



ISSN NO. 2320-5407

Journal homepage: <http://www.journalijar.com>
Journal DOI: [10.21474/IJAR01](https://doi.org/10.21474/IJAR01)

**INTERNATIONAL JOURNAL
OF ADVANCED RESEARCH**

REVIEW ARTICLE

TISSUE EXPANDER – A REVIEW

Nur Liyana Hannah Binti Izham Akmal, Dr. Caroline Jacob

Manuscript Info

Manuscript History:

Received: 14 April 2016
 Final Accepted: 19 May 2016
 Published Online: June 2016

Key words:

Tissue expander, Tissue expansion,
 Implant, Soft tissue.

*Corresponding Author

**Nur Liyana Hannah Binti
 Izham Akmal,
 Dr. Caroline Jacob.**

Abstract

Aim:-

To review the history, evolution and indications of tissue expanders as a treatment modality to expand resorbed alveolar ridges.

Objective:-

To investigate the relevance and success of tissue expanders in alveolar ridge augmentation for future placement of a prosthesis.

Background and Reason:-

Inadequate regeneration of soft tissue or bone may cause problems for dental implant surgery in patients. Tissue expansion is a relatively direct procedure. A tissue expander is a balloon-shaped device with a smooth elastomer shell, used to provide enough soft tissue closure for final implantation. It is capable of self-inflating due to the presence of hydrogel that undergoes osmosis to increase its volume constantly until the predefined form and size are obtained, which stimulates the growth of soft tissue. This growth of additional soft tissue by controlled overstretching reforms any part of the body, including tissue regeneration or organ repair. In cases of ridge augmentation tissue expanders provide adequate soft tissue coverage for the implantation of missing teeth. Advantages include the ability to resurface wider defects with neighbouring skin that is similar in colour and texture, high biocompatibility, high rate of success and low risk of infection. This review discusses the application of tissue expanders in surgical procedures and its significance in the future of dentistry.

Copy Right, IJAR, 2016,. All rights reserved.

Introduction:-

Implants are gradually being considered as a routine treatment modality to replace missing teeth.^[1] In certain circumstances, a severely resorbed alveolar ridge complicates implant placement. This is managed by reconstructing the resorbed alveolar ridge which includes various techniques of bone or ridge augmentation that help to provide sufficient space for appropriate implant placement.^[2]

However, inadequate regeneration of bone and soft tissues may lead to various problems for such a procedure, which includes complications such as implant failure. A technique to avoid such a scenario is soft tissue expansion. Soft tissue expansion is a reconstructive surgical procedure that provides space for the development of additional skin, bone or other tissues due to resorption.^{[3] [4] [5]} This space is provided by the insertion of tissue expanders in the defect site, which allows the enlargement of soft tissues to provide the adequate soft tissue closure.^[6]

History of tissue expander:-

The idea for a self-inflating tissue expander was first described by Austad and Rose^[7] in 1982 who created a permeable silicone balloon filled with a concentrated sodium chloride (NaCl) solution. However, there were some major problems related to the use of the device. In the early stages of expansion, the balloon ruptured, releasing the hypertonic solution stored within, resulting in the necrosis of the overlying tissue. Moreover, the device required a long time to expand, which was about 8 to 14 weeks.^[8]

The use of tissue expanders prior to bone graft procedures has been reported in various studies by Lew et al. (1988)^[9], Wittkamp (1989)^[10] and Bahat and Handelsman (1991).^[11] Standard tissue expanders consisting of inflatable silicone balloons were used in all these studies, in which saline solution is injected into the expander until the skin above the expander appears pale. However, there were many issues related to the use of this tissue expander. A study done by Pietila (1990)^[12] resulted in a low tissue perfusion and hypoxia due to the presence of intraluminal pressure caused by the irregular filling method. A similar condition occurred in a study done by Wiese (1993)^[8], which lead to tissue necrosis, followed by perforation of balloon expander through the mucosa which increased susceptibility to infections due to penetration of the skin by percutaneous valve constructions.

Problems with the balloon and hypertonic solution were successfully overcome by K. G. Weise in 1993 who replaced the NaCl solution with hydrogel.^[8] The use of hydrogels proves advantageous, as it is a hydrophilic polymer solution, capable of inflating spontaneously by absorbing body fluid at a known rate of up to a volume that is 10 to 12 times larger than its initial size or volume.^[13] The hydrogel is inserted into the self-filling tissue expander easily without the need for external inflation.

In the field of dentistry, expansion of alveolar ridges can be done by various surgical procedures of augmentation, which include onlay grafts, vertical or horizontal ridge augmentation, autogenous bone block grafts, allogenic bone blocks and distraction osteogenesis.^{[14][15]} Tissue expansion is a modern procedure for the development of additional tissue without involving the transfer of the tissue flap^[16] while providing adequate amount of soft tissue for alveolar bone augmentation.

Device:-

A soft tissue expander is a silicone elastomer inflatable expander with a remote silicone elastomer injection dome.^[17] The expander is loosely bounded by a silicone envelope, which has an extension for the placement of a fixation screw and pores that allow fluid to reach the osmotic active hydrogel. The silicone envelope decreases in thickness after expansion due to stretching. The size of a tissue expander is large enough to overcome the expansive forces that exist to provide the required tissue augmentation on the resorbed alveolar ridge. A tissue expander is normally implanted below the muscles and is accessible by a syringe needle which is periodically used to inject sterile isotonic saline until the tissue expander attains the required dimension.^[18]

Advantages and disadvantages:-

Advantages^{[19][20][21]}:- In comparison to other techniques used for a similar procedure, tissue expanders provide more advantages which include:

1. A simple surgical procedure with minimal rate of complications and infections
2. Use of safe materials to provide similar color, sensation and texture as the adjacent tissues
3. Minimal risk of trauma and incisional scarring.
4. Short surgical period for reducing post-operative pain.
5. Low cost of surgery.
6. Involve remote incisions, smaller incisions and lesser incisions, which can be placed at a distance from the area of expansion to reduce the stress applied on the incision during expansion period and the risk of tissue expander extrusion.^[22]

Disadvantages:-

1. Temporary deformity during expansion and requirement for additional treatments due to complications arising from tissue expansion such as excessive post-operative bleeding and scarring.
2. Hypoxia may occur due to the quick expansion of tissue expander leading to high-pressure peaks.^[23]
3. Allergic responses due to the use of injected fluids or sutures, which may be incompatible to the patients
4. Infections may exist within the expander and this should be overcome by removing the implant.^[20]
5. Lack of tissues generated resulting in post surgical graft exposition and loss of grafted bone.^[24]

Indications and contraindications:-

Indications:- Tissue expansion is used in various surgical procedures that include:

1. augmentation of resorbed edentulous ridges^[25]
2. bone regeneration and onlay grafting procedures^[20]

3. intraoperative procedures in cleft lip repair surgery^[26]
4. treatment of decubitus ulcers with local flaps^[27]
5. development of post-auricular skin for external ear reconstruction surgery^[28]
6. extension of forehead skin for forehead flap total nasal reconstruction

Contraindications^[29]:- Tissue expansion is contraindicated in patients with:

1. psychological disturbances
2. active infections in the body
3. poor vascularization of tissue in the implantation area
4. systemic diseases such as diabetes mellitus, bacterial pneumonia, chronic liver disease, renal failure and hypertension^[30]

Types of tissue expander:-

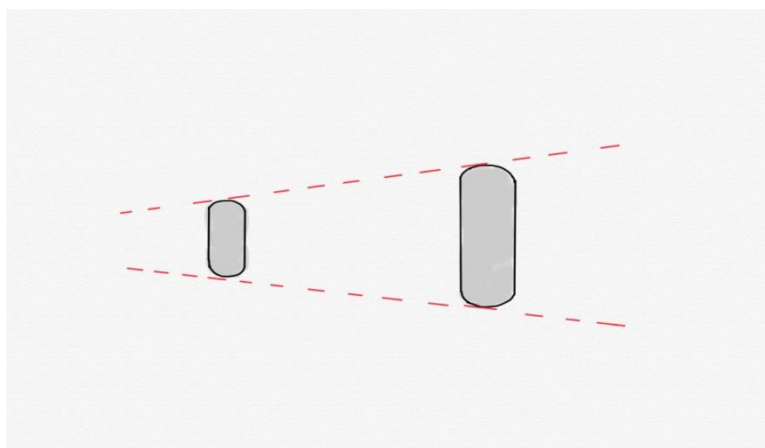
Tissue expanders mainly exist in two forms; cylinder and cupola. The cylinder-shaped tissue expander is normally used for straight edentulous regions while the cupola form of tissue expander is usually utilized for curved frontal edentulous region with one or more missing teeth.^[20]

Commercially available forms of tissue expander^[31]:-

TISSUE EXPANDERS	FEATURES	INDICATIONS
1) Standard Tissue Expander	- Normally circle, rectangle or crescent-shaped - It has a volume of 50cc to 1000cc	Indicated for tissue development to aid in: 1) reconstruction of breast after mastectomy 2) scar revision surgery 3) development of skin flap
2) Custom-built Expander	- Can be made with specific designations including the width, length and volume depending on the defect	Indicated for patients with ^[32] : 1) congenital abnormalities such as trauma and extremities. 2) skin pathology such as burns, vascular deformity, severe irregular scars and post-infection defects
3) Differential Expander	- Designed to expand more on one side compared to the other areas of the expander. - The thickness and elasticity of different part of the expander can be changed.	Indicated in ^[33] : 1) breast reconstruction surgery (post-mastectomy) 2) ear reconstruction surgery 3) nose reconstruction surgery
4) Anatomical Expander	- Temporarily used as a breast shaped extension of skin covering before being replaced by implants in breast reconstruction.	Indications include: 1) reconstruction of breast after mastectomy 2) scar revision surgery 3) reconstruction procedure for hypoplasia and tissue defects

Commercially available tissue expanders:-

TISSUE EXPANDER	MECHANISM	SPECIAL FEATURES
Osmed self-inflating tissue expander (Osmed GmbH, Germany)	It is covered by a perforated silicone shell to ensure that the flow of body fluid and continuous swelling of the expander occur under a controlled condition.	The gradual increase in size and volume of the expander stimulates the growth of additional soft tissues.
Mentor tissue expander (Mentor Worldwide LLC, Minneapolis)	Dacron-reinforced base allows directional expansion by providing a solid platform. Low risk of side-wall leakage due to its bottom-loading design. Presence of remote injection dome.	Used in breast reconstruction after mastectomy and reconstruction of facial features such as the lips, nose and eyelids. 4 shapes are available: round, rectangular, elliptical and crescent-shaped.
CUITM Brand Tissue Expander (Allergan, California)	Consists of a silicone elastomer envelope, a remote injection dome and a patented fill valve, which allows high rate intraoperative inflation. It is gradually inflated by injecting sterile saline solution at intervals until the required volume and size is obtained.	Temporarily used for the development of skin flap and reconstruction of a defect to provide adequate coverage of prosthetics.

Dimensions^[20]:-

Dimensions of tissue expander before and after expansion

Types of Tissue Expander	Before Expansion			After Expansion		
	Volume	Length	Diameter	Volume	Length	Diameter
Cylinder Dental 0.24 ml	0.045 ml	7.5 mm	3 mm	0.024 ml	12 mm	6 mm
Cylinder Dental 0.7 ml	0.15 ml	12 mm	4 mm	0.7 ml	20 mm	7 mm
Cylinder Dental 1.3 ml	0.25 ml	13 mm	5 mm	1.3 ml	22 mm	9 mm
Cylinder Dental 2.1 ml	0.42 ml	15 mm	6mm	2.1 ml	24 mm	10.5 mm

Surgical procedure:-**Implantation:-**

Under local anesthesia, a scalpel and scissors are initially used to make a small incision to create a submucosal patch without elevating the periosteum for easy insertion and removal of the tissue expander.^[24] Incision is normally made at a proper depth of 3 cm and wide enough to allow the expander to be placed bilaterally on either side of the defect area.^{[34][35]} Incision can also be made at a position away from the attached gingival margin of the tooth distal to the level of the bone, in order to form a passage on the lateral part of the defect area. The same incision can be done on the distal part of the area to be expanded to tunnel a suture, which provides stabilization of the expander. A longitudinal incision is normally made either on the palatal or lingual aspect of the expanded tissue to remove the expander after about two weeks.

This provides more benefits compared to subperiosteal placement of the expanders as the periosteum is not likely to expand. Instead, it is replaced by a network of connective tissues after the subperiosteal implantation of tissue expanders is completed, along with the formation of a new periosteum beneath the expander.^{[36][37][38]}

Significant resorption of underlying bone in subperiosteal implantation is also not seen with the use of this method. A tissue expander is then placed beneath the skin, adjacent to the area of defect. A bone fixation screw and continuous fine monofilament sutures are used to maintain the expander within the bone and skin respectively.^[39]

Self-inflating Stage:-

This stage takes about 40 to 60 days to complete, followed by its termination. The ability of the tissue expander to self-inflate is due to the kinetic action of the hydrogen swelling caused by the capillary rise of water and diffusion across the hydrogel. This occurs together with water diffusion into the polymer network under the influence of network relaxation and water-polymer interaction.^[24]

Post-operative Stage:-

Pain is a common symptom and wound management is done to ensure that the potential complications arising from the procedure are reduced or prevented. Administration of antibiotics, mainly amoxicillin 750 mg or clindamycin 600 mg is given 1 hour prior to surgery and continued for 7 days. In addition, Ibuprofen (400mg) is prescribed as an analgesic. Patients are advised for weekly follow-ups and given 0.2% chlorhexidine for rinsing until the suture is removed around 2 weeks after surgery. Expansion usually lasts about 6-8 weeks in order to reach its maximum volume and this is followed by bone augmentation.^[39]

Since tissue expanders are meant for temporary subcutaneous or submuscular implantation, it should not be used for more than six months and pre-existing infection should be treated before the implantation of the expander.

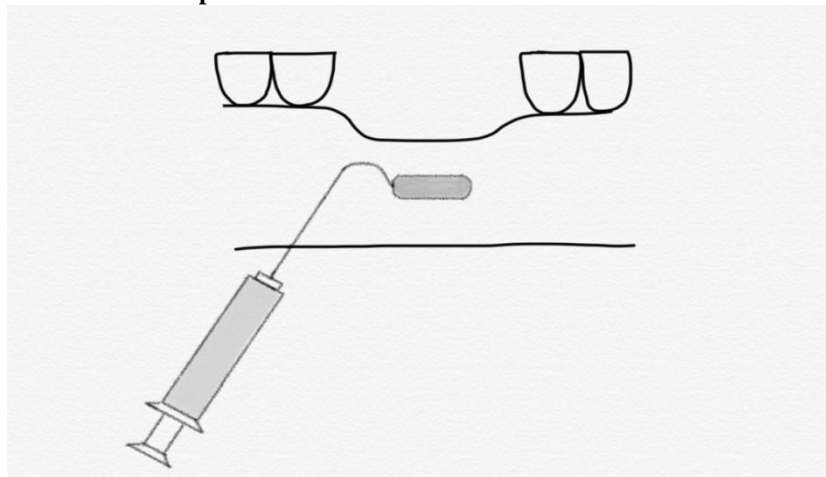
Mechanism of action – osmotic tissue expander^[40]:-

Figure 1 (a):- A surgical template is used before the placement of tissue expander.

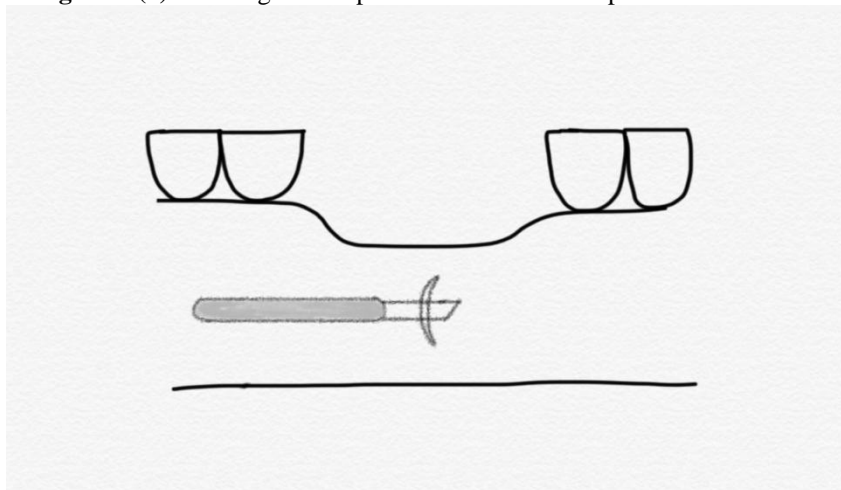


Figure 1 (b):- A small incision is made

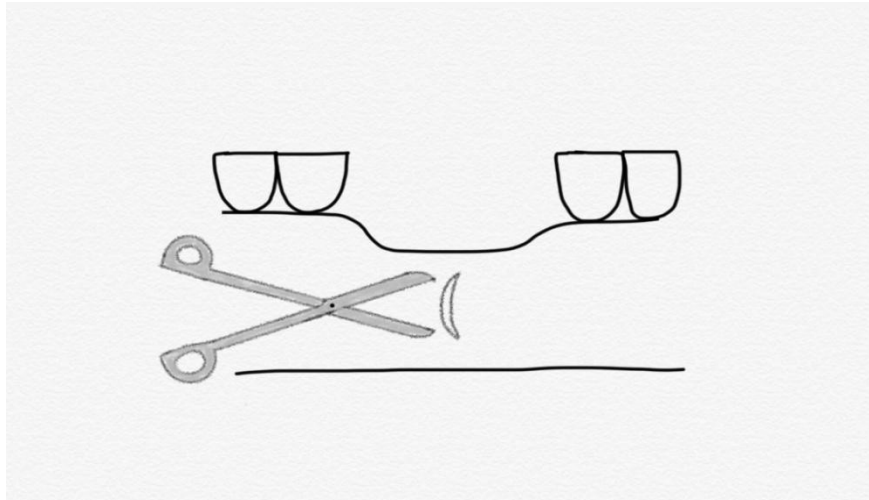


Figure 1 (c):- Scissor is used to make the incision bigger for the insertion of tissue expander

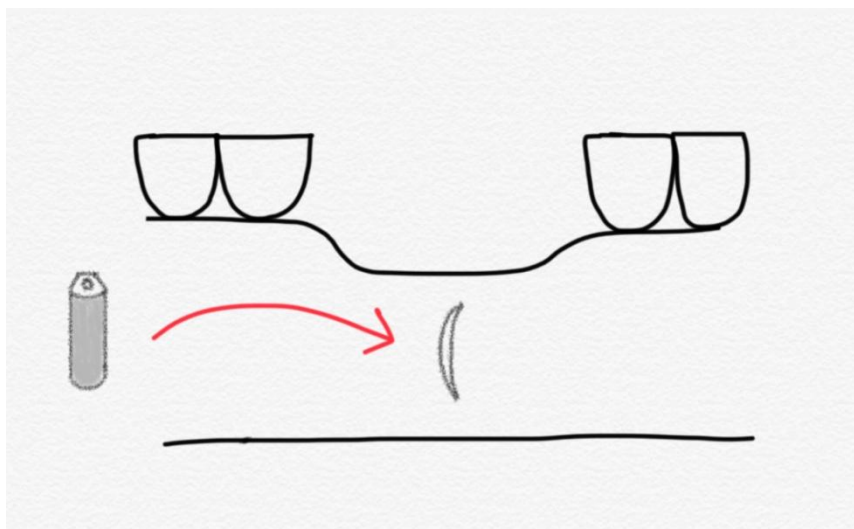


Figure 1 (d):- The tissue expander is inserted and fixed in its place using a screw.

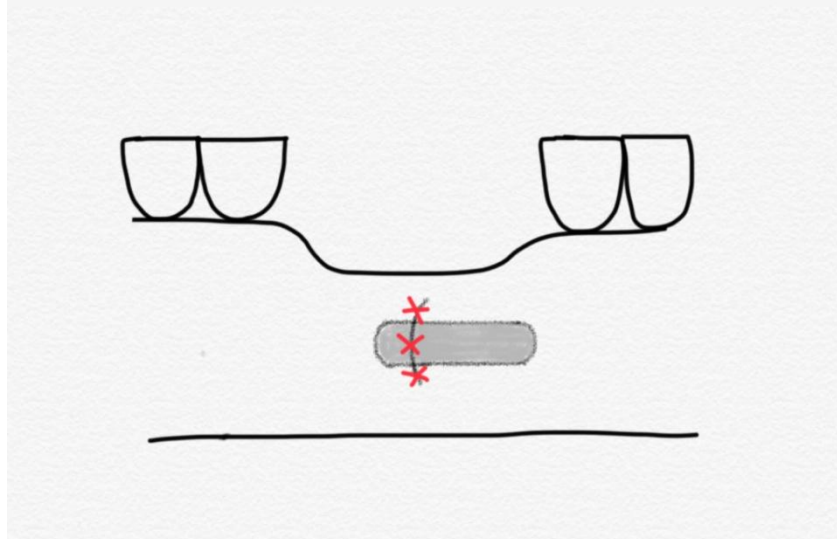


Figure 1 (e):- The incision is closed using fine sutures.

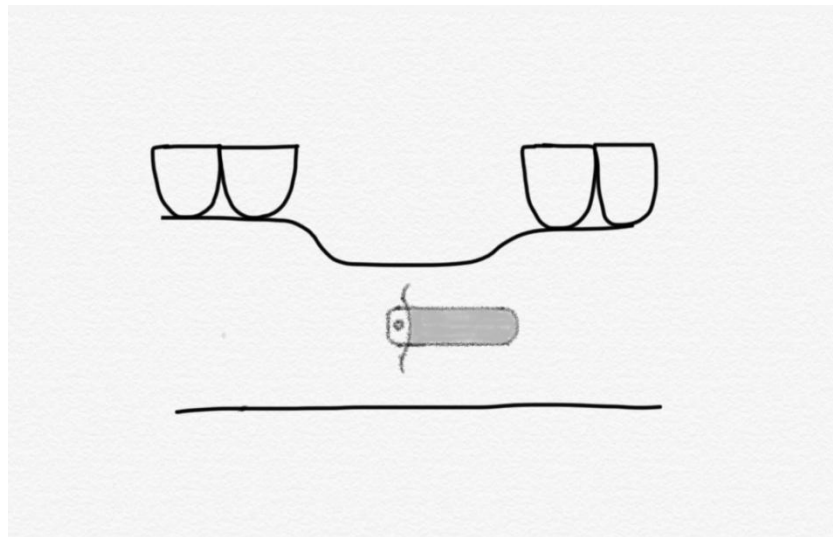


Figure 1 (f):- The tissue expander is left to expand.

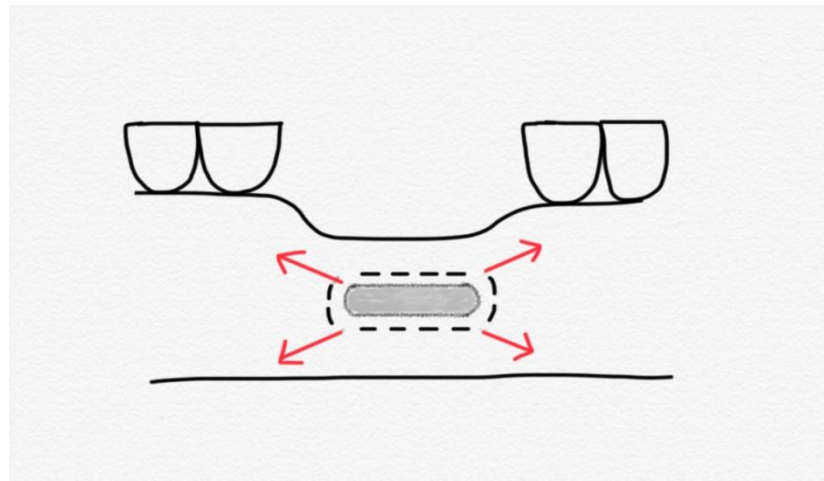


Figure 1 (g):- Autonomous growth of tissue expander.

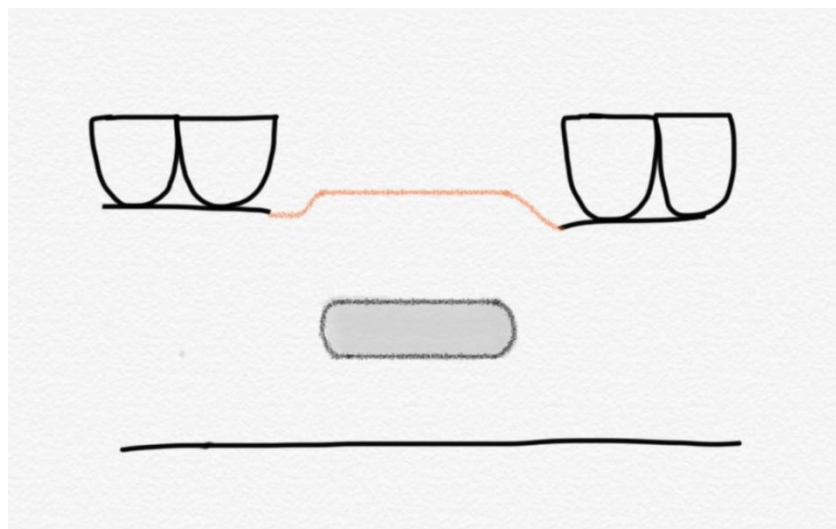


Figure 1 (h):- The tissue expander achieved the required volume.

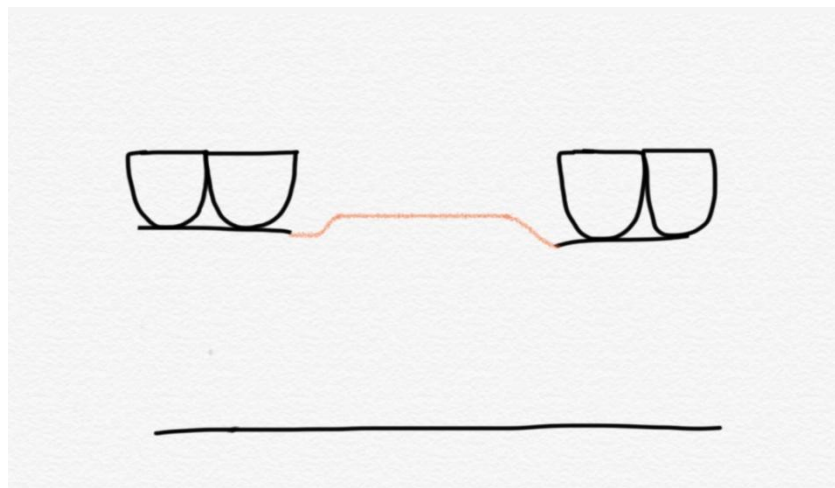


Figure 1 (i):- New soft tissue is created by the tissue expander.

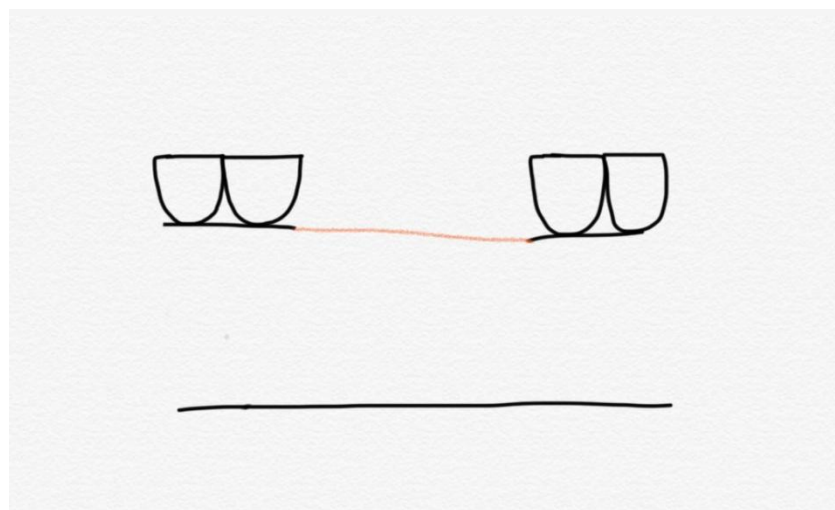


Figure 1 (j):- The area of defect is back to normal.

Related studies of tissue expander:-

Several studies have been performed by investigators related to the use of tissue expanders in various surgical procedures.

Park et al^[41] performed a study on two middle-aged women with severe bone resorption and ridge resorption. The first patient, aged 48 years old, was diagnosed with severe bone resorption after peri-implantitis with the removal of 3 implants caused by the disease. Vertical bone augmentation and soft-tissue expansion were done to overcome the severely resorbed ridge and three new implants were used to replace the previous ones. A tissue expander (cylinder type, 0.15 mL) was placed subperiosteally in the lower right posterior area and was secured by a micro screw. The expander was then left to expand from the initial 0.15 mL to 0.17 mL in volume for 6 weeks. It was followed by bone augmentation with composite bone graft and a successful implantation of 25 Ncm torque. The grafted bone became very rigid and intact after 6 months of its insertion. The adequate formation of soft tissue provided a tension-free closure of the augmented bone. The report stated that there was no complication observed as the area of defect was healing after the prosthetic treatment.

The second patient, aged 54 years old, was diagnosed with severe bone resorption on the right mandibular posterior area. The vertical height of the remaining alveolar bone was low and near to the inferior alveolar nerve, leading to difficulty for implantation. A buccolingual incision was made to form a pouch for the insertion of a tissue expander (0.045 mL). The expander was then left to expand from the initial volume of 0.045 mL to 0.24 mL for 3 weeks. The inferior alveolar nerve was repositioned in a nerve repositioning surgery. Successful implantation was done after

autogenous and xenogenic bone graft and tension-free tissue closure were obtained from the expansion of the self-inflating osmotic tissue expander. Effective healing was observed for both the implant and expanded soft tissue after one and a half years.

In another study done at University of Heidelberg, Germany,^[16] patients were diagnosed with acute bone atrophy of the maxilla or mandible, which required implant-retained rehabilitation involving bone augmentation procedures, either horizontally or vertically due to the insufficiency of the remaining bone. A small vertical incision was first made in the relation to the area of the atrophied bone, followed by a subperiosteal canal, which later formed a small pouch for the insertion of the tissue expander. A surgical template was used to measure the pouch dimensions, along with the volume and dimension of the expander from the initial phase to the final expansion phase. A tissue expander was successfully placed into the pouch and secured in its place using an osteosynthesis screw to avoid movement and dislocation of the expander during its expansion. Sutures were removed after 10 days of the surgery.

All patients described a slight pressure that was not painful in the operated area during the expansion stage. Complications were observed in two patients, in which the tissue expanders perforated through the oral mucosa. Treatment was done by removing the exposed tissue expanders and cleaning the soft tissue cavities, followed by suturing. Bone grafting procedure was later performed normally with periosteal releasing incisions for a sufficient soft tissue closure. The tissue expanders implanted in all the patients achieved similar texture, color and thickness without any symptoms of inflammation or thinning mucosa. The keratinized mucosa was normal after the expansion stage.

In a study by Biswas et al^[42], a 24 year-old female patient was aesthetically treated for a blue nevus on the left side of her face. A reconstruction procedure was done with the use of local tissues. A tissue expander was placed into a pocket with a subcutaneous tube for the insertion of saline. New tissue was successfully formed and repositioned on an incised area, followed by suturing to cover the area. The presence of lymphocyte, plasma cells, macrophages, eosinophils and multinucleated giant cells was observed around the blood vessels, adnexal structures and granulation tissue, indicating a successful implantation of the tissue expander.

Mertens et al^[43] conducted a study on the use of soft tissue expander prior to bone augmentation, along with the possible complications resulting from the procedure. 12 patients between 21 to 73 years old were selected with resorbed edentulous or partially edentulous ridges, to be treated by vertical bone augmentation for placing dental implants. Soft tissue expanders were placed in 24 surgical sites during vertical bone augmentation, followed by onlay grafting after two months of the implantation. Dental implants were then placed after approximately 4 to 6 months of bone augmentation. The results were examined using cone-beam computed tomography (CBCT) while micro-computed tomography (micro-CT) was used for bone biopsies. The procedure was considered successful as primary wound closure was easily done with low rate of graft exposures during bone augmentation after the placement of the soft tissue expander. The CBCT measurement tool displayed high mean vertical bone gain (7.5 ± 2.4 mm) before implantation. The required bone or tissue volumes were obtained with dense network of connective tissue and no infiltration. The implants osseointegrated as there was no relative movement between the implant and the bone, which were in direct contact. It was concluded that both the placement of soft tissue expander and the following vertical bone augmentation lead to successful implantation with minimal rate of complications. A total of 53 implants with approximately 1 to 19 implants for one patient were successfully placed as intended without the need for further grafting.

However, there were some complications with the treatment during expansion and healing stages. Perforation of the tissue expander through the mucosa was observed in two patients due to the presence of a seroma and infections after 4 weeks of implantation. It may also be due to the use of incompatible tissue expander on the area of defect. The tissue expanders were removed and retreated using smaller expanders with higher compatibility. Development of fistulae was also seen after the seroma was formed prior to bone augmentation, which was treated using tetra-cycline/cortisol paste. Presence of paraesthesia in the mental region was observed in one patient after ramus graft augmentation but it naturally resolved after 4 months. A minor exposition in the posterior part of maxilla could also be seen after vertical augmentation but it naturally healed following debridement and after applying chlorhexidine gel frequently.

Future of tissue expanders:-

The use of a tissue expander is seen to be an effective method in developing the required amount of tissue after a surgical procedure as it provides adequate tissue coverage and aesthetics.^[36] Tissue expansion involves a simple

procedure, which can also be done by novice surgeons. The use of self-inflating or osmotic tissue expander has started to gain attention in various surgical procedures due to its numerous advantages that can overcome problems such as the loss of bone graft and disclosure of graft.

Recent advances in tissue expander technology have made it easier for successful implantation of bone grafts or synthetic grafts and development of tissue with matching color and texture to the area of defect. Based on the current responses of patients for the restoration of aesthetics, form and function, the tissue expander is expected to play an important role in intra oral tissue reconstruction in the future.

References:-

1. American Academy of Periodontology. Parameter on placement and management of the dental implant. J periodontol. 2000;71:870-2
2. Sanan A & Haines SJ. Repairing holes in the head: A history of cranioplasty. Neurosurgery 1997; 40: 588 – 603.
3. Argenta LC - Tissue expansion. In: Aston SJ, Beasley RW & Thorne CHM - Plastic Surgery. 5th ed. New York, Lippincott-Raven, 1997. p.91.
4. Radovan C - Tissue expansion soft-tissue reconstruction. Plast Reconstr Surg, 1984; 74:482.
5. Iconomou TG, Michelow BJ & Zuker RM - Tissue expansion in the pediatric patient. Ann Plast Surg, 1993; 31:134.
6. Dogan Kaner, Han Zhao, Hendrik Terheyden, Wolfgang Arnold, Anton Friedmann, Effect of soft tissue expansion on microcirculation and healing after vertical augmentation in dogs. grant 687-2010
7. Austad ED, Rose GL. A self-inflating tissue expander. Plastic and reconstructive surgery. 1982 Nov 1;70(5):588.
8. K.G.Wiese. Osmotically induced tissue expansion with hydrogels: a new dimension in tissue expansion? Journal of Cranio-Maxillofacial Surgery October 1993, 21(7); 309-313.
9. Lew, D., Amos, E. L. & Shroyer, J. V. III (1988) The use of a subperiosteal tissue expander in rib reconstruction of an atrophic mandible. Journal of Oral & Maxillofacial Surgery 46, 229–232.
10. Wittkampf, A. R. (1989) Short-term experience with the subperiosteal tissue expander in reconstruction of the mandibular alveolar ridge. Journal of Oral & Maxillofacial Surgery 47, 469–474.
11. Bahat O, Handelsman M. Controlled tissue expansion in reconstructive periodontal surgery. Int J Periodontics Restorative Dent. 1991;11:32–47.
12. Pietilä JP. Tissue expansion and skin circulation. Scandinavian Journal of Plastic and Reconstructive Surgery and Hand Surgery. 1990 Jan 1;24(2):135-40.
13. Wichterle O, Lim D. Hydrophilic gels in biologic use. Nature 1960; 185:117.
14. Roccheita I, Fontana F, Simion M. Clinical outcomes of vertical ridge augmentation to enable dental implant placement: A systematic review. J Clin Periodontol. 2008;35:203–15. [PubMed]
15. Esposito M, Grusovin MG, Felice P, Karatzopoulos G, Worthington HV, Coulthard P. Interventions for replacing missing teeth: Horizontal and vertical bone augmentation techniques for dental implant treatment. Cochrane Database Syst Rev. 2009;4:CD003607. [PubMed]
16. Mertens, Christian, et al. "The Use of Self-Inflating Soft Tissue Expanders Prior to Bone Augmentation of Atrophied Alveolar Ridges." Clinical implant dentistry and related research 17.1 (2015): 44-51.
17. G.Harini, DR.G.Kaarthikeyan. Periodontal Soft Tissue Expanders - A Review. IOSR Journal of Dental and Medical Sciences Volume 13, Issue 1 Ver. VII. (Jan. 2014), PP 31-3518.
18. Wiese KG, Heinemann DE, Ostermeier D, Peters JH. Biomaterial properties and biocompatibility in cell culture of a novel self-inflating hydrogel tissue expander. J Biomed Mater Res. 2001;54:179–188.
19. Austad ED, Rose GL. A self-inflating tissue expander. Plast Reconstr Surg. 1982 Nov. 70(5):588-94.[Medline].
20. Hallock GG. Tissue Expansion Techniques to Minimize Morbidity of the Anterolateral Thigh Perforator Flap Donor Site. J Reconstr Microsurg. 2013 Jun 19. [Medline].
21. Pasyk KA, Austad ED, McClatchey KD, Cherry GW. Electron microscopic evaluation of guinea pig skin and soft tissues "expanded" with a self-inflating silicone implant. Plast Reconstr Surg. 1982 Jul. 70(1):37-45.[Medline].
22. Sharobaro V I, Moroz V Y, Starkov Y G, Strekalovsky V P. First experience of endoscopic implantation of tissue expanders in plastic and reconstructive surgery. Surg Endosc. 2004;18:513–517. [PubMed]

23. Henri J.J.Uijlenbroek, Yuvelian Liu, Jian Feng He, Cornie Visscher, Marinus A.J. van Waas, Daniel Wismeyer, Expanding soft tissue with Osmed tissue expander in goat maxilla, Department of Oral Implantology and Prosthodontics. 13 April 2010. doi:10.1111/j.1600-0501.2010.01972.x.
24. Prasad Vijayrao Dhadse, Ramareddy Krishnarao Yeltiwar, Manohar Laxmanrao Bhongade, Sunil Dattuji Pendor. Soft tissue expansion before vertical ridge augmentation: Inflatable silicone balloons or self-filling osmotic tissue expanders? . Journal of Indian Society of Periodontology aug 2014; 18(4).
25. "Osmed - Self-inflating Hydrogel Tissue Expander - Self-inflation by Osmotic Principle." Osmed - Self-inflating Hydrogel Tissue Expander - Self-inflation by Osmotic Principle. Web. 04 Mar. 2016.
26. Sagehashi N. Cleft lip repair by soft-tissue expansion. *Ann Plast Surg.* 1992 Aug. 29(2):164-8; discussion 168-9. [Medline].
27. Esposito G, Di Caprio G, Ziccardi P, Scuderi N. Tissue expansion in the treatment of pressure ulcers. *Plast Reconstr Surg.* 1991 Mar. 87(3):501-8. [Medline].
28. Kludt NA, Vu H. Auricular reconstruction with prolonged tissue expansion and porous polyethylene implants. *Ann Plast Surg.* 2014 May. 72 Suppl 1:S14-7. [Medline].
29. "Tissue Expansion ." Tissue Expansion: Introduction and History, Physiology, Indications. Web. 12 Mar. 2016.
30. Li X, Kolltveit KM, Tronstad L, Olsen I. Systemic diseases caused by oral infection. *Clinical microbiology reviews.* 2000 Oct 1;13(4):547-58.
31. Wagh, Milind S., and Varun Dixit. "Tissue expansion: Concepts, techniques and unfavourable results." *Indian journal of plastic surgery: official publication of the Association of Plastic Surgeons of India* 46.2 (2013): 333.
32. Majdak-Paredes EJ, Shafighi M, Fatah F. Custom-made tissue expanders in reconstructive surgery for challenging skin defects. *European Journal of Plastic Surgery.* 2013 Jan 1;36(1):13-20.
33. Connell A, inventor; Connell Anthony F, assignee. Differential Tissue Expander Implant. United States patent application US 10/558,805. 2004 May 26.
34. Bonomo DJ. Subperiosteal tissue expander for ridge augmentation. *CDS Review.* 1986;79:34-9.[PubMed]
35. Wilson TG, Kornman KS, Newman MG. *Advances in Periodontics.* Singapore: Quintessence Publishing Co Inc; 1992. Esthetic reconstruction of alveolar ridge defects.
36. Tominaga K, Matsuo T, Kuga Y, Mizuno A. An animal model for sub periosteal tissue expansion. *J Oral Maxillofac Surg.* 1993;51:1244-49. [PubMed]
37. Stuehmer C, Rucker M, Schumann P, Bormann KH, Harder Y, Sinikovic B, et al. Osseous alterations at the interface of hydrogel expanders and underlying bone. *J Craniomaxillofac Surg.* 2009;37:258-62.[PubMed]
38. Muller R, Van Campenhout H, Van Damme B, Van Der Perre G, Daquekar J, Hildebrand T, et al. Morphometric analysis of human bone biopsies: A quantitative structural comparison of histological sections and microcomputed tomography. *Bone.* 1998;23:59-66.[PubMed]
39. Kaner, Doğan, and Anton Friedmann. "Soft tissue expansion with self-filling osmotic tissue expanders before vertical ridge augmentation: a proof of principle study." *Journal of clinical periodontology* 38.1 (2011): 95-101.
40. Dhadse, Prasad Vijayrao, et al. "Soft tissue expansion before vertical ridge augmentation: Inflatable silicone balloons or self-filling osmotic tissue expanders?." *Journal of Indian Society of Periodontology* 18.4 (2014): 433.
41. Sung Ho Pak, Sung Keun Choi, Jin Hyun Jang, Jin Woo Kim, JiYoun Kim, Myung Rae Kim et al. Self-inflating oral tissue expander for ridge augmentation in the severely atrophic mandible. *J Korean Association Oral Maxillofacial Surgery* 2013; 39: 31-34.
42. Biswas, B. K., S. Pal, and S. Bag. "Clinical efficacy of an indigenously developed tissue expander."
43. Christian Martins, Oliver Thiele, Michael Engel, Robin Seeberger, Jügen Hoffman, Kolja Freier. The use of Self-Inflating soft tissue expanders prior to bone augmentation of atrophied alveolar ridges. *Clinical Implant Dentistry and Related Research* 2013