian, Gosain Arun K, Kuhl Ellen. Growing skin: tissue expansion in pediatric forehead reconstruction. Biomech Model Mechanobiol 2011;11(6):855–67.
[2] Neumann CG. The expansion of an area of skin by progressive distention of a subcutaneous balloon; use of the method for securing skin for subtotal reconstruction of the ear. Plast Reconstr Surg 1957;19(2):124–30.
[3] Bonaparte JP, Corsten M, Allen M. Cost-effectiveness of a topically applied pre-operative tissue expansion device for radial forearm free flaps: a cohort study. Clin Otolaryngol 2011;36(4):345–51.
[4] Radovan C. Tissue expansion in soft-tissue reconstruction. Plast Reconstr Surg 1984;74(4):482–92.
[5] Zöllner Alexander M, Buganza Tepole Adrian, Kuhl Ellen. On the biomechanics and mechanobiology of growing skin. Theor Biol 2012;297:166–75.
[6] Buganza Tepole Adrian, Ploch Christopher Joseph, Wong Jonathan, Gosain Arun K, Kuhl Ellen. Growing skin: tissue expansion in pediatric forehead reconstruction. Biomech Model Mechanobiol 2011;11(6):855–67.
[7] Chun JT, Rohrich RJ. Versatility of tissue expansion in head and neck burn reconstruction. Ann Plast Surg 1998;41(July (1)):11–6.
[8] Razzak MA, Hossain MS, Radzi ZB, Yahya NA, Czernuszka J, Rahman MT. Cellular and molecular responses to mechanical expansion of tissue. Front Physiol 2016;7 (November)540 eCollection 2016. Review.
[9] Zöllner AM, Holland MA, Honda KS, Gosain AK, Kuhl E. Growth on demand: reviewing the mechanobiology of stretched skin. J Mech Behav Biomed Mater 2013;28 (December):495–509.
[10] Alex JC, Bhattacharyya TK, Smyrniotis G, O'Grady K, Konior RJ, Toriumi DM. A histologic analysis of three-dimensional versus two-dimensional tissue expansion in the porcine model. Laryngoscope 2001;111(January (1)):36–43.
[11] Wilhelmi BJ, Blackwell SJ, Mancoll JS, Phillips LG. Creep vs. stretch: a review of the viscoelastic properties of skin. Ann Plast Surg 1998;41(August (2))215–9 Review.
[12] Voinchet V, Magalon G. Repair of skin defects by skin extension procedures. Ann Chir Plast Esthet 1996;41(October (5))563–71 Review.
[13] Baker SR. Fundamentals of expanded tissue. Head Neck 1991;13(July–August (4))327–33 Review.
[14] Verhaegen PD, Schouten HJ, Tigchelaar-Gutter W, van Marle J, van Noorden CJ, Middelkoop E, et al. Adaptation of the dermal collagen structure of human skin and scar tissue in response to stretch: an experimental study. Wound Repair Regen 2012;20(September–October (5)):658–66.
[15] Al Madani JO. Second generation self-inflating tissue expanders: a two-year experience. Plast Surg Int 2014;2014:457205.
[16] Zhernov OA, Kozynets' HP, Zhernov AO. Stretching method for the soft tissues using the tissue expanders in a reconstructive surgery. Klin Khir 2013;(March (3))63–6 Review.
[17] Awadein A, Gawdat G. Comparison of superior oblique suture spacers and superior oblique silicone band expanders. J AAPOS 2012;16(April (2)):131–5.
[18] Balaji SM. A single center experience of craniofacial tissue expansion and reconstruction. Ann Maxillofac Surg 2015;5 (January–June (1)):37–43.
[19] Mobley SR, Sjogren PP. Soft tissue trauma and scar revision. Facial Plast Surg Clin North Am 2014;22(November (4)):639–51.
[20] Desai SC, Sand JP, Sharon JD, Branham G, Nussenbaum B. Scalp reconstruction: an algorithmic approach and systematic review. JAMA Facial Plast Surg 2015;17(January–February (1)):56–66.
[21] Farzaneh FC, Kaldari S, Becker M, Wikström SO. Tissue expansion 1984–1999: a 15-year review. Scand J Plast Reconstr Surg Hand Surg 2006;40(2):89–92.
[22] Hurvitz KA, Rosen H, Meara JG. Pediatric cervicofacial tissue expansion. Int J Pediatr Otorhinolaryngol 2005;69(November (11)):1509–13.
[23] Hoffmann JF. Tissue expansion in the head and neck. Facial Plast Surg Clin North Am 2005;13(May (2))315–24 vii. Review.
[24] Hata Y, Umeda T. Reconstruction of congenital microtia by using a tissue expander. J Med Dent Sci 2000;47(June (2))105–16 Review.
[25] Jhuma H, Shibahara T, Nomura T, Takeda E, Noma H, Tonoki M. Repair of a cheek defect with the tissue expander method: a case report. Bull Tokyo Dent Coll 1997;38(November (4))311–6 Review.
[26] Malata CM, Williams NW, Sharpe DT. Tissue expansion: an overview. J Wound Care 1995;4(January (1))37–44 Review.
[27] Wieslander JB. Tissue expansion in the head and neck: a 6-year review. Scand J Plast Reconstr Surg Hand Surg 1991;25 (1):47–56.
[28] Hu X, Zeng G, Zhou Y, Sun C. Reconstruction of skin defects on the mid and lower face using expanded flap in the neck. J Craniofac Surg 2017;28(March (2)):e137–41.
[29] Heidekrueger PI, Broer PN, Tanna N, Ninkovic M. Postburn head and neck reconstruction: an algorithmic approach. J Craniofac Surg 2016;27(January (1)):150–5.
[30] Ashab Yamin MR, Mozafari N, Mozafari M, Razi Z. Reconstructive surgery of extensive face and neck burn scars using tissue expanders. World J Plast Surg 2015;4(January (1)):40–9.
[31] Khalatbari B, Bakhshaeekia A. Ten-year experience in face and neck unit reconstruction using tissue expanders. Burns 2013;39(May (3)):522–7.
[32] Zan T, Li H, Gu B, Liu K, Xie F, Xie Y, et al. Surgical treatment of facial soft-tissue deformities in postburn patients: a proposed classification based on a retrospective study. Plast Reconstr Surg 2013;132(December (6)):1001e–14e.
[33] Wooten KE, Ozturk CN, Ozturk C, Laub P, Aronoff N, Gurunluoglu R. Role of tissue expansion in abdominal wall reconstruction: a systematic evidence-based review. J Plast Reconstr Aesthet Surg 2017;70(June (6)):741–51.
[34] Alam NN, Narang SK, Pathak S, Daniels IR, Smart NJ. Methods of abdominal wall expansion for repair of incisional herniae: a systematic review. Hernia 2016;20(April (2)):191–9.
[35] Adetayo OA, Aka AA, Ray AO. The use of intra-abdominal tissue expansion for the management of giant omphaloceles: review of literature and a case report. Ann Plast Surg 2012;69 (July (1)):104–8.
[36] Yeşilada AK, Akçal A, Dağdelen D, Sucu DÖ, Kılınç L, Tatlıdede HS. The feasibility of tissue expansion in reconstruction of congenital and aquired deformities of pediatric patients. Int J Burns Trauma 2013;3(July (3)):144–50.
[37] Park H, Lee S, Kim B, Lim do H, Choi YL, Choi GS, et al. Tissue expander placement and adjuvant radiotherapy after surgical resection of retroperitoneal liposarcoma offers improved local control. Medicine (Baltimore) 2016;95(August (32)):e4435.
[38] Shash H, Al-Halabi B, Jozaghi Y, Aldekhayel S, Gilardino MS. A review of tissue expansion-assisted techniques of cleft palate repair. J Craniofac Surg 2016;27(May (3)):760–6.
[39] Lansdale N, Henderson L, Hennayake S. Novel use of an osmotic self-inflating tissue expander for hypospadias revision surgery. Urology 2015;85(April (4)):924–6.

[40] Carrera J, Albert A, Parri FJ, Vicente MA, Brualla D, Rovira C, et al. Surgical treatment of giant congenital melanocytic nevi: a change of aim. Cir Pediatr 2014;27(January (1)):36–42.
[41] Badeau AM, Granick M, Deleyiannis FW. Considerations for tissue expansion in the management of massive dermatofibrosarcoma protuberans of the head and neck. Eplasty 2013;13(December)e63 eCollection 2013.
[42] Park SH, Choi SK, Jang JH, Kim JW, Kim JY, Kim MR, et al. Self-inflating oral tissue expander for ridge augmentation in the severely atrophic mandible. J Korean Assoc Oral Maxillofac Surg 2013;39(February (1)):31–4.
[43] Farronato G, Giannini L, Galbiati G, Cannalire P, Martinelli G, Tubertini I, et al. Oral tissues and orthodontic treatment: common side effects. Minerva Stomatol 2013;62(November–December (11–12))431–46 Review.
[44] Mangubat EA. Scalp repair using tissue expanders. Facial Plast Surg Clin North Am 2013;21(August (3)):487–96.
[45] Branski LK, Rennekampff HO, Vogt PM. Keloid and hypertrophic scar treatment modalities. An update. Chirurg 2012;83(September (9))831–4 quiz 845–846.
[46] Mir T, Simpson RL, Hanna MK. The use of tissue expanders for resurfacing of the penis for hypospadias cripples. Urology 2011;78(December (6)):1424–9.
[47] Fahmy MA, Mazy A. The feasibility of tissue expanders in reconstruction of giant congenital melanocytic nevi in children. Surg Innov 2010;17(September (3)):189–94.
[48] Jenq TF, Hilliard SM, Kuang AA. Novel use of osmotic tissue expanders to treat difficult anterior palatal fistulas. Cleft Palate Craniofac J 2011;48(March (2)):217–21.
[49] Dotan L, Icekson M, Yanko-Arzi R, Ofek A, Neuman R, Margulis A. Pediatric tissue expansion: our experience with 103 expanded flap reconstructive procedures in 41 children. Isr Med Assoc J 2009;11(August (8)):474–9.
[50] Bozkurt A, Groger A, O'Dey D, Vogeler F, Piatkowski A, Fuchs PCh, et al. Retrospective analysis of tissue expansion in reconstructive burn surgery: evaluation of complication rates. Burns 2008;34(December (8)):1113–8.
[51] Spector JA, Blei F, Zide BM. Early surgical intervention for proliferating hemangiomas of the scalp: indications and outcomes. Plast Reconstr Surg 2008;122(August (2)):457–62.
[52] LoGiudice J, Gosain AK. Pediatric tissue expansion: indications and complications. J Craniofac Surg 2003;14 (Nopvember (6))866–72 Review.
[53] Hodgkinson DJ, Lam Q. Expansion techniques after Mohs' surgery on the face. Australas J Dermatol 2001;42(February (1))9–14 Review.
[54] Wang N, Qi K. Uses of skin expanders in auricle reconstruction. Lin Chuang Er Bi Yan Hou Ke Za Zhi 1998;12 (April (4))188–9 Review.
[55] Mutaf M, Ustuner ET, Celebioglu S, Kocer U, Sensoz O. Tissue expansion-assisted prefabrication of the forehead flap for nasal reconstruction. Ann Plast Surg 1995;34(May (5))478–84 discussion 485–487. Review.
[56] Fisher J, Hammond DC. The combination of expanders with autogenous tissue in breast reconstruction. Clin Plast Surg 1994;21(April (2))309–20 Review.
[57] Fröhlich G, Stratmeyer R. Reconstruction of the scrotum using a tissue expander. Urologe A 1994;33(March (2))159–62 Review.
[58] Neves RI, Kahler SH, Banducci DR, Manders EK. Tissue expansion of sensate skin for pressure sores. Ann Plast Surg 1992;29(November (5)):433–7.
[59] Quayle AA, McCord JF. Current status of tissue expanders in alveolar ridge augmentation: a review. Implant Dent 1992;1 (Fall (3))177–81 Review.
[60] Cano I, Encinas A, Herrero E, Lagarón E, Vilariño A, Berchi FJ. The indications, technics and results of the use of tissue expanders in pediatric surgery. Cir Pediatr 1991;4(October (4)):173–7.
[61] Tanino R, Miyasaka M. Reconstruction of microtia using tissue expander. Clin Plast Surg 1990;17(April (2))339–53 Review. PubMed PMID: 2189648.
[62] Sasaki GH. Tissue expansion in reconstruction of acquired auricular defects. Clin Plast Surg 1990;17(April (2))327–38 Review. PubMed PMID: 2189647.
[63] Bauer BS. The role of tissue expansion in reconstruction of the ear. Clin Plast Surg 1990;17(April (2))319–25 Review. PubMed PMID: 2189646.
[64] Ortega MT, McCauley RL, Robson MC. Salvage of an avulsed expanded scalp flap to correct burn alopecia. South Med J 1990;83(February (2))220–3 Review.
[65] Wittkampf AR. Short-term experience with the subperiosteal tissue expander in reconstruction of the mandibular alveolar ridge. J Oral Maxillofac Surg 1989;47(May (5)):469–74.
[66] Guzey S, Alhan D, Şahin I, Aykan A, Eski M, Nişancı M. Our experiences on the reconstruction of lateral scalp burn alopecia with tissue expanders. Burns 2015;41(May (3)):631–7.
[67] Abada H, Aktouf A, Delaunay F, Lievain L, Auquit-Auckbur I. Alopecia reconstruction by expansion after a scalp burn injury caused by Taser(®): a case report. Ann Dermatol Venereol 2014;141(December (12)):769–72.
[68] Lohana P, Moiemen NS, Wilson YT. The use of Osmed(TM) tissue expanders in paediatric burns reconstruction. Ann Burns Fire Disasters 2012;25(March (1)):38–42.
[69] Branski LK, Rennekampff HO, Vogt PM. Keloid and hypertrophic scar treatment modalities. An update. Chirurg 2012;83(September (9))831–4 quiz 845–846.
[70] Cho JY, Jang YC, Hur GY, Koh JH, Seo DK, Lee JW, et al. One stage reconstruction of skull exposed by burn injury using a tissue expansion technique. Arch Plast Surg 2012;39(March (2)):118–23.
[71] Zöllner AM, Buganza Tepole A, Gosain AK, Kuhl E. Growing skin: tissue expansion in pediatric forehead reconstruction. Biomech Model Mechanobiol 2012;11(July (6)):855–67.
[72] Mimoun M, Boccara D, Chaouat M. Tissue expansion in burns sequelae. Ann Chir Plast Esthet 2011;56(October (5)):358–68.
[73] Böttcher-Haberzeth S, Kapoor S, Meuli M, Neuhaus K, Biedermann T, Reichmann E, et al. Osmotic expanders in children: no filling-no control-no problem? Eur J Pediatr Surg 2011;21(May (3)):163–7.
[74] Van Damme PA, Freihofer HP. Palatal mucoperiosteal expansion as an adjunct to palatal fistula repair: case report and review of the literature. Cleft Palate Craniofac J 1996;33 (May (3))255–7 Review.
[75] Gao B, Xiao K, Zhu H, Sheng L, Yu Q, Mao X, et al. An algorithm for using expanded cervical flaps to resurface facial defects based on five different methods. Burns 2016;42(December (8)):1867–74.
[76] Topalan M, Guven E, Demirtas Y. Hemifacial resurfacing with prefabricated induced expanded supraclavicular skin flap. Plast Reconstr Surg 2010;125(May (5)):1429–38.
[77] Fan J, Liu L, Tian J, Gan C, Lei M. Aesthetic full-perioral reconstruction of burn scar by using a bilateral-pedicled expanded forehead flap. Ann Plast Surg 2009;63(December (6)):640–4.
[78] Song B, Zhao J, Guo S, Yi C, Liu C, He L, et al. Repair of facial scars by the free expanded deltopectoral flap. Plast Reconstr Surg 2013;131(February (2)):200e–8e.
[79] Song B, Jin J, Liu Y, Zhu S. Prefabricated expanded free lower abdominal skin flap for cutaneous coverage of a forearm burn wound defect. Aesthetic Plast Surg 2013;37(October (5)):956–9.
[80] Zhang L, Yang Q, Jiang H, Liu G, Huang W, Dong W. Reconstruction of complex facial defects using cervical expanded flap prefabricated by temporoparietal fascia flap. J Craniofac Surg 2015;26(September (6)):e472–5.
[81] Weissman O, Hundeshagen G, Bank J, Zilinsky I, Solomon E, Remer E, et al. Distant blunt forceps dissection in tissue

expander insertion: a novel technique. Plast Surg (Oakv) 2016;24(Fall (3)):174–6.
[82] McCarthy CM, Disa JJ, Pusic AL, Mehrara BJ, Cordeiro PG. The effect of closed-suction drains on the incidence of local wound complications following tissue expander/implant reconstruction: a cohort study. Plast Reconstr Surg 2007;119 (June (7)):2018–22.
[83] van Rappard JH, Sonneveld GJ, Borghouts JM. Geometric planning and the shape of the expander. Facial Plast Surg 1988;5(July (4))287–90 Review.
[84] Belghith A, Jeblaoui Y, Njah H, Zairi I, Zitouni K, Adouani A. Complications of head and neck skin expansion. Rev Stomatol Chir Maxillofac 2012;113(December (6)):411–4.
[85] Karagergou E, Papas A, Foroglou P, Demiri E. Management of the complications of tissue expansion during a 5-year period (2005–2010). J Plast Surg Hand Surg 2012;46(September (3–4)):167–71.
[86] North WD, Kubajak CS, St Martin B, Rinker B. Dermal autograft using donor breast as alternative to acellular dermal matrices in tissue expander breast reconstruction: a comparative review. Ann Plast Surg 2017;78(June (6S Suppl 5)):S282–5.
[87] Ota D, Fukuuchi A, Iwahira Y, Kato T, Takeuchi M, Okamoto J, et al. Identification of complications in mastectomy with immediate reconstruction using tissue expanders and permanent implants for breast cancer patients. Breast Cancer 2016;23(May (3)):400–6.
[88] Dzonov B, Daskalov O, Noveski L, Zhivadinovik J, Isjanovska R. Tissue expansion in limbs vs other body regions. Pril (Makedon Akad Nauk Umet Odd Med Nauki) 2014;35 (1):219–24.
[89] Patel PA, Elhadi HM, Kitzmiller WJ, Billmire DA, Yakuboff KP. Tissue expander complications in the pediatric burn patient: a 10-year follow-up. Ann Plast Surg 2014;72(February (2)):150–4.
[90] McCullough MC, Roubard M, Wolfswinkel E, Fahradyan A, Magee W. Ectropion in facial tissue expansion in the pediatric population: incidence, risk factors, and treatment options. Ann Plast Surg 2017;78(March (3)):280–3.
[91] Zhao X, Wu X, Dong J, Liu Y, Zheng L, Zhang L. A meta-analysis of postoperative complications of tissue expander/implant breast reconstruction using acellular dermal matrix. Aesthetic Plast Surg 2015;39(December (6)):892–901.
[92] Hirsch EM, Seth AK, Kim JY, Dumanian GA, Mustoe TA, Galiano RD, et al. Analysis of risk factors for complications in expander/implant breast reconstruction by stage of reconstruction. Plast Reconstr Surg 2014;134(November (5)):692e–9e.
[93] Taboada-Suarez A, Brea-García B, Magán-Muñoz F, Couto-González I, González-Álvarez E. Risk factors associated with complication rates of becker-type expander implants in relation to implant survival: review of 314 implants in 237 patients. Ann Plast Surg 2015;75(December (6)):596–602.
[94] Wang J, Huang X, Liu K, Gu B, Li Q. Complications in tissue expansion: an updated retrospective analysis of risk factors. Handchir Mikrochir Plast Chir 2014;46(April (2)):74–9.
[95] Fochtmann A, Keck M, Mittlböck M, Rath T. Tissue expansion for correction of scars due to burn and other causes: a retrospective comparative study of various complications. Burns 2013;39(August (5)):984–9.
[96] Yeong EK, Chen KW, Chan ZH. Risk factors of tissue-expansion failure in burn-scar reconstruction. J Plast Reconstr Aesthet Surg 2011;64(December (12)):1635–40.
[97] Siegert R, Weerda H. Tissue expansion. Part 1: technical and physiologic principles. HNO 1994;42(February (2))124–37 Review.
[98] Cheng NX, Chen YF. Advances in clinical uses of soft tissue expansion. Zhonghua Zheng Xing Shao Shang Wai Ke Za Zhi 1994;10(January (1))40–2 Review.
[99] Collins SA, Swanson NA. Chronic tissue expansion. J Dermatol Surg Oncol 1993;19(December (12))1090–8 Review.
[100] Marcus J, Horan DB, Robinson JK. Tissue expansion: past, present, and future. J Am Acad Dermatol 1990;23(November (5 Pt 1))813–25 Review.
[101] Pasyk KA, Argenta LC, Austad ED. Histopathology of human expanded tissue. Clin Plast Surg 1987;14(July (3))435–45 Review.
[102] Duan C, Xu G, Zhou J, Wei G, Li S. Effect of botulinum toxin type A on excessive expansion of myocutaneous flap. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2011;25 (September (9)):1063–6.
[103] Winocour S, Murad MH, Bidgoli-Moghaddam M, Jacobson SR, Bite U, Saint-Cyr M, et al. A systematic review of the use of Botulinum toxin type A with subpectoral breast implants. J Plast Reconstr Aesthet Surg 2014;67(January (1)):34–41.
[104] Layeeque R, Hochberg J, Siegel E, Kunkel K, Kepple J, Henry-Tillman RS, et al. Botulinum toxin infiltration for pain control after mastectomy and expander reconstruction. Ann Surg 2004;240(October (4))608–13 discussion 613–614.
[105] McCullough MC, Roubard M, Wolfswinkel E, Fahradyan A, Magee W. Ectropion in facial tissue expansion in the pediatric population: incidence, risk factors, and treatment options. Ann Plast Surg 2017;78(March (3)):280–3.
[106] Liu Y, Feng G, Yang K, Peng Z. Application of facial tissue expander fibrous envelope for tension reduction. Zhongguo Xiu Fu Chong Jian Wai Ke Za Zhi 2012;26(August (8)):939–42.
[107] Thimmappa ND, Prince MR, Colen KL, Ahn CY, Dutruel SP, Boddu SR, et al. Breast tissue expanders with magnetic ports: clinical experience at 1.5 T. Plast Reconstr Surg 2016;138 (December (6)):1171–8.
[108] Fischer LH, Nguyen D. Double-chamber tissue expanders optimize lower pole expansion in immediate breast reconstruction requiring adjuvant radiation therapy. Ann Plast Surg 2016;76(May (Suppl 3)):S171–4.
[109] Ascherman JA, Zeidler KR, Jacoby A, Appel JZ, Berkowitz RL, Castle J, et al. Carbon dioxide versus saline tissue expanders: does it matter? Plast Reconstr Surg 2016;137(January (1)):31–5.
[110] Khavanin N, Gust MJ, Grant DW, Nguyen KT, Kim JY. Tabbed tissue expanders improve breast symmetry scores in breast reconstruction. Arch Plast Surg 2014;41(January (1)):57–62.
[111] Kirschke J, Georgas D, Sand M, Bechara FG. External tissue expander for closing large defects of the extremities and trunk. J Cutan Med Surg 2013;17(November–December (6)) 423–5 Review.
[112] O'Reilly AG, Schmitt WR, Roenigk RK, Moore EJ, Price DL. Closure of scalp and forehead defects using external tissue expander. Arch Facial Plast Surg 2012;14(November (6)):419–22.
[113] Chew BK, Yip C, Malyon AD. Becker expander implants: truly a long term single stage reconstruction? J Plast Reconstr Aesthet Surg 2010;63(August (8)):1300–4.
[114] Mazzoli RA, Raymond 4th WR, Ainbinder DJ, Hansen EA. Use of self-expanding, hydrophilic osmotic expanders (hydrogel) in the reconstruction of congenital clinical anophthalmos. Curr Opin Ophthalmol 2004;15(October (5))426–31 Review.
[115] Chummun S, Addison P, Stewart KJ. The osmotic tissue expander: a 5-year experience. J Plast Reconstr Aesthet Surg 2010;63(December (12)):2128–32.
[116] Levi B, Brown DL, Cederna PS. A comparative analysis of tissue expander reconstruction of burned and unburned chest and breasts using endoscopic and open techniques. Plast Reconstr Surg 2010;125(February (2)):547–56.
[117] As'adi K, Emami SA, Salehi SH, Shoar S. A randomized controlled trial comparing endoscopic-assisted versus open neck tissue expander placement in reconstruction of post-burn facial scar deformities. Aesthetic Plast Surg 2016;40 (August (4)):526–34.

[118] Kim BJ, Lee Y. Use of scar and capsule flap for preventing the contour deformity after applying tissue expansion in patients with scar. J Craniofac Surg 2014;25(2):e151–4.
[119] Gu Y, Guo X, Wang T, Yu H, Yang W, Wang J. Reconstruction of total upper eyelid with prefabricated capsule-lined advancement flaps. J Craniofac Surg 2013;24(May (3)):1038–41.
[120] Latifi NA, Karimi H. Why burn patients are referred? Burns 2017;43(March (3)):619–23.
[121] Latifi Noor-Ahmad, Karimi Hamid. Acute electrical injury: a systematic review. J Acute Dis 2017;6(March (3)):93–6.
[122] Latifi NA, Karimi H, Motevalian SA, Momeni M. Economical burden of burn injuries in a developing country. J Burn Care Res 2017;38(June (6)):e900–5.
[123] Sönmez Ergün S, Yildiz K, Baygöl EG, Ozpür MA, Duygu C. A novel approach to soft-tissue repair: reoverexpanded flaps. J Burn Care Res 2013;34(July–Auguat (4)):e228–31.