in the experimental group compared with the control group; however, excised phonation was not achieved in 2 of the 3 cases in the control group.

Conclusions: This polypropylene-based tissue engineering technique appears to be a viable tool for glottal reconstruction: however, additional refinement is required to maximize long-term phonatory function.

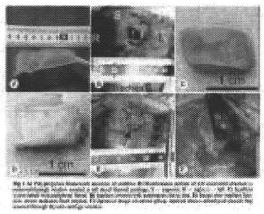
Key Words: fascia, laryngeal defect, polypropylene, reconstruction, tissue engineering, tissue regeneration.

INTRODUCTION

Many surgical procedures have been used to reconstruct laryngeal defects after partial resections due to malignancy, but no currently available surgical technique is ideal. Current procedures include the use of the autologous muscle flap,1"3 myocutaneous flap,4·5 fascial graft,69 cartilage graft,11112 thyroid gland flap,13·14 and mucosal graft,15·'7 and all demand a high degree of skill and involve complicated surgical techniques. Additionally, most functions remain suboptimal after these procedures. For example, poor vocal function is inevitable after repeated surgeries, because these graft tissues are poor substitutes for the anatomic and biomechanical properties of the native vocal fold.

Remarkable recent progress in regenerative medicine has resulted in the ability to regenerate differentiated tissues and certain organs under appropriate conditions by use of tissue engineering techniques. Many published articles have addressed regenerative approaches for laryngeal tissues, but relatively few have focused on regeneration of the vocal fold structure following a gross glottal defect.18"20 Tissue engineering techniques hold promise for the regeneration of functional vocal fold tissue without the need for complicated surgical procedures. The feasibility of this approach for vocal fold reconstruction, however, has not yet been established.

Our previous research in which a polypropylene mesh scaffold coated with collagen sponge enabled us to successfully regenerate tracheal and cricoid defects2'"27 supports the value of this scaffold as a promising tool for regenerative medicine in the head and neck region. Subsequent work using this scaffold seeded with bone marrow-derived stromal cells showed promise in the treatment of a glottal defect20; however, the reepithel ialization rate was suboptimal , and outcome data were limited to endoscopic and radiographic findings.



View Image - Fig LA) Polypropylene framework structure of scaffold. B) Membranous portion of left vocal fold structure is removed through window created in left ala of thyroid cartilage. S - superior; R - right; L - left. C) Scaffold is preclotted with peripheral blood. D) Implant covered with autologous fascia lata. E) Image after implant fixation. Arrow indicates fixed implant. F) Operative image of control group. Asterisk shows sternohyoid muscle flap inserted through thyroid cartilage window.

In this study, therefore, glottal restoration following partial resection of the larynx was attempted in a canine model by a modified in situ tissue engineering approach, based on the introduction of an artificial scaffold constructed of polypropylene and autologous fascia lata. Endoscopic, radiographic, histologic, and vibratory data were compiled to evaluate the performance of this tissue engineering technique.

Our hypothesis was that reepithel ialization, vocal fold contour, and functional vibratory performance would be superior after this tissue engineering intervention, compared with traditional muscle flap reconstruction.

MATERIALS AND METHODS

Preparation of Scaffold. A single polypropylene mesh sheet with a pore size of 260 μm (Marlex mesh; CR Bard Ine, Billerica, Massachusetts) was used as a scaffold framework (Fig IA). A 1% porcine dermal atelocollagen (supplied by Nippon Meatpackers Ine, Ibaraki, Japan) preparation comprising type I (70%) and type III (30%) collagens dissolved in aqueous hydrochloric acid (pH 3.0) was coated on both sides of this polypropylene framework. After collagen-coating, freeze-drying with a freeze dryer (FDU-810, Tokyo Rikakikai Co Ltd, Tokyo, Japan) and cross-linkage with a vacuum dry oven (VOS300SD, Tokyo Rikakikai Co Ltd) were performed. The resultant spongy collagen matrix was designed to enhance cellular attachment and ingrowth into the scaffold.

Animals and Surgical Procedures. Animal care, housing, and experimental procedures were conducted according to the Guidelines for Animal Experiments of Kyoto University. Eight adult beagle dogs weighing 9 to 1 1 kg were anesthetized with subcutaneous injections of ketamine hydrochloride (5.0 mg/kg; Sankyo Co Ltd, Tokyo) and xylazine hydrochloride (2.0 mg/kg; Bayer Ltd, Tokyo). They were divided into groups of 5 experimental animals and 3 control animals.

After a cervical longitudinal skin incision, the left ala of the thyroid cartilage was exposed. A 1 .2 ? 0.7cm cartilage window was created with a scalpel, and the membranous portion of the left vocal fold, including the vocalis and thyroarytenoid muscles, was removed via this cartilage defect (Fig 1 B). The vocal process was kept intact, and the anterior edge of the left vocal fold was physically inaccessible through the created window defect.

In the experimental group, a scaffold implant, preclotted with 2 mL of arterial blood, was trimmed to match the size of the cartilage window. The clotting procedure rendered the implant completely infiltrated with blood and eliminated all air spaces (Fig IC). Next, the scaffold was wrapped in a 4 ? 2-cm autologous fascia lata graft harvested from the quadriceps muscle (Fig ID). Fascia lata was chosen because of its thickness and accessibility for harvesting an area large enough to cover the scaffold completely. Pilot experimental data (unpublished) demonstrated that the addition of fascia lata produced favorable outcomes compared with the use of the collagen-treated polypropylene scaffold alone.

In the control group, the left sternohyoid muscle was cut and the superior aspect was used as a reconstructive flap (Fig IF). The fully prepared implant in the experimental group or the muscle flap in the control group for each animal was inserted through the window defect and anastomosed according to the resected boundaries of the thyroid cartilage with 3-0 absorbable sutures (Vicryl, Ethicon Ine, Somerville, New Jersey; Fig IE).

Ampicillin sodium (Meiji Seika Kaisha Ltd, Tokyo; 250 mg per animal, subcutaneous) was administered in both groups for 7 days to prevent postoperative infection.

Endoscopic Evaluation. Endoscopic examinations were undertaken weekly with a video-endoscopy system consisting of a video bronchoscope (BF type 1T240, Olympus Co Ltd, Tokyo) and a video processor (CV-240, Olympus Co Ltd) coupled to a light source (CLV-U40D, Olympus Co Ltd). All examinations were performed under general anesthesia induced with ketamine and xylazine at the previously noted dosages.

Tissue Harvest and Outcome Measurements. Three months after surgery, the animals were humanely sacrificed with a cardiac injection of pentobarbital sodium (50 mg/kg; Dainippon Sumitomo Pharma Co, Ltd, Osaka, Japan) after the induction of general anesthesia. Laryngés were harvested en bloc and subjected to 3-dimensional (3-D) computed tomography (CT), excised larynx phonation, and processing for histology. The 3-D CT scanning was performed with a helical CT scanner system (Legato Duo, GE Yokogawa Medical Systems, Tokyo). Judgments were made from the CT images by an otolaryngologist and 2 radiologic technologists.

The vibratory function of the repaired glottis was evaluated with an excised larynx setup. Each larynx was mounted on an artificial trachea that delivered warmed (37°C) and humidified (more than 90% humidity) air. Bilateral arytenoid adduction and closure of the posterior glottal space were achieved with a 3-0 nylon string,28 and vocal fold vibration at maximum amplitude was recorded with a high-speed video camera system (Memrecam Ci, NAC Image Technology, Ine, Tokyo). Using frame-by-frame analysis, we compared the vibratory amplitude ratio (R) of the operated side to that of the control side using the formulae A = (D max - D min)/L and R = (A op/A cont) ? 100%, where A = vocal fold vibratory area, D max = distance from the vocal fold medial surface to the glottal midline at the moment of maximum vibratory amplitude, D min = distance from the vocal fold medial surface to the glottal midline at the moment of minimum vibratory amplitude, and L = length of the glottis extending from the anterior commissure to the vocal process.28

The phonation threshold pressure of each harvested larynx was also recorded with an arterial pressure sensor (22 18 A, NEC San-ei Instruments, Ltd, Tokyo) located in the subglottis, 3 cm below the vocal folds.

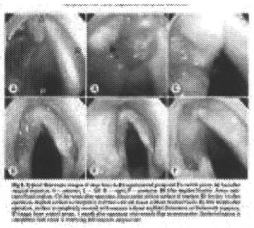
After 3-D CT and excised larynx phonation, the laryngés were processed for histologic analysis. Each larynx was fixed with formalin, and 4-um axial paraffin sections were prepared. Histologic assessment of hematoxylin and eosin-stained sections under light microscopy was performed to evaluate the status of each surgical site.

RESULTS

All 8 dogs recovered well from the initial surgical procedure, with no local or systemic complications. An oral diet was administered to each dog. No lifethreatening symptoms were seen in any dog during the observation period.

Endoscopic Evaluation. The fiberscopic findings in the 5 dogs in the experimental group were negative for stenosis or scaffold dislocation. The 3 animals in the control group were also negative for the dislocation of muscle flaps. No aspirated food was observed by endoscopy between the trachea and the main bronchi in any animal during the observation procedures in either group.

Figure 2A-E illustrates typical fiberscopic images of an operated larynx with a successfully reconstructed vocal fold at 1 month after surgery (Fig 2E), compared with an image immediately following surgery (Fig 2A). Figure 2C, taken 7 days after surgery, indicates that fascia still exists on the implant surface at this time point. The preclotted and fixed scaffold implant was an adequate size match for the laryngeal defect, and the implant surface was covered with soft tissue by day 14 (Fig 2D). Figure 2E, taken 1 month after surgery, illustrates regenerated mucosa without dislocation of the scaffold. The regenerated mucosa had a convex contour analogous to the anatomy of the native vocal fold. Figure 2F shows an image from a case in the control group; soft tissue was seen overlying the left, concave vocal fold.



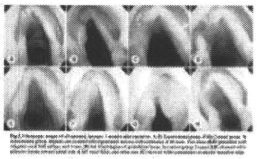
View Image - Fig 2. Typical fiberscopic images of dogs from A-E) experimental group and F) control group. A.) Just after surgical resection. A - anterior; L - left; R - right; P - posterior. B) After implant fixation. Arrow indicates fixed implant. C) One week after operation, fascia exists still on surface of implant. D) On day 14 after operation, implant surface is completely covered witfi soft tissue without residual fascia. E) One month after operation, surface is completely covered with mucosa witliout scaffold dislocation or framework exposure. F) Image from control group, 1 month after operation with muscle flap reconstruction. Epithel ialization is completed. Soft tissue is overlying left concave surgical site.

Figure 3 contains fiberscopic images from all operated laryngés at the 3-month time point. The implanted scaffolds were completely covered with newly regenerated mucosa with capillaries in all cases in the experimental group (Fig 3 A-E). Two of the 5 cases (Fig 3BJJ) presented an irregularly regenerated vocal fold surface, and 1 case (Fig 3D) presented a small degree of granulation tissue. In the control group, 2 cases showed white adhesive lesions toward the lateral side of the left vocal folds (Fig 3FJrI), and the third case showed a white granulation at the anterior resection edge (Fig 3G). No sign of infection or fistula was seen in either group.

CT Examination. Axial (Fig 4A) and 3-D CT images (Fig 4B) of the surgical sites revealed a clear luminal view of the reconstructed vocal fold, with no evidence of cartilage formation, in all cases in the experimental group. The control group also showed no evidence of cartilage formation.

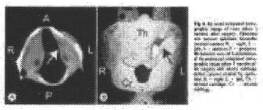
Excised Larynx Examination. The vibratory amplitude of the reconstructed vocal fold (normalized to that of the contralateral control vocal fold) was evaluated with a high-speed video camera system. Excised larynx phonation was not achieved in 2 cases from the control group because of persistent glottal gaps, even with bilateral arytenoid adduction and closure of the posterior glottis. The other case in the control group required granulation removal before data collection.

The mean vibratory amplitude of the reconstructed vocal fold in the experimental group was 12.20% (SD, 8.80%) of that of the contralateral fold. (This value should be 100% in a normal larynx.) The I successfully phonated larynx in the control group had 39.2% as the vibratory amplitude (average, 13.07%; SD, 22.64%). Statistical analysis using the Wilcoxon rank sum test showed a significant decrease in vibratory amplitude in the reconstructed fold compared to the contralateral fold ($p = 0.009$) in the experimental group. The mean phonation threshold pressure in the experimental group was 6.9 cm H2O (SD, 2.3 cm H2O), and the pressure in the 1 successfully phonated larynx in the control group was 7.0 cm H2O. The phonation threshold pressure in a normal canine larynx ranges from 4 to 6 cm ?2?.28



View Image - Fig 3. Fiberscopie images of all operated laryngés 3 months after operation. A-E) Experimental group. F-H) Control group. In experimental group, implants are covered with regenerated mucosa with capillaries in all cases. Two cases (BJD) presented with irregular vocal fold surface, and I case (D) had small degree of granulation tissue. In control group, 2 cases (F,H) showed white adhesive lesions toward lateral side in left vocal folds, and other case (G) showed white granulation at anterior resection edge.

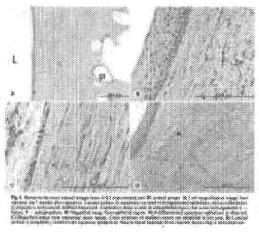
Histologic Assessments. Figure 5 shows hematoxylin-eosin-stained images taken 3 months after operation from the experimental group (Fig 5A-C) and the control group (Fig 5D). Histologic evaluation revealed a complete squamous epithelial lining in both groups (Fig 5A3J3). Disorganized connective tissue was observed in the subepithelial region (Fig 5BJD). No evidence of an inflammatory reaction was found in any specimen in either group. A small amount of skeletal muscle tissue was observed in the space between the epithelium and the polypropylene scaffold framework in 2 of the 5 cases in the experimental group (Fig 5C). In the control group, muscle tissue from the inserted muscle flap was identified. No cartilage formation was observed in any case in either group.



View Image - Fig 4. A) Axial computed tomographic image of case taken 3 months after surgery. Operated site (arrow) indicates favorable luminal contour. R - right; L - left; A - anterior; P - posterior. B) Anterior view of 3-dimensional reconstructed computed tomographic image taken 3 months after surgery still shows cartilage defect (arrow) created by operation. R - right; L - left; Th - thyroid cartilage; Cr - cricoid cartilage.

DISCUSSION

Various treatment options to reconstruct the larynx after partial surgical resection and/or structural damage have been pursued for more than 50 years.29·30 The established treatments have remained controversial, as surgeons continue to encounter poor postoperative voice function and the need for complicated repeat surgeries to achieve adequate laryngeal reconstruction. Factors that contribute to unsatisfactory surgical outcomes include 1) difficulty reconstructing delicate tissues and structures, which as a whole are dynamic and influenced by movements necessary for swallowing and phonation; 2) difficulty reconstructing the native contour of the laryngeal luminal surface; and 3) infection or foreign body reaction.



View Image - Fig S. Hematoxylin-eosin stained images from A-C) experimental and D) control groups. A) Low-magnification image from operated site 3 months after operation. Luminal surface is completely covered with regenerated epithelium, and no inflammatory response is seen around scaffold framework. Connective tissue is seen in subepithelial region, but is not well organized. L - lumen; P - polypropylene. B) Magnified image from epithelial region. Well-differentiated squamous epithelium is observed. C) Magnified image from interstitial tissue region. Cross-striations of skeletal muscle are identified in this case. D) Luminal surface is completely covered with squamous epithelium. Muscle tissue (asterisk) from inserted muscle flap is still observed.

Although autologous tissue and homografts have been employed as implant materials for laryngeal reconstruction,117 damage inflicted on the donor site and/or the difficulty of these surgical procedures highlights the need for a more clinically efficient treatment approach. Moreover, in cases of tumor invasion into the larynx, deformities of the reconstructed site often render it difficult to monitor tumor recurrence. Regenerative approaches to tissue reconstruction in this area hold promise for overcoming these problems.

Regenerative medicine is a powerful clinical discipline with the potential to enhance the quality of life of patients who undergo organ reconstruction. This technique generally exploits 3 fundamental components: 1) cells acting as "seeds" for tissue regeneration; 2) a scaffold on which cells can proliferate and grow; and 3) regulatory factors that mediate cell behavior.3 ' The approach reported here represents in situ tissue engineering. Under this paradigm, scaffolds are the key component, as providing a well-prepared scaffold to the target site in vivo can lead to successful tissue regeneration even without cells or regulation factors under favorable conditions. Using this in situ tissue engineering approach, we have successfully achieved the regeneration of cricoid cartilage,24-27 trachea,23·25·27 and peripheral nerves.32 These procedures have already been applied to clinical cases in our institutions.23·26

Because polypropylene is a widely used polymer with high levels of biocompatibility and morphological plasticity, it is well suited as a scaffold material. Polypropylene has already been used clinically in reconstruction surgery for the abdominal wall.33 Using a columnar-shaped prosthesis with porous-type collagen and polypropylene as a scaffold, Nakamura et al21 and Okumura et al22 reported favorable outcomes in canine tracheal regeneration, as shown by cellular invasion to intact collagen, epithelialization of the luminal surface of the implants, and complete integration of the scaffold into the recipient's tissue. Yamashita et al25 demonstrated the possibility of regenerating a layered tissue structure, namely, epithelium, subepithelial tissue, and cartilage, in a canine tracheal resection model. Omori et al also demonstrated encouraging results with this scaffold for regeneration of the human trachea23·26 and human cricoid cartilage.26

Huber et al18 and Ringel et al19 reported favorable outcomes in the treatment of partial and complete hemilaryngectomy models using a xenogeneic extracellular matrix derived from decellularized porcine urinary bladder tissue. Their histologic data suggested the possibility of tissue regeneration in the larynx; however, their techniques require donor tissue from other animals. Also, functional vocal fold performance was not evaluated.18,19

The goal of this study was to evaluate the effectiveness of a similar scaffold composed of polypropylene mesh, collagen from porcine skin, and autologous fascia, to reconstruct a functional vocal fold after a partial laryngeal defect. Autologous fascia was incorporated here, as polypropylene-treated scaffolds without fascia produced poor outcomes in preliminary experiments (unpublished data), as evidenced by a lack of epithelialization, framework exposure, and early detachment of the coated collagen sponge. As fascial tissue contains a robust fibrous protein network and is frequently used as a coating material in the area of plastic and reconstructive surgeries, we used fascia lata to wrap the scaffold in the present experiment.

The fiberscopie and histologic data reported here demonstrate the viability of the scaffold in vivo 3 months after implantation, without infection. We observed restoration of epithelium, some muscle

tissue ingrowth, an adequate anatomic contour in the majority of cases, minimal granulation, and no cartilage formation in the experimental group. The vibratory performance of the reconstructed vocal fold, although present, was suboptimal. However, considering vibratory data from the control group, this tissue engineering technique appears to hold greater functional potential than a traditional muscle flap reconstruction method. Additional research is required to engineer tissues that can closely mimic the native biomechanical properties of an intact vocal fold.

It is important to note that although the focus of this study was the application of a tissue engineering scaffold, complete restoration of a functionally intact glottis is a demanding challenge and may depend on the addition of therapeutic cell populations and/or growth regulation factors.

CONCLUSIONS

This preliminary study demonstrated that a polypropylene-based scaffold infiltrated with arterial blood and wrapped in autologous fascia lata is a viable tool for glottal reconstruction after partial resection of the larynx. Useful outcomes and other advantageous reconstructive factors may eventually favor the present tissue engineering approach over conventional surgical approaches, although further investigation and refinement are needed to maximize long-term phonatory function.

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REFERENCES

1. Bailey BJ. Glottic reconstruction after hemilaryngectomy: bipedicle muscle flap laryngoplasty. Laryngoscope 1975; 85:960-77.

2. Calcaterra TC. Bilateral omohyoid muscle flap reconstruction for anterior commissure cancer. Laryngoscope 1987; 97:810-3.

3. Hirano M. A technique for glottic reconstruction following vertical partial laryngectomy. Auris Nasus Larynx 1978;5: 63-70.

4. Eliachar I , Roberts JK, Hayes JD, Levin HL, Tucker HM. Laryngotracheal reconstruction. Sternohyoid myocutaneous rotary door flap. Arch Otolaryngol Head Neck Surg 1987;113: 1094-7.

5. Schuller DE, Mountain RE, Nicholson RE, Bier-Laning CM, Powers B, Repasky M. One-stage reconstruction of partial laryngopharyngeal defects. Laryngoscope 1997;107:247-53.

6. Krajina Z, Kosokovié F, Vecerina S. Laryngeal reconstruction with sternohyoid fascia in partial laryngectomy. J Laryngol Otol 1979;93:1181-9.

7. Prlic A, Krajina Z. Partial laryngectomy in transglottic carcinoma. Acta Med Croatica 1992;46:37-9.

8. Elo J, Horváüi E, Késmárszky R. A new method for reconstruction of the larynx after vertical partial resections. Eur Arch Otorhinolaryngol 2000;257:212-5.

9. Apostolopoulos K, Samaan R, Labropoulou E. Experience with vertical partial laryngectomy with special reference to laryngeal reconstruction with cervical fascia. J Laryngol Otol 2002;116:19-23.

10. Duncavage JA, Toohill RJ, Isert DR. Composite nasal septal graft reconstruction of the partial laryngectomized canine. Otolaryngology I978;86:ORL285-ORL290.

1 1 . Butcher RB II, Dunham M. Composite nasal septal cartilage graft for reconstruction after extended frontolateral hemilaryngectomy. Laryngoscope 1984;94:959-62.

12. Burgess LP, Quilligan JJ, Yim DW. Thyroid cartilage flap reconstruction of the larynx following vertical partial laryngectomy: a preliminary report in two patients. Laryngoscope 1985; 95:1258-61.

13. Kojima H, Omori K, Fujita A, Nonomura M. Thyroid gland flap for glottic reconstruction after vertical laryngectomy. Am J Otolaryngol 1 990; 1 1 :328-3 1 .

14. Zur KB. Urken ML. Vascularized hemitracheal autograft for laryngotracheal reconstruction: a new surgical technique based on the thyroid gland as a vascular carrier. Laryngoscope 2003;113:1494-8.

15. Salam MA, el-Kahky M, el-Mehiry H. The use of pyriform sinus mucosa for reconstruction after vertical partial laryngectomy. J Laryngol Otol 1992;106:900-2.

16. Biacabe B, Crevier-Buchman L, Hans S, Laccourreye O, Brasnu D. Vocal function after vertical partial laryngectomy with glottic reconstruction by false vocal fold flap: durational and frequency measures. Laryngoscope 1999;109:698-704.

17. Biacabe B, Crevier-Buchman L, Hans S, Laccourreye O, Brasnu D. Phonatory mechanisms after vertical partial laryngectomy with glottic reconstruction by false vocal fold flap. Ann Otol Rhinol Laryngol 2001 ;1 10:935-40.

18. HuberJE.Spievack A.Simmons-ByrdA.Ringel RL5Badylak S. Extracellular matrix as a scaffold for laryngeal reconstruction. Ann Otol Rhinol Laryngol 2003;! 12:428-33.

19. Ringel RL, Kahane JC, Hillsamer PJ, Lee AS, Badylak SF. The application of tissue engineering procedures to repair the larynx. J Speech Lang Hear Res 2006;49: 194-208.

20. Yamashita M, Omori K, Kanemaru S, et al. Experimental regeneration of canine larynx: a trial with tissue engineering techniques. Acta Otolaryngol Suppl 2007;557:66-72.

21 . Nakamura T, Teramachi M, Sekine T, et al. Artificial trachea and long term follow-up in carinal reconstruction in dogs. Int J Artif Organs 2000;23:7 1 8-24.

22. Okumura N, Nakamura T, Takimoto Y, et al. A new tracheal prosthesis made from collagen grafted mesh. ASAIO J 1993;39:M475-M479.

23. Omori K, Nakamura T, Kanemaru S, et al. Regenerative medicine of the trachea: the first human case. Ann Otol Rhinol Laryngol 2005;114:429-33.

24. Omori K, Nakamura T, Kanemaru S, et al. Cricoid regeneration using in situ tissue engineering in canine larynx for the treatment of subglottic stenosis. Ann Otol Rhinol Laryngol 2004;113:623-7.

25. Yamashita M, Kanemaru S, Hirano S, et al. Tracheal regeneration after partial resection: a tissue engineering approach. Laryngoscope 2007;117:497-502.

26. Omori K, Tada Y, Suzuki T, et al. Clinical application of in situ tissue engineering using a scaffolding technique for reconstruction of the larynx and trachea. Ann Otol Rhinol Laryngol 2008;117:673-8.

27. Omori K, Nakamura T, Kanemaru S, Magrufov A, Yamashita M, Shimizu Y. In situ tissue engineering of the cricoid and trachea in a canine model. Ann Otol Rhinol Laryngol 2008; 117:609-13.

28. Hirano S, Bless DM, Nagai H, et al. Growth factor therapy for vocal fold scarring in a canine model. Ann Otol Rhinol Laryngol 2004;] 13:777-85.

29. Conley JJ. One-stage radical resection of cervical esophagus, larynx, pharynx, and neck, with immediate reconstruction. AMA Arch Otolaryngol 1953;58:645-54.

30. Som ML. Reconstruction of the larynx and the trachea; report of a case of extensive cicatrical stenosis. J Mt Sinai Hosp NY 1951;17:1117-26.

31. Bianco P, Robey PG. Stem cells in tissue engineering. Nature 2001;414:118-21.

32. Kanemaru S, Nakamura T, Omori K, et al. Recurrent laryngeal nerve regeneration by tissue engineering. Ann Otol Rhinol Laryngol 2003; 1 12:492-8.

33 . Bucky LP, May JW Jr. Synthetic mesh. Its use in abdominal wall reconstruction after the TRAM. Clin Plast Surg 1994; 21:273-7.

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Indexing (details)

MeSH	Animals, Disease Models, Animal, Dogs, Feasibility Studies, Glottis -- surgery ####, Laryngeal Diseases -- surgery ####, Polypropylenes ## ##, Prosthesis Design, Reconstructive Surgical Procedures, Surgical Mesh ####, Tissue Engineering -- methods ####
####	Glottal Reconstruction With a Tissue Engineering Technique Using Polypropylene Mesh: A Canine Experiment
##	Yamashita, Masaru, Kanemaru, Shin-ichi, Hirano, Shigeru, Umeda, Hiroo, Kitani, Yoshiharu, Omori, Koichi, Nakamura, Tatsuo, Ito, Juichi
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