Tissue Regeneration Adjacent to Titanium Implants Placed with Simultaneous Transposition of the Inferior Dental Nerve: A Study in Dogs

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Transposition of the inferior alveolar nerve was performed in an experimental dog model. Four adult greyhounds were used in the study. Surgical transposition of the nerve was made bilaterally, and 3 implants were placed on each side while the nerve was lateralized. On one side, the nerve was repositioned in contact with the implants, while on the contralateral side a resorbable membrane was positioned between the implant surface and the neurovascular bundle. Histologic section after 4 months of healing showed an intimate contact between implants and nerve tissue in all cases without an interpositional membrane, in contrast to cases with membranes. Histomorphometric measurements of the distance between the implants and the nerve tissue showed that the membrane side had a considerably larger distance between the implant and the nerve, although not with concomitant bone formation. (INT J ORAL MAXILLOFAC IMPLANTS 2000;15:119–124)

Key words: *biologic membrane, dog, experimental, implants, nerve transposition*

Implant rehabilitation of the posterior edentulous mandible may be somewhat problematic because of a short distance between the superior alveolar crest and the mandibular nerve canal. During orthognathic surgical procedures, nerve transposition has been traditionally used to perform osteotomies posterior to the first premolar region. Nerve transposition represents an approach that offers the advantage of increasing total mandibular volume in the posterior region.[1–6] Two different techniques may be used: either lateralization of the nerve without engaging the mental foramen, or "true" transposition, where the nerve is released from the mental foramen and placed distal to it.[4,7–11] Both these procedures permit later bicortical anchorage of implants.

Success rates with nerve transposition differ somewhat among various studies, although generally a very positive outcome has been reported.[4–6,8,10,12,13] When nerve lateralization is compared with nerve transposition, a tendency of the former to produce fewer side effects can be seen.[2,11,13] Nerve lateralization with no interference at the mental foramen and no cutting of the anterior canine incisive nerve branch is naturally a less invasive technique than transpositioning. Nerve transposition with severing of the anterior branch to the inferior alveolar nerve may decrease the vascular supply to the anterior teeth, in addition to depriving them of their sensitivity. In most cases, this may not be a major problem for the patient, but it does, nevertheless, represent a certain drawback to the method. The postoperative positioning of the nerve may differ from clinic to clinic. Bone transplants can be placed between the implants and the nerve, or the nerve can simply be

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repositioned in the canal close to the implants. To analyze the healing pattern after nerve transpositioning and implant surgery, an experimental model in the dog has been designed to determine whether the use of a membrane changes the relationship between the nerve and the implants.

MATERIALS AND METHODS

Animals and Care

Four adult greyhounds, in good systemic health, were used in this study. Prior to surgery, the animals were fed standard dry dog food ad libitum. Two weeks prior to the study, the animals' teeth were scaled and cleaned. Following surgery, the animals were fed a soft diet for 2 weeks, after which they resumed their normal diet. After surgery the animals were given streptopen 1.5 mg (200 mg procaine penicillin/250 mg streptomycin). This antibiotic was continued once daily for 14 days. Oral prophylaxis was administered biweekly using a standard toothbrush with chlorhexidine gluconate (0.12%) gel as a dentifrice. All animals remained healthy throughout the duration of the study.

Surgical Treatment

Prior to surgery, the dogs were anesthetized with a mixture of sodium thiopenthal and pentabarbital sodium 50:50 (30 mg/kg administered intravenously), intubated, and maintained on a mixture of nitrous oxide and oxygen 1:1 with halothone general anesthesia (between 1 and 1.5%). A local anesthetic (2% xylocaine, 1:80,000 adrenalin, Astra AB, Södertälje, Sweden) was infiltrated into the areas of surgery. Bilateral full-thickness mucoperiosteal flaps were reflected, and high-speed carbide burs were used to hemisect P3 and P4 at the furcation. The roots were separated and removed.

Careful removal of the bone immediately adjacent to the buccal aspect of the inferior dental nerve was carried out to expose the nerve, using the procedure previously described by Kahnberg and Ridell (Figs 1a and 1b).[8]

Accessory branches of the nerve penetrating the lingual cortical plate were severed to allow lateralization buccally through a prepared window. The window defects were approximately 10 mm high, 3 mm deep, and 50 mm long. The dimensions were recorded clinically and photographically. Following lateralization of the inferior dental nerve, 3 Brånemark System implants (Nobel Biocare AB, Göteborg, Sweden) were placed bicortically through the extraction sites to engage the inferior border of the mandible ad modum Brånemark.[14] In 2 dogs all the implants were 13 mm in length, in 1 dog a single 10-mm and five 13-mm implants were placed, and in the fourth dog, six 18-mm implants were placed.[14] The implant heads were placed approximately 2 mm below the surrounding alveolar crest. All implants were stable after placement. Cover screws were placed in the usual manner.

In alternate animals, on one side the transpositioned neurovascular bundle was repositioned and the mucoperiosteal flap was closed with interrupted sutures. On the contralateral side, a resorbable barrier membrane, Resolut (WL Gore & Associates, Flagstaff, AZ), was placed so as to separate the repositioned neurovascular bundle from, and prevent contact with, the surfaces of the placed implants (Figs 2a and 2b). The mucoperiosteal flap was then closed with interrupted sutures.

Clinical Observations

The animals were monitored monthly for changes in the color of the anterior teeth and for any tissue complications in the surgical area.

Specimen Retrieval

At 14 weeks postsurgery, the animals were anesthetized as previously described. The implanted sites were inspected for membrane exposure and tissue inflammation. The anesthetized animals were sacrificed with an overdose of barbiturates, and block sections of the implants and adjacent bone were removed and fixed in 10% neutral buffered formalin.

Histologic Evaluation

The bone blocks (containing 3 implants) were fixed by immersion in 4% neutral buffered formaldehyde (pH 7.0), followed by routine preparation according to the laboratory procedures at the Department of Biomaterials/Handicap Research, Göteborg, Sweden. In brief, the procedure involved treatment under vacuum and with stirring during every step: fixation, dehydration in ethanol (70% absolute ethanol), preinfiltration in diluted resin, then in pure resin, and finally embedment in pure light-curing resin (Technovit VLC, Kulzer, Wehrheim, Germany). The cured blocks were divided into 3 smaller ones, with 1 implant in each. These blocks were divided in a buccolingual manner by dividing the implant along its long axis. Undecalcified ground sections with a final thickness of about 10 µm were prepared according to the Exakt/Donath technique.[15,16] The sections were stained routinely in toluidine blue in pyronin G. Qualitative and quantitative microscopic observations were made using a Leitz Aristoplan light microscope (Leitz, Wetzlar,

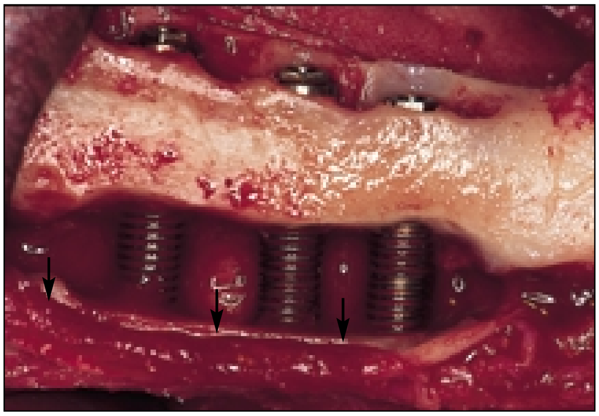

Fig 1a Transposition of the inferior alveolar nerve *(arrows)* laterally and placement of 3 implants.

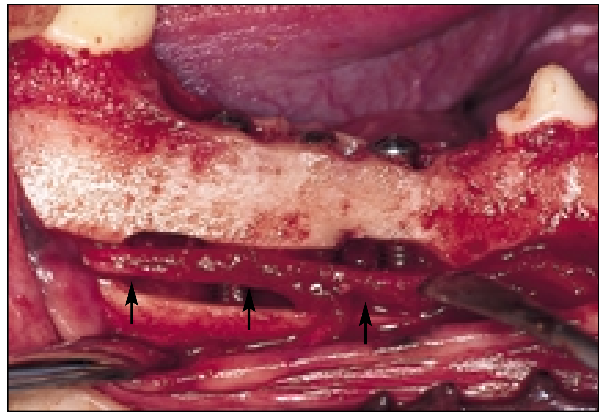

Fig 1b The nerve trunk *(arrows)* is repositioned close to the implants before the flap is sutured.

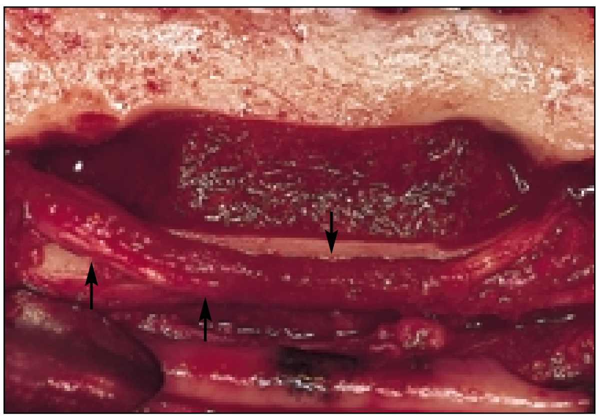

Fig 2a A resorbable membrane is placed lateral to the implants. Arrows point to the nerve.

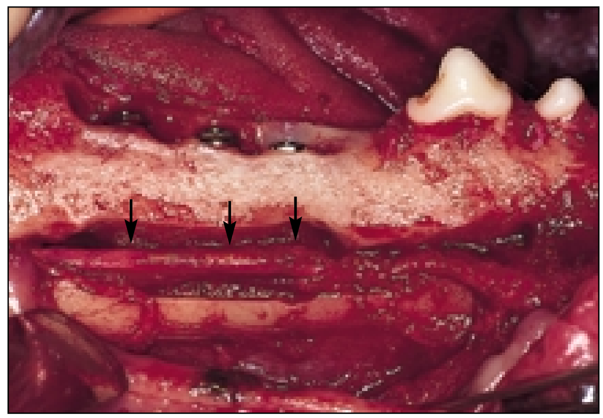

Fig 2b The nerve *(arrows)* is repositioned outside the membrane, and the flap is sutured.

Germany) with a computerized system connected to it as described by Johansson and Albrektsson.[17] The qualitative observations involved a general description of the tissue structure on the sides with and without membranes. The quantitative observations involved measurement of the distance from the closest point on an implant thread to the closest nerve bundle (250 µm or longer in cross section; smaller nerve branches were not included). If the nerve was of an adequate size, measurements were made of the distances to 3 consecutive threads. In some cases, depending on the size of a nerve, only 1 or 2 threads were included in the measurements.

RESULTS

Uncomplicated healing followed the surgical procedure in all dogs. No exposure of implants was seen during the healing time of 14 weeks. Discoloration was observed in several of the canine teeth in 2 of the dogs, but this diminished during the postoperative period.

Histologic analysis of the tissue specimens showed that in all specimens in which the nerve was repositioned after lateralization, but without an interpositioned membrane, there was close contact between the nerve and the implant surface (Fig 3).

Remodeling of the bone tissue adjacent to the bony window was minimal in all specimens. Occa-

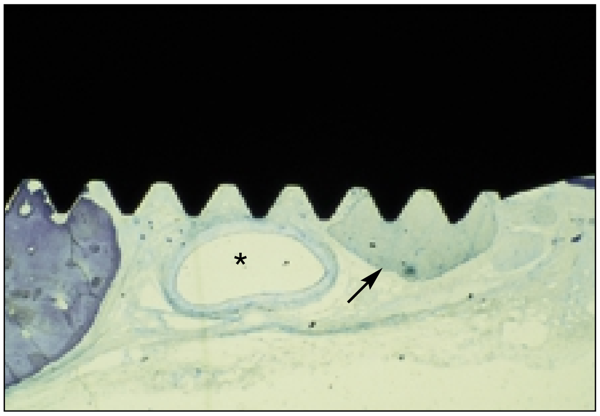

Fig 3 Photomicrograph of specimen in which the nerve *(arrow)* and vessel *(asterisk)* are in close contact with the implant surface (original magnification ×40).

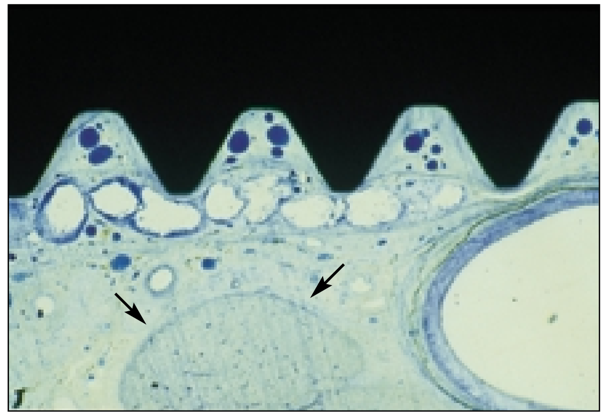

Fig 4 Close-up of membrane with the nerve *(arrows)* distalized from the implant (original magnification ×125).

Table 1 Distance Between Implants and Nerve Bundles in the 4 Different Experimental Animals

Dog #	Left (L) and right (R) mandible	Sites measured	Distance between implant and nerve bundle (µm) With interpositional membrane	Without membrane	*P*
1	339 (L)	P_1 P_2 P_3	392 ± 96.6	17.8 ± 13.5	< .07
	341 (R)	P_1 P_2 P_3			
2	345 (L)	P_1 P_2 P_3	287 ± 62.8	86.7 ± 27.5	< .08
	340 (R)	P_1 P_2 P_3			
3	343 (L)	P_1 P_2 P_3	447.3 ± 40.5	39.3 ± 26.8	< .02
	342 (R)	P_1 P_2 P_3			
4	344 (L)	P_1 P_2 P_3	265.9 ± 91.1	15.3 ± 12.5	< .1
	346 (R)	P_1 P_2 P_3			
Total mean			348.3 ± 39.5	39.8 ± 12.3	< .008

sionally, spicules of bone could be observed. Signs of inflammation, including plasma cells, macrophages, and polymorphonuclear granulocyte cells, were frequently seen on the membrane side. There were also numerous giant cells and macrophages. The vascularization was much more pronounced on this side compared to the side in which no membranes had been placed. On the other hand, the membrane did not seem to enhance bone-to-implant contact. On the side in which no membranes had been placed, direct measurement of sections revealed close contact between the nerve and the implant surface. In some cases, the nerve was in immediate proximity to the implant and "folded onto the threads." In reality, there was a capsule less than 10 µm thick in some regions, but in others this capsule was not visible. The bone-to-implant contact seemed to be disturbed if an implant was in contact with the nerve.

When a membrane was interpositioned between the implant and the nerve bundle, the distance between the implant surface and the nerve increased by about 4 to 8 times that of the contralateral side (Fig 4, Table 1). After thorough measurements of 4 different spots at each implant from nerve to implant, it was found that the mean distance in dog number 1 was 392 µm on the membrane side and 17.8 µm on the non-membrane side; in dog number 2, 287 µm on the membrane side and 86.7 µm on the non-membrane side; in dog number 3, 447.3 µm on the membrane side and 39.3 µm on the non-membrane side; and in dog number 4, 265.9 µm on the membrane side and 15.3 µm on the non-membrane side. The average distance measured on the membrane side was 348.3 µm, compared with 39.8 µm on the non-membrane side (Table 1).

DISCUSSION

Manipulation of the nerve may cause minor effects in nerve function. Sensory nerve disturbance in connection with sagittal split osteotomy, from slight hypoesthesia to total numbness, is reported in up to 40% of patients.[18] However, in spite of the risk for sensory disturbances, nerve transposition is indicated in patients in whom the anatomy of the posterior mandible makes it necessary. The patients should be made aware of the consequences that can arise.

Clinical application of nerve transposition or nerve lateralization has been reported in a number of publications.[1–8] In some patients, this may be the method of choice, with the only alternative being onlay bone grafting, which also must be attached to the alveolar crest, thus risking nerve damage. The reported success rate with regard to disturbances of nerve sensation or pain has overall been very good, with only a few reported incidents of paresthesia, anesthesia, or hyperesthesia. However, for the patients who do experience a complication like anesthesia or hyperesthesia, the problem may be very disturbing. In a number of studies, it has been reported that the success rate of total sensory recovery is almost 100%, and thus with good surgical technique, nerve transposition may be regarded as a safe procedure. However, the surgical procedure is time-consuming and demands intense concentration and experienced surgical assistance, as well as the selection of suitable patients.

The surgical problem with nerve transposition in the elderly patient with advanced resorption of the posterior mandible is that the residual mandibular body consists of 2 cortical layers and an interposed nerve canal. In the present experiments, it was of interest to know how healing proceeded after transposition of the nerve following removal of the buccal bone plate covering the canal. Repositioning of the nerve directly against the implants resulted in very close nerve-to-implant contact, possibly potentially inducing symptoms. When a membrane was placed between the nerve and the implants, close contact was avoided, but no bone regeneration was observed.

The results of this study indicate that repositioning the nerve toward the implants gave the impression of almost nerve-to-implant contact, whereas with an interposed membrane, a soft tissue zone was created between the implant and the nerve tissue. Bone regeneration in the buccal window was not evident, except for small bony spicules on the margin of the window. It is difficult to speculate about the clinical implication of the experimental results in terms of increased failure risk or subjective symptoms for the patient. However, close contact between the nerve and the implant could at least mean a higher sensitivity to thermal variations. The idea of an interposed barrier between the implant surface and the nerve may thus serve to prevent thermal conduction via the implant. The lack of bone regeneration in the buccal window probably does not affect the survival rate of the implants. The experimental dog model is useful for the study of the nerve-to-implant relationship, although the anatomy of the inferior alveolar nerve trunk is somewhat more complicated than in humans.

SUMMARY

Transposition of the inferior alveolar nerve in an experimental dog model showed intimate contact between the nerve tissue and the implant when repositioning was performed without an interposed membrane. If a membrane was positioned between the nerve trunk and the implant, soft tissue kept the nerve from contact with the implant.

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