ORIGINAL ARTICLE

Periosteal expansion of rabbit mandible with an osmotic self-inflatable expander

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Abstract
We aimed to evaluate a new technique for intraoral expansion of soft tissue with a self-inflatable expander in rabbits. We placed a self-inflatable soft tissue expander bilaterally in eight rabbits under the periosteum of the mandible through an extraoral approach. The expander was left to self-inflate for two weeks, after which the animals were killed and specimens collected for histological examination. The self-inflatable soft tissue expanders expanded the periosteum. There were no dehiscences or infections. Histological observations showed no signs of any inflammatory reaction and there was no evidence of bony resorption. New bone had formed at the edges of the expanded periosteum. In the control area no new bone had formed. The osmotic soft tissue expander model for intraoral soft tissue and periosteal expansion suggests a promising way of creating a surplus of soft tissue that can be used to cover bone grafts.

Key Words: Oral, soft tissue, self inflatable expander

Introduction
Radovan [1,2] described tissue expansion as a method of creating soft tissue that permitted normal colour, texture, thickness, and sensation with minimal scarring and little donor site morbidity. Soft tissue expansion is often used for the reconstruction of defects [3–6], whereas tissue expansion is primarily used in breast reconstruction. Complications of soft tissue expansion have been described, and the most common are infection, dehiscence, haematomata, and failure [5–7]. These are best avoided by keeping the incisions small and as distant from the expander and the port as the site permits [2,4,8]. It is to avoid some of these problems with the conventional expander that a self-inflatable expander has been assessed [9,10].

Wherever possible new tissue should be created with the same colour and texture as adjacent skin, which was first described in 1957 for ear reconstruction by Neumann [11]. In the head and neck area the scalp in particular has been successfully reconstructed with expansion of soft tissue [8,12,13]. Noses and ears have also been successfully reconstructed by soft tissue expansion [14].

Intraoral soft tissue expansion has also been used to create a surplus of soft tissue for later reconstruction with a bone graft, or bone substitutes [15–17]. The possibility of creating soft tissue for covering a bone graft in craniofacial surgery has been described by Argenta and VanderKolk [14]. Further intraoral soft tissue expansion has been described in cleft lip in rabbits where a positive effect was seen on midfacial growth, using soft tissue expansion to reduce postoperative pressure of the lip [18].

To minimise complications an extraoral method has been attempted to place a soft tissue expander in resorbed edentulous mandible [19], but to our knowledge no publications have been found for intraoral use of a self-inflatable expander.

The purpose of this study was to evaluate a new technique for intraoral soft tissue expansion with a self-inflatable expander in rabbits.
Materials and methods

This study was approved by Malmö/Lund ethics committee for animal research.

Eight adult Swedish loop rabbits, one female and seven male were used, weighing 3.2-4.0 kg. The self-inflatable soft tissue expander was a custom-made device provided by Osmed (Ilmenau, Germany). This expander consisted of an osmotic active hydrogel, a vinyl pyrrolidone, and methylmethacrylate, surrounded by a perforated silicone envelope. The initial size of the hydrogel was $2.5 \times 7.5 \times 3.0$ mm (Figure 1a). The size after maximal swelling was $5.6 \times 11 \times 6.0$ mm (Figure 1b). The number and size of the perforations in the surrounding silicone envelope adjusted the expansion speed (Figure 2). The silicone envelope had a flat end to permit fixation of the expander to the bone, which prevents the expander from moving while it is expanding.

The rabbits were anaesthetised with ketamine/medetomidine hydrochloride (Ketalar®/Domitor®) 25 mg/kg and 0.5 mg/kg by intramuscular injection. To reverse the Domitor® effect, atipamezole hydrochloride (Antisedan®) was used. Lidocaine 1 ml (20 mg/ml) and adrenaline (12.5 µg/ml), were infiltrated into the lateral border of the body of the mandible.

The skin at the lower border of the mandible was shaved and disinfected with 70% ethanol. A skin incision was made bilaterally (roughly 15 mm) at the lower border of the mandible followed by blunt dissection to the periosteum. The periosteum was cut in the direction of the lower border of the mandible and then raised towards the alveolar crest. The base of the expander was fixed to the lateral border of the mandible with a 1.5 mm titanium screw (Figure 3). The periosteum, fascia, and skin were sutured in layers with 4-0 polyglactin 910 (Vicryl®). The expander was placed away from the suture line in the pocket created under the periosteum, so there were no problems closing the tissues. The control area, which was not expanded, was the flat end where two layers of silicone were applied, with no hydrogel, extending 5 mm from the expanding area. Intake of water and solid food was recorded daily and the animals were weighed every other day. After two weeks, the animals were killed by induction of tiopentalnatrium (Pentothal®) 2.5 g in a 2.5% solution followed by an overdose of pentobarbital 100 mg/ml given intravenously.

Assessment of soft tissues after expansion

Specimens of soft tissue and bone were collected and soaked in 10% buffered formalin. They were embedded in methyl methacrylate, sectioned in a cutting and grinding procedure, EXAKT system procedure, to obtain samples of calcified bone. Goldner staining was used. All sections were examined under a light microscope. A pathologist, not a member of the research team, made the histomorphometric analysis.

Results

Clinical

For seven rabbits the operation and healing was uneventful; these rabbits resumed normal diet during the 24 hours after the operation, and gained weight during the two postoperative weeks (0.15–0.41 kg). One rabbit died before operation from an overdose of general anaesthetic. There were no signs of wound infection or dehiscence.

Histology

The cross-sectioned area of bone, soft tissue, and expander were examined histologically. No signs of inflammation were found around the expander. In six rabbits the periosteum had expanded on both sides. On the edges where the periosteum was slowly raised, new bone had been formed by the periosteal distraction (Figure 4a). In one rabbit the expander had failed on one side. This expander (presumably

Figure 1. (a) Expander with active hydrogel (H) surrounded by silicone shell (S). Flat silicone end (F) is for fixation with a titanium miniscrew. Scale (mm). (b) Hydrogel without silicone shell before (A) and after (B) expansion. Scale (mm).
herniated through the periosteum) did not raise the periosteum, and instead created a pocket over the periosteum that resulted in soft tissue expansion, but no formation of new bone. At the sites of the other 13 expanders the periosteum was intact. All 14 devices produced expansion of tissue and the height was measured in the histological specimens. The mean end height was 5.5 mm (5.2-5.8 mm). All expanders were covered by a collagen-rich capsule. There were no signs of bony resorption as a result of pressure from the expander.

In the control areas, with flat silicone and the titanium screw, the periosteum remained flat and no new bone formed (Figure 4b).

Discussion

Previous publications on intraoral soft tissue expansion in humans have included few patients with no long term follow-up [15-17]. To find a more predictable way of expanding intraoral soft tissues, a pilot study was started, but not published. In this study a self-inflatable expander was used for 14 days in five rabbits. In two rabbits a bone graft was placed after expansion and left for 12 weeks. This showed that the rabbit model was appropriate for intraoral soft tissue expansion and later bony augmentation.

An extraoral approach was used to gain access to the mandible of the rabbit. Complications such as intraoral dehiscence were avoided by keeping the incision small and away from the expander, as in other reports [8]. As the expander is quite small it was easy to place it under the periosteum away from the incision line. It was also possible to close the periosteum, as the expander is flat.

If one uses an osmotic self-inflatable expander it is not necessary to use a filling port. The method is also cost effective, as there is no need to fill the expander repeatedly. A disadvantage is that the expansion rate is not adjustable after it has been inserted. The expansion rate has been minimised by the use of a silicone shell and few perforations. The rate of expansion was slow enough not to cause any perforation of the soft tissue. None of our rabbits showed any signs of postoperative infection and all the expansion devices worked as planned, possibly because an extraoral approach left the oral mucosa intact.

All expanders were covered by a collagen rich capsule. Histological analysis of expanded skin in dogs showed thickening of the epidermis and thinning of the dermis, and a fibrous capsule around the expander. The main component of the capsule is collagen fibres [20]. We identified no capsule between the expander and the bone. The space created between the bone and the raised periosteum can be filled with a bone graft.

Figure 2. Expansion rate of hydrogel in vivo with and without surrounding silicone envelope in 0.9% sodium chloride.

Figure 3. Self-inflatable expander (S) with flat silicone end (F) fixed to the bone with a titanium miniscrew.
A titanium screw was used to fix the expander to the alveolar bone to avoid migration of the device during expansion. Histological evaluation showed that the soft tissue expanders raised the periosteum and, at the margins, where the soft tissue had been raised least, new bone had formed. The slow lifting of the periosteum creates new bone as seen in periosteal distraction [22–23]. The fixation area of the expander is a flat junction of two layers of silicone with no expanding capacity, and in this area where no periosteum was expanded, no new bone was formed. During expansion one device migrated and ended supraperiostally, resulting in soft tissue expansion without expanded periosteum and no bony formation. This shows how important it is to place the expander in the right plane.

There is often need for intraoral soft tissue expansion in the anterior maxillar region where patients have high aesthetic demands. Reconstruction of lost tissue, such as before implants, is necessary for a satisfying aesthetic result.

Trauma to the face resulting in loss of bone and soft tissue, will result in a bony defect covered by scar tissue. Such defects are difficult to reconstruct and the lack of soft tissue can compromise coverage of a future bone graft. In a cleft lip in a rabbit, Edington et al. [18] created soft tissue expansion that reduced the limiting effect of scar tissue on midfacial growth. With a soft tissue expander it is proposed that compromised soft tissue could be expanded to create a surplus to cover a bone graft.

Soft tissue expansion created useful expanded periosteum with no signs of inflammatory reactions. Further studies are in progress to evaluate how well the newly-created soft tissue will function in covering bone grafts.

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References