APPLICATION OF THE SOFT TISSUE EXPANDING TECHNIQUE BEFORE GUIDED BONE REGENERATION OF AN ATROPHIC ALVEOLAR RIDGE

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Abstract

Objective: This study aimed to evaluate the effectiveness of the application of a self-inflating tissue expander before guided bone regeneration (GBR) in cases of atrophy of the alveolar ridge.

Methods: Experimental group patients underwent preliminary soft tissue expansion (STE) by a hydrogel-type soft tissue expander TissueMax® (Osstem, Seoul, South Korea) before GBR. Control group patients underwent conventional bone augmentation without tissue expansion. The combination of autograft and xenograft was used in GBR in both groups. The influence of STE on the thickness and microcirculation parameters of the gingivae were studied through ultrasound intraoral scanner and laser doppler flowmetry (LDF). In addition, the authors assessed and analyzed the results of the following GBR and dental implantation with prosthetic loading: rate of bone resorption, complications, and stability of dental implants.

Results: 38 patients with alveolar bone atrophy included in the study were randomly assigned to two groups. No complications or significant changes in the thickness of the mucosa were observed after a 28-day expansion. Gradual stretching had a positive influence on the parameters of microcirculation. Enough volume of soft tissues provided suturing without tension and additional vertical releasing incisions in GBR. Less traumatization caused a more favorable course of the postoperative period. The experimental group showed significantly higher values of horizontal (4.4 ± 0.11 mm) and vertical (4.07 ± 0.3 mm) radiographic bone gain after 6 months of GBR compared to control group ($p < 0.05$). The lowest values of bone resorption were also in this group on CBCT bone assessment 12-month post loading. The stability of dental implants reached high values (ISQ ≥70) in a shorter period in the experimental group.

Conclusion: Results of the study showed the effectiveness of self-inflating expanders for soft tissue augmentation before GBR and their positive influence on local microcirculation. However, further studies comparing different techniques of soft tissue and bone augmentation with different types of grafts should be carried out for a more complete evaluation of the effectiveness of self-inflating expanders.

Keywords: Alveolar Bone Atrophy, Guided Bone Regeneration, Dental Implant, Osseointegration, Tissue Expansion Device

Introduction

The success of guided bone regeneration (GBR) to a certain extent depends on the closure of the wound without tension. The lack of soft tissues in cases of alveolar ridge atrophy makes performing GBR more difficult and requires a special design of muco-periosteal flap (MPF). In cases of severe bone atrophy, significantly decreased blood flow negatively affects both the healing processes of soft tissues and the process of reparative osteogenesis of the transplanted graft (1-3).

It should be noted that there are four main principles of successful GBR, identified by Istvan A. Urban and Alberto Monje (4). One of these principles is the primary closure of the wound without tension to minimize the risk of membrane exposure and the creation of space to prevent tension, which is directly related to the mucosa of the recipient zone. It requires preliminary planning of the MPF design, enlargement of volume of the soft tissue, or in most cases, additional releasing incisions are needed to avoid tension during suturing.

The first expanders used in maxillofacial surgery were inflatable device to increase the volume of skin for the following plastic surgery. The usage of this type of device was then integrated into other fields of medicine including oral surgery and dental implantology. Inconveniences in the application and numerous complications led to the improvement of the expansion mechanism and the development of self-inflating soft tissue expanders. However, only a limited number of studies have been carried out in clinical cases, and few conclusive reports were available in the literature (5-7). In addition, there is no published research on the influence of soft tissue stretching on the local microcirculation of the alveolar ridge. Thus, all these factors make it necessary to conduct a more detailed research.

Materials and methods

Patient selection

A prospective randomized clinical trial was conducted at the Department of Maxillofacial Surgery of the clinic of the Tashkent State Dental Institute from September 2020 to November 2022 (Protocol No. 6/16-1578 from 27.09.2020). The team of specialists consisted of experienced implant specialists. Each of them had at least 5 years of continuous clinical experience. The inclusion criterion was partial edentulousness with atrophic alveolar ridge.

The exclusion criteria were as follows: 1) age under 18 and over 75 years; 2) complete edentulousness; 3) severe atrophy with a complete loss of the alveolar process; 4) smoking and poor oral hygiene; 5) pronounced bruxism; 6) severe uncontrolled periodontitis; 7) previous mucogingival and/or periodontal flap surgery, GBR history, implantation, etc. on the same site. The exclusion criteria also included pregnancy or lactation, decompensated chronic diseases, cancer, diseases of the hemostasis system, active therapy with anticoagulants, allergy to the used materials, active treatment by medication affecting bone metabolism (e.g., bisphosphonates, denosumab), inflammatory and autoimmune diseases, viral hepatitis, AIDS, and tuberculosis.

Study design (protocol No. 6/16-1578 from 27.09.2020)

The patients were divided into two groups by block randomization, depending on treatment strategy (with or without soft tissue expansion) in ratio 1:1.

Group 1 (control). Conventional GBR with a mixture of autograft (bone chips) from the retromolar region and Bone-D XB xenomaterial (MedPark, Busan, South Korea) in a ratio of 1:1.

Group 2 (experimental). Patients underwent preliminary soft tissue expansion of the recipient zone by inserting a hydrogel-type soft tissue expander TissueMax® (Osstem, Seoul, South Korea) before bone augmentation. Then GBR was conducted using the same graft material as in the control group.

Soft tissue expanders

Depending on the required volume of expansion of the soft tissue, 3 types of expanders TissueMax® (Osstem, Seoul, South Korea) were used: TEX007, TEX010, and TEX021. Each expander was inserted into a subperiosteal "pouch" prepared under local anesthesia. To make sure that the device was placed in the prepared place without tension, a special surgical template was used (Figure 1). The final expanded volume was assessed on day 28. The parameters (length, diameter, volume) of the removed expanders were compared with the data of manufacturer for each type of device used in this research.

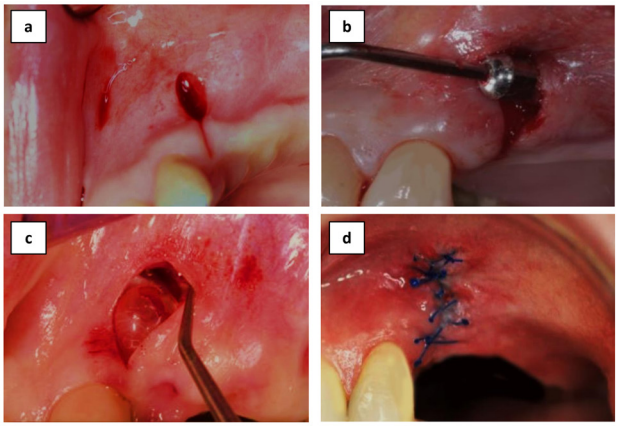

Figure 1: Clinical photos of the soft tissue expander insertion procedure (a-d)

Outcome measurements

The thickness of the attached gingivae was assessed with E-CUBE 9 Diamond (Alpinion medical systems®, Seoul, South Korea) ultrasound visualization system with a special intraoral sensor IO3-12 (3~12 MHz). Changes in the volume of the soft tissue expander and the thickness of the mucosa over the device were measured by evaluating the height and diameter during preliminary expansion at intervals of 3-5 mm followed by the calculation of the average values.

Microcirculation parameters were studied using laser doppler flowmetry (LDF) on device "LAKK-02" (Lazma, Moscow, Russia). Measurements were carried out before the insertion, after three days, after two weeks, and just before the extraction of the expander in patients of group 2.

Post-operative pain, local hyperemia, and collateral edema were evaluated during examinations.

Bone volume was recorded using CBCT on a Gendex GXCB-500 tomograph (KavoDental, Biberach, Germany) at the initial examination (before surgery), immediately following GBR, and 6 months after the GBR (before dental

implantation). The amount of bone augmentation was calculated by subtracting the parameters of the initial examination from those obtained immediately following GBR. The amount of bone retention was calculated by subtracting parameters got immediately after GBR from those obtained before dental implantation. The peri-implant marginal bone resorption after prosthetic loading was calculated using CBCT on the follow-up assessment 12 months after dental implantation.

A total of 96 dental implants TS III SA® (Osstem, Seoul, South Korea) were used. The Osstell ISQ (Osstell®, Göteborg, Sweden) device was used to determine the stability of dental implants at the stage of their installation (primary stability), when fixing the healing abutment (secondary stability), and post-loading.

Statistical analysis

The null hypothesis was that the mean values of bone gain and implant stability would be the same. Statistics and data plotting were performed in OriginPro 8.6 using Two-sample t-Test method of statistical analysis and comparison. A p-value less than 0.05 was considered statistically significant in this study.

Results

At the beginning, a total of 40 partially edentulous patients with atrophic alveolar ridge were included in the study. But two patients from the experimental group were excluded due to their unforeseen departure abroad. Thus, a total 38 patients (21 men and 17 women) participated in the study. Patients were 35-52 years old, with a mean age of 44.8 **±** 3.8 years (Table 1).

Table 1: Patient data

Parameters		Control (n=20)	Experimental (n=18)	Total (n=38)
Age		**44.5 ± 3.6**	**45.3 ± 3.8**	**44.8 ± 3.8**
Sex	**Male**	12	9	21
	Female	8	9	17
Location	**Maxilla**	8	6	14
	Mandible	12	12	24
Augmentation dimension	**Vertical**	10	9	19
	Horizontal	5	4	9
	Vertical & Horizontal	5	5	10

Effect of expander on soft tissue parameters

Patients from group 2 received 28-day preliminary soft tissue expansion before osteoplasty. According to control examinations, the process of expanding generally passed without complaints of discomfort and any sign of inflammation, rupture, or damage.

No statistically significant reduction in the thickness of the mucous membrane was observed after expansion on ultrasound examination (1.5 ± 0.08 mm before the insertion of the expander and 1.48 ± 0.09 mm after expansion ($p>0.05$)). This points to a minimal risk of divergence and traumatization of mucous membrane during the expansion.

After removing expanders, there were no signs of potential resorption on the bone surface of the recipient zone. It should be noted that all the extracted expanders were intact, without signs of the connective tissue capsule formation, violation of the silicone shell, and leakage of a hydrogel. The liquid inside all the expanders was transparent.

In addition, the final parameters (length, diameter, volume) were compared with the data in the manuals for each size of expander used in the research (Table 2).

In this study, expansion of the soft tissues obtained was, to some extent, smaller in size as compared to the parameters stated in the manuals by the manufacturer. The biggest increase in volume was observed in expanders of the TEX021 type (92.7% of the volume stated by the manufacturer). On average, the final parameters of the expanders were 90% of the ones stated in the manuals for each model. This should be taken into account during the process of treatment planning.

Suturing without tension was commonly achieved in group 2 without the need for additional vertical releasing incisions during GBR. In most patients from the control group, additional staggered dissections of the periosteum were needed in order to suture the wound without tension.

Dynamics of microcirculation parameters

The edentulous part of the alveolar ridge without a masticatory load indicates functionally inactive bone (8). Thus, the effectiveness of its microcirculation reduces due to a decrease in the intensity of blood flow and the involution of functionally inactive micro-vessels.

Table 2: Comparative characteristics of real changes in the size after expansion (M±m) and manufacturer parameters of soft tissue expanders

Types	L, mm		D, mm		V, mm³	
	clinic	manufacturer	clinic	manufacturer	clinic	manufacturer
TEX007 (n=7)	17,8 ± 0,66	20	6,26 ± 0,3	7	624,6 ± 3,87	700
	89%		**89,4%**		**89,2%**	
TEX010 (n=8)	19,4 ± 0,26	22	8,4 ± 0,18	9	1170 ± 6,5	1300
	88,2%		**93,3%**		**90%**	
TEX021 (n=8)	22,2 ± 0,19	24	10,2 ± 0,16	11	1947,3 ± 6,5	2100
	92,5%		**92,7%**		92,7%	

L, length; D, diameter; V, volume.

The initial parameters of laser doppler flowmetry (LDF) indicated a reduction in the level of blood flow (M) by 45%, its intensity (σ) by 60%, and the vasomotor activity of micro-vessels (Kv). Pulse fluctuations were higher than normal values by 12%. Compared to the symmetrical side, the vascular tone was decreased, indicating vasoconstriction. The deterioration of microcirculation is caused by a reduction in the chewing load in this area.

The indicators of microcirculation were re-measured on the 3rd day after inserting the expander. The values pointed to hyperemia and increasing blood flow intensity in response to surgery.

On the 28th day of the expanding, LDF indicated slight hyperemia in micro-vessels due to stretching effect of the expander.

The indicators of the blood flow level (M) approached the initial values, and the intensity of the blood flow (σ) increased by 1.3 times. The vasomotor activity of micro-vessels also increased by 45%, which was close to the initial values. Positive changes in microcirculation indicators were noted which were as close to normal as possible (Figure 2).

Characteristics of the postoperative period

Similar dynamics of pain and local edema were observed in both groups. Pain and local edema intensity indicators were close to average on the day of surgery. The severity increased and peaked on the 3rd day after GBR. The highest intensity of pain and local edema was registered in patients for whom additional releasing incisions were performed. Then, a gradual decrease in pain and collateral edema to complete absence were observed. It should be noted that in group 2 the pain and edema completely disappeared on the 10th day after surgery. The control patients had minor pain sensations and local puffiness on the 14th day after GBR (Figure 3).

The complications such as early wound dehiscence and decreased sensitivity were observed in the early post-operative period. The most probable cause of these sensorineural disorders was soft tissue ischemia due to collateral edema. The number of complications with their possible reasons is shown in Table 3.

In group 2, only one patient had hypoesthesia in the skin of the chin area for 9 days. It was conducted by compression of mental nerve due to local edema after GBR in the area of the premolars on the right side of the mandible.

In the control group, there were more cases of complications. In cases of early wound dehiscence, we re-sutured the wound to obtain primary closure. The wound healed completely, so these patients were not excluded from the study. The process of healing took more time and caused additional discomfort and prolonged pain syndrome with local edema.

The average healing time in group 2 was 11 ± 0.5 days, whilst in the control group, it was longer 14.5 ± 0.5 days.

A smaller soft tissue injury in GBR in the experimental group contributed to the fact that the pain and edema were less pronounced and post-operative wound healing was faster, compared with patients of the other groups.

Radiographic measurements after GBR

According to the results of CBCT, 6 months after the GBR, mean values of both horizontal and vertical parameters of bone decreased. This phenomenon is associated with the process of remodeling of bone graft and the partial loss of bone volume.

The control group showed lower values of bone retention in both horizontal and vertical measurements – 3.3 ± 0.12 mm (34.4 % reduction) and 2.7 ± 0.14 mm (40.9 % reduction), respectively. The experimental group showed significantly higher values of horizontal (4.4 ± 0.11 mm) and vertical (4.07 ± 0.3 mm) bone gain after 6 months of GBR.

No statistically significant difference was indicated in values of bone resorption of peri-implant marginal zone in both groups ($p > 0.05$) after prosthetic loading (Table 4).

Thus, group 2 showed better values of bone retention and low dynamics of resorption of graft. It means, that

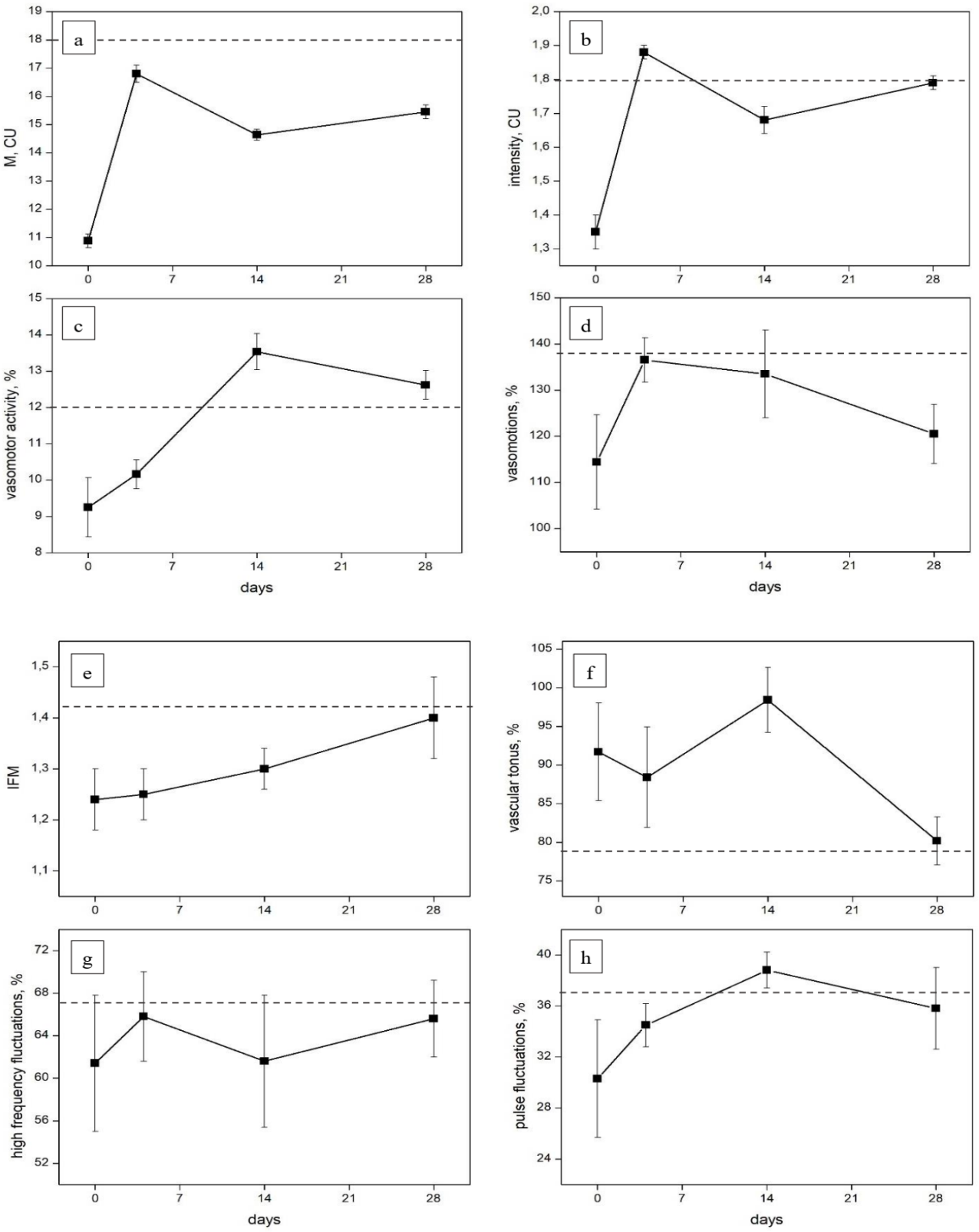

Figure 2: Most of the microcirculation parameters after 28-day expansion changed close to normal values. (a) Blood flow level (M) picked up on the 3rd day after insertion as a reaction to trauma; (b, c) Intensity of microcirculation and vasomotor activity increased and showed high values due to constant tension by expander; (d) Increased value of vasomotions indicated a high level of local blood supply caused by both trauma and expander; (e) Increase of index of flaxmotions (IFM) reflected improving the efficiency of local microcirculation regulation; (f) Gradual normalization of microvascular tone and blood supply; (g, h) Initial low parameters indicated obstructed venous outflow. Constant tension during expansion led to the enhancement of passive modulation of tissue blood flow and improvement of venous outflow.

* dashed lines show average normal values of indicators.

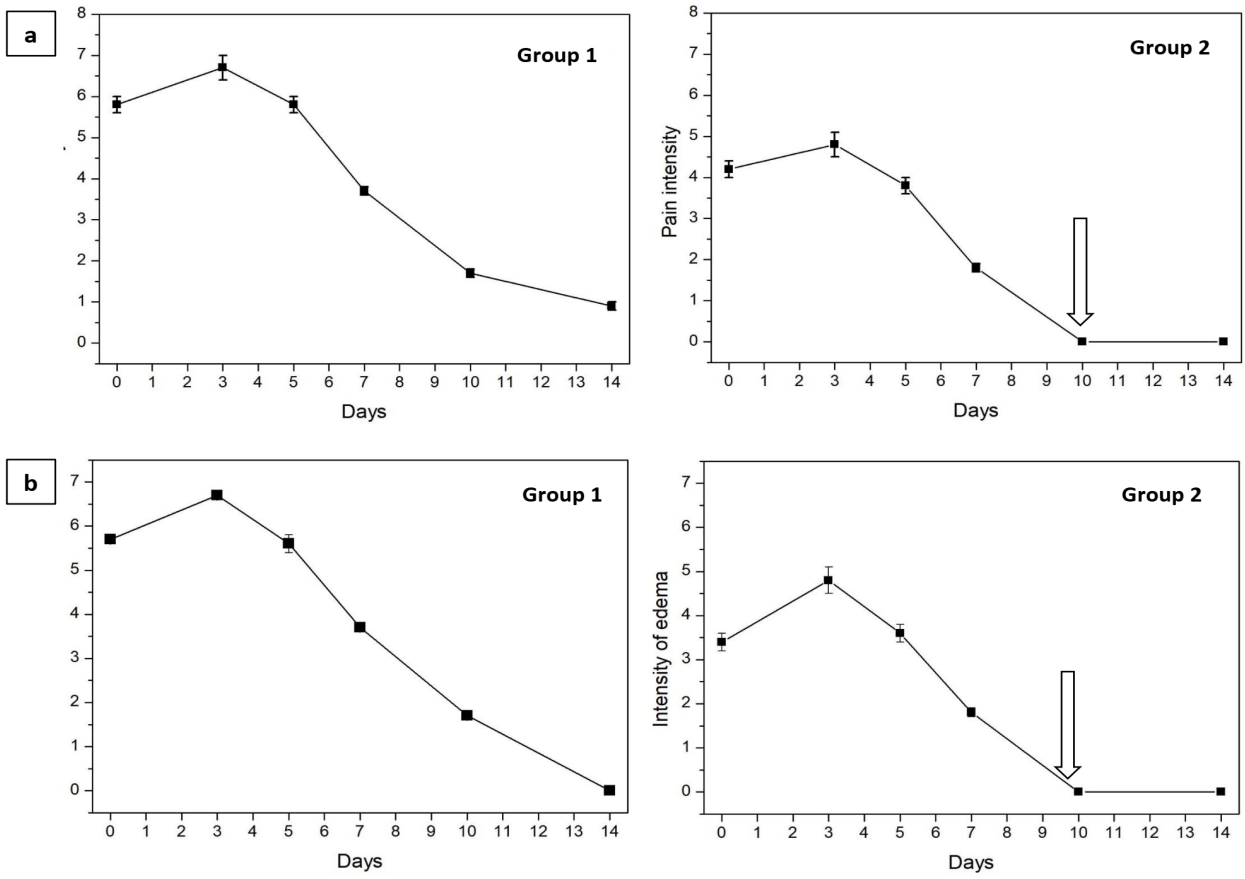

Figure 3: Pain (a) and local edema (b) intensity reduced faster in the experimental group after GBR due to less intraoperative trauma

Table 3: Complications in the postoperative period

Complication	Number of cases in groups		Reason	Outcomes
	control	experimental		
Early wound dehiscence	2	-	MPF tension Redundant graft Devascularization	Complete healing of the wound after re-suturing
Temporary hypoesthesia	4	1	Collateral edema Ischemia	Disappeared in 2-3 days after edema subsiding

the volume of reconstructed bone is more stable and the possibility of occurrence of uncontrolled resorption is much lower. This may provide effective functioning of the prosthesis.

The values of dental implants stability

The stability of dental implants was measured at different stages of the study. The higher indicators of primary implant stability were observed in patients of group 2 (76 ± 8 ISQ). The parameters conformed to medium (ISQ 60-64) and high (ISQ ≥70) stability. The lower values were found in group 1 (65 ± 8 ISQ).

By the stage of healing abutment fixation, the stability of dental implants increased in both groups. In the control group the mean value was 73 ± 7 ISQ, but the stability of dental implants in some patients was still medium (65-69 ISQ) according to the Osstell ISQ scale. The values of secondary stability were high in all patients of the experimental group (Figure 4).

The highest osseointegration was observed in patients of group 2 at all stages of measurements during the study. We indicated the high stability of dental implants in this group at the stage of fixing of healing abutment, while some patients of the control group showed medium values.

Table 4: Amount of augmentation and bone preservation

Parameters	control	experimental	p-value
Horizontal bone gain	4.9 ± 0.14	5.74 ± 0.11	0.018
Vertical bone gain	4.75 ± 0.16	5.85 ± 0.42	0.025
Horizontal bone resorption	1.57 ± 0.12 **(34.1 %)**	1.34 ± 0.22 **(23.3 %)**	0.032
Vertical bone resorption	2.01 ± 0.15 **(40.9 %)**	1.78 ± 0.12 **(30.4 %)**	0.041
Resorption in the peri-implant marginal zone	0.508 ± 0.097	0.454 ± 0.127	**0.095**

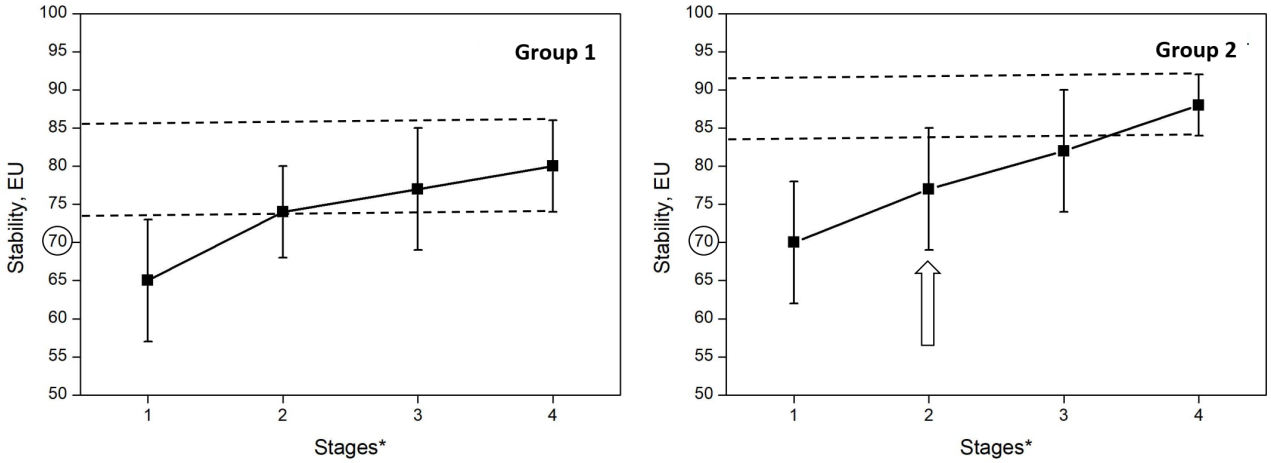

Figure 4: The values of dental implant stability were higher in the experimental: high osseointegration values were indicated at the stage of the fixing of healing abutment.

Osstell ISQ scale (https://www.osstell.com/clinical-guidelines/the-osstell-isq-scale/): ISQ <60 – low stability, ISQ 60-69 – medium stability, ISQ ≥70 – high stability.

* Time of measurement: 1 – primary stability (just after installation), 2 – secondary stability (at the stage of the fixing of healing abutment), 3 – at the stage of getting dental mold, 4 – at the stage of permanent prosthetic loading.

Discussion

The very first expanders used before GBR were made of silicone and filled weekly by injection of saline until the skin over the expander becomes pale. However, this technique of filling led to critical tension of tissue, hypoxia, followed by necrosis, and possible perforation of the device through the gingiva. Furthermore, regular injection of saline into the expander was inconvenient to use, because of the requirement of local anesthesia and the risk of infection (9, 10). Due to these shortcomings, this type of expander has not found wide application.

The soft tissue expander used in this study consists of methyl methacrylate and 1-vinyl-2-pyrrolidone in a semi-permeable silicone shell (membrane). The mechanism of expansion is based on the osmotic effect of hydrogel. The osmotic gradient causes a continuous flow of tissue fluid into the expander. As a result, the volume of the device increases with the accompanying growth of soft tissues. Gradual expansion of soft tissues without critical tension points to a minimal risk of divergence and traumatization of tissues (5, 7).

The first samples of osmotic tissue expanders assessed final volume in 60 days (10). These expanders were placed in a submucosal pouch to avoid possible bone resorption. In our study, the duration of expanding was 28 days. The short optimal period of expanding avoided the resorption of the underlying bone. In addition, an adequate expansion rate provided sufficient time for soft tissue adaptation which led to the preservation of its thickness and avoided mucosal perforations.

Another controversial issue is a fibrous capsule that forms around the expander due to the reaction to foreign body. This capsule may greatly complicate the process of expander removal and may cause additional trauma. The longer the time of expansion, the greater the probability of encapsulation. According to several clinical studies, subperiosteal expander after 3-4 weeks of expanding does not show any signs of the formation of connective tissue capsule (5, 7). The opposite opinion is that this capsule can protect the device and reduce the possibility of hydrogel breakdown into the surrounding tissues (11). In our study, there was no formation of a connective tissue capsule

around the device during the 28-day expansion period and the removal process was without any complications.

According to previous clinical trials, TissueMax® (Osstem, Seoul, South Korea) expanders result in enough enlargement of soft tissues (7). In our study, the expansion was less in volume compared to the values stated in manuals by the manufacturer. On average, the final size of the expanders was 90% of the values specified in the manuals for each model. This should be taken into account when choosing an appropriate size. However, following GBR, wounds were sutured without tension and additional releasing vertical incisions.

Gradual soft tissue enlargement had a positive influence on microcirculation parameters. Most of them came close to normal values during the expansion. The gradual stretching effect of the expander continued to stimulate blood flow in soft tissues. It also caused primary ischemia and degradation of periosteal cells with its rearrangement into connective tissue with a rich capillary network, which also had a positive effect on the results of bone formation and retention.

Soft tissue dehiscence following exposure to bone grafts and infection is one of the most common complications of bone augmentation. It leads to partial or complete loss of the graft volume (12, 13). In our study, soft tissue enlargement significantly reduced the number of post-operative complications and eliminated the need for additional laxative cuts. Subsequently, a smaller soft tissue injury in GBR led to less pronounced pain syndrome and edema. Post-operative wound healing rate was faster, compared with patients without preliminary expansion.

The choice of osteoplastic material significantly affects the results of augmentation. Although autogenous bone augmentation is considered to be a “gold standard”, it often shows uncontrolled bone resorption and loss of the volume of the graft (14-16). There are numerous clinical trials evaluating the effectiveness of using a combination of autogenous bone chips with xenograft. It is suggested that this technique might avoid uncontrolled bone resorption and autogenous bone chips could stimulate bone formation (15, 17). Thus, in this study the combination of autograft and xenograft was used in GBR. The lowest resorption rate was in the group with preliminary expansion. Adequate volume of soft tissue and suturing without tension resulted in positive conditions for bone formation. There were no statistically significant differences in values of bone resorption of the peri-implant marginal zone in all four groups after prosthetic loading ($p > 0.05$).

The quality of bone is one of the factors which affect osseointegration (18-21). In this study, the highest values of implant stability were in patients who had preliminary soft tissue expansion at all stages of measurements. These results observed the high quality of bone formation for optimal osseointegration and following prosthetic loading. In addition, high osseointegration values (ISQ ≥70) were indicated at the stage of fixing of healing abutment i.e. 3 weeks earlier compared with the other groups. It could be the basis for an earlier prosthetic loading and help to reduce the duration of treatment.

The augmentation of tissue to close the bone grafted areas can also be done with soft tissue grafts, e.g. free gingival graft, connective tissue graft etc. But these techniques are associated with additional traumatization and some complications. The choice of a particular technique and graft parameters (size and thickness) depends on the localization of the defect, and this requires certain skills and experience from the surgeon. It is also a well-known phenomenon that a graft duplicates its phenotype (of a certain donor zone) even after transplantation. This may lead to an unsatisfactory aesthetic result (22, 23). At this point STE is more optimal and might improve the outcome of treatment.

Conclusion

In conclusion, self-inflating expanders provide enough enlargement of soft tissues and normalize local microcirculation. Therefore, the use of this device has a positive effect on the outcomes of GBR and following dental implantation and minimizes side effects and complications such as bone resorption in cases of severe alveolar bone atrophy. Further prospective studies using different techniques of soft tissue augmentation and osteoplasty with various types of grafts should be carried out for a more complete evaluation of the effectiveness of self-inflating expanders.

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Ethical Clearance

We obtained ethical approval from the Ethical Committee of the Ministry of Health of the Republic of Uzbekistan (protocol No. 6/16-1578 from 27.09.2020). Informed consent was obtained from all patients in this study.

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Competing Interests

The authors declare that they have no competing interests.

References

1. Khoury F, Antoun H, Missika P, Bessade J. Bone Augmentation in Oral Implantology. 1st Ed. London, UK: Quintessence Pub Co. 2007.

2. Fu JH, Su CY, Wang HL. Esthetic soft tissue management for teeth and implants. J Evid Based Dent Pract. 2012;12(3 Suppl):129-42.
3. Zhao X, Zou L, Chen Y, Tang Z. Staged horizontal bone augmentation for dental implants in aesthetic zones: A prospective randomized controlled clinical trial comparing a half-columnar bone block harvested from the ramus versus a rectangular bone block from the symphysis. Int J Oral Maxillofac Surg. 2020;49(10):1326-34.
4. Urban IA, Monje A. Guided bone regeneration in alveolar bone reconstruction. Oral Maxillofac Surg Clin North Am. 2019;31(2):331-8.
5. Abrahamsson P, Isaksson S, Gordh M, Andersson G. Onlay bone grafting of the mandible after periosteal expansion with an osmotic tissue expander: an experimental study in rabbits. Clin Oral Implants Res. 2010;21(12):1404-10.
6. Tan WL, Wong TL, Wong MC, Lang NP. A systematic review of post-extractional alveolar hard and soft tissue dimensional changes in humans. Clin Oral Implants Res. 2012;23(Suppl 5):1-21.
7. Byun SH, Kim SY, Lee H, Lim HK, Kim JW, Lee UL, *et al.* Soft tissue expander for vertically atrophied alveolar ridges: prospective, multicenter, randomized controlled trial. Clin Oral Implants Res. 2020;31(7):585-94.
8. Kelendzheridze YM. The state of microcirculation in the periodontal tissues of the supporting teeth in the orthopedic treatment of a limited defect of the dentition. Dentistry = Stomatologiia. 2007;1:18-23. (In Russ.).
9. Wiese KG. Osmotically induced tissue expansion with hydrogels: a new dimension in tissue expansion? A preliminary report. J Craniomaxillofac Surg. 1993;21(7):309-13.
10. Kaner D, Friedmann A. Soft tissue expansion with self-filling osmotic tissue expanders before vertical ridge augmentation: a proof of principle study. J Clin Periodontol. 2011;38(1):95-101.
11. Shin H, Quinten Ruhé P, Mikos AG, Jansen JA. In vivo bone and soft tissue response to injectable, biodegradable oligo (poly(ethylene glycol) fumarate) hydrogels. Biomaterials. 2003;24(19):3201-11.
12. Canullo L, Malagnino VA. Vertical ridge augmentation around implants by e-PTFE titanium-reinforced membrane and bovine bone matrix: a 24- to 54-month study of 10 consecutive cases. Int J Oral Maxillofac Implants. 2008;23(5):858-66.
13. Burkhardt R, Lang NP. Role of flap tension in primary wound closure of mucoperiosteal flaps: a prospective cohort study. Clin Oral Implants Res. 2010;21(1):50-4.
14. Chiapasco M, Casentini P, Zaniboni M, Corsi E. Evaluation of peri-implant bone resorption around Straumann Bone Level implants placed in areas reconstructed with autogenous vertical onlay bone grafts. Clin Oral Implants Res. 2012;23(9):1012-21.
15. Temmerman A, Cortellini S, Van Dessel J, De Greef A, Jacobs R, Dhondt R, *et al.* Bovine-derived xenograft in combination with autogenous bone chips versus xenograft alone for the augmentation of bony dehiscences around oral implants: A randomized, controlled, split-mouth clinical trial. J Clin Periodontol. 2020;47(1):110-9.
16. Altiparmak N, Akdeniz SS, Diker N, Bayram B, Uckan S. Comparison of success rate of dental implants placed in autogenous bone graft regenerated areas and pristine bone. J Craniofac Surg. 2020;31(6):1572-7.
17. Janner SFM, Bosshardt DD, Cochran DL, Chappuis V, Huynh-Ba G, Jones AA, *et al.* The influence of collagen membrane and autogenous bone chips on bone augmentation in the anterior maxilla: a preclinical study. Clin Oral Implants Res. 2017;28(11):1368-80.
18. Nelson CE. Factors Affecting the Success of Dental Implants. In: Turkyilmaz I, ed. Implant Dentistry – A Rapidly Evolving Practice. London, UK: IntechOpen. 2011.
19. Vootla NR, Reddy KV. Osseointegration – Key factors affecting its success-an overview. IOSR J Dent Med Sci. 2017;16:62-8.
20. Krisam J, Ott L, Schmitz S, Klotz AL, Seyidaliyeva A, Rammelsberg P, *et al.* Factors affecting the early failure of implants placed in a dental practice with a specialization in implantology – a retrospective study. BMC Oral Health. 2019;19:208.
21. Sharma A, Singh R, Sharma S, Sahi Sh, Thakur V, Jamwal P. A review on "Factors affecting osseointegration in dental implants". Int J Appl Dent Sci. 2020;6(3):745-8.
22. Cardaropoli D, Casentini P. Soft Tissues and Pink Esthetics in Implant Therapy. 1st Ed. Batavia, IL: Quintessence Publishing Co, Inc. 2019.
23. Speroni S, Cicciu M, Maridati P, Grossi GB, Maiorana C. Clinical investigation of mucosal thickness stability after soft tissue grafting around implants: a 3-year retrospective study. Indian J Dent Res. 2010;21(4):474-9.