Laser Doppler Flowmetry for Assessment of Anterior Mandibular Teeth in Conjunction with Bone Harvesting in the Symphysis: A Clinical Pilot Study

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Purpose: *To evaluate the pulp sensitivity and vitality of mandibular incisors and canines before and after bone harvesting in the symphysis.* ***Materials and Methods:*** *In 20 patients requiring bone grafts from the symphysis, pulp sensitivity (carbon dioxide [CO_2]) and pulpal blood flow (laser Doppler flowmetry [LDF]) of mandibular incisors and canines were evaluated preoperatively, postoperatively, and 6 months after surgery. Teeth were allocated to 1 of 3 groups according to their initial and final reaction to CO_2 (group A = teeth with a positive reaction throughout the study, group B = teeth that exhibited a sensitivity change from positive to negative, and group C = teeth with a negative reaction throughout the study).* ***Results:*** *Preoperative flux measurements (LDF) did not differ between groups A, B, and C. Teeth with sensitivity changes (group B) showed the greatest decrease (a statistically significant decrease) of pulpal blood flow over time, whereas teeth in groups A and C demonstrated an insignificant reduction of flux over time.* ***Discussion and Conclusions:*** *LDF was purely used as an experimental tool in the present study. Pulpal blood flow measurements using LDF demonstrated a decrease of flux over time in anterior mandibular teeth following bone harvesting in the symphysis. A significant change of flux, however, was only observed for teeth that also demonstrated a loss of pulp sensitivity during the same study period. Loss of pulp sensitivity appeared to be correlated to a significant decrease of blood flow assessed by LDF.* INT J ORAL MAXILLOFAC IMPLANTS 2007;22:383–389

Key words: *bone harvesting, laser Doppler flowmetry, pulp sensitivity, pulp vitality, symphysis*

The symphysis is a frequently used donor site for harvesting of larger bone volumes in patients requiring alveolar ridge augmentation or sinus floor elevation prior to implant placement. In comparison to other intraoral donor sites, the symphysis is characterized by relatively simple surgical access and harvesting. It yields enough corticocancellous bone to enhance the bone volume of up to 4 units. However, the use of the symphysis as a donor site may increase the risk of pulp and soft tissue sensitivity changes, which may not completely resolve over time.

Negative reactions to thermal pulp tests have frequently been reported in mandibular incisors and canines following bone harvesting in the symphysis.[1–4] However, a thermal test only allows for evaluation of pulp sensitivity; pulpal blood flow (pulp vitality) cannot be evaluated using thermal tests.

Laser Doppler flowmetry (LDF) has been recently introduced in dentistry, particularly to assess the pulp vitality of traumatized teeth.[5–9] Other applications of LDF have included the assessment of blood perfusion of mucoperiosteal flaps following bone augmentation,[10] evaluation of gingival blood flow during Le Fort I osteotomy,[11] and detection of blood flow in sinus bone grafts.[12]

LDF is a noninvasive continuous measure of microcirculatory blood flow. It measures the Doppler shift, ie, the frequency change that light undergoes

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Fig 1 Positioning of the LDF probes on 2 anterior mandibular teeth.

when reflected by moving objects, such as erythrocytes. LDF uses monochromatic light emitted from a low-power laser. The light emitted and reflected is fed through optical fibers from the target to the analyzer-recorder. Measurement of the erythrocyte motion is recorded, and the output value constitutes the flux of red cells, defined as the number of erythrocytes times their velocity. The flux is reported in microcirculatory perfusion units. The relationship between the flowmeter output signal and the flux of erythrocytes is linear.

In contrast to LDF evaluation of patients with traumatized teeth, LDF evaluation of patients undergoing bone harvesting can be carried out pre- and post-trauma (ie, pre- and postsurgery).

The objective of this clinical study was 2-fold:

1. To evaluate changes in pulpal blood flow of mandibular incisors and canines prior to and after bone harvesting in the symphysis
2. To correlate LDF measurements with thermal tests (carbon dioxide [CO_2]) obtained concurrently

MATERIALS AND METHODS

The study comprised 20 consecutive patients subjected to bone harvesting from the symphysis. Patients were referred for either alveolar ridge augmentation or sinus floor elevation procedures.

Basic evaluation included medical history, smoking habit evaluation, extra- and intraoral examination, and radiographic investigation. The mandibular symphysis was preoperatively estimated on a panoramic radiograph to be sufficient in height for bone harvesting. Patients signed informed consent documents after they had been fully notified about the surgical procedures.

During the preoperative examination, pulp sensitivity of mandibular incisors and canines was assessed with carbon dioxide snow (CO_2), and pulpal blood flow of the same teeth was measured with LDF. The LDF measurements were carried out with a Laser Doppler Monitor DRT4 (Moor Instruments, Axminster, Devon, England) using 2 probes, enabling the examination of 2 analogous teeth in the anterior mandible. The flux signal was calibrated by means of the thermal (Brownian) motion of the microspheres of a standard calibration fluid. To reduce artifacts of movement, the patients were instructed to bite down on a mouth prop. The probes were positioned perpendicular to the tooth surface in the lower half of the labial crown (Fig 1). Pulpal blood flow was recorded for 10 seconds at 20 Hz. The registered flux curve was subsequently printed out, and the lowest flux measurement per tooth was recorded for further analysis.

The surgeries were performed under local anesthesia (Ultracain DS forte; Aventis Pharma, Zurich, Switzerland). Premedication included sedation (Dormicum; Roche, Basel, Switzerland), atropin to reduce salivary flow, and a centrally active analgesic (Tramal; Grünenthal Pharma, Mitlödi, Switzerland).

Surgical Procedure

As a first step, the recipient site was analyzed to determine the amount of autogenous bone to be harvested from the symphysis. Full mucoperiosteal flaps were reflected to expose the atrophic alveolar ridge for ridge augmentation. In sinus floor elevation cases, the lateral wall of the maxillary sinus was exposed. Subsequently, a bony window was created, and the sinus membrane was carefully elevated to create a subantral space.

Following bilateral block anesthesia of the mental nerve and buccal infiltration in the chin area, a mucoperiosteal incision was made approximately 5 mm inferior to the attached gingiva. The incision was extended distally but limited to either canine and slightly curved caudally. Caution was exercised to avoid the branches of the mental nerve. A full mucoperiosteal flap was raised with an elevator, and the soft tissues, including the mentalis muscle, were reflected to the inferior border of the mandible. The mental foramina were not exposed.

The locations of the apices of adjacent incisors and canines were estimated from the panoramic radiograph. The length of the tooth was transferred to the clinical, intraoperative situation using a periodontal probe. A safety line 5 mm caudal to the estimated apices was drawn onto the exposed cortical bone using a sterile marker. A minimum distance of 5 mm is generally allowed to avoid the adjacent apices.[1,4,13–16]

Fig 2 Intraoperative situation showing typical donor site in the symphysis after the cutting of a bone block.

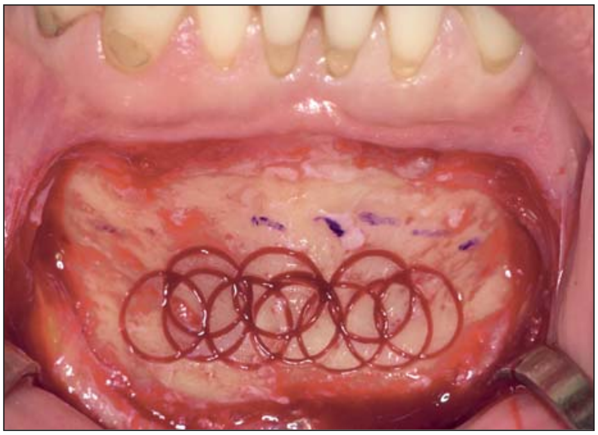

Fig 3 Intraoperative situation following trephination for bone harvesting in the symphysis.

Bone harvesting included either procurement of block grafts for ridge augmentation (Fig 2) or trephination of particulate graft material for sinus floor elevation (Fig 3). Block grafts were outlined with a small round bur. Drilling holes were subsequently connected with a fissure bur. The blocks were mobilized with a flat chisel, and lag-screw holes were drilled before block removal.

Particulate grafts were harvested with a trephine drill (diameter 6 mm). Cuts were overlapped to facilitate graft removal. This graft material was further chipped using a bone mill. Usually, additional (spongy) bone was harvested with curets or curved chisels, but the lingual cortex of the symphysis was never perforated.

Sharp bony edges were smoothed, and the donor site was packed with collagen (TissuCone E or TissuFleece E; Baxter, Deerfield, IL). Wound closure was accomplished with a resorbable suture material in a monolayer technique using multiple mattress sutures (Vicryl; Johnson & Johnson/Ethicon, Somerville, NJ). An extraoral pressure dressing was applied for 3 days.

Medication included antibiotics (Aziclav, 1 g twice a day for 6 days, Spirig Pharma, Egerkingen, Switzerland), analgesics (Spiralgin, 500 mg 3 times a day, Spirig Pharma), and 0.1% chlorhexidine-digluconate mouth rinse (1 minute twice a day for 10 days).

Follow-up Examinations

Patients returned after 3 days. The extraoral pressure dressing was removed, and the augmentation and donor sites were inspected and cleaned. Ten days after surgery, the nonresorbable sutures at the augmentation site were removed. The resorbable suture material at the donor site was left in place. Pulp sensitivity testing (CO_2) and pulpal blood flow evaluation (LDF) of the mandibular canines and incisors were repeated at the time of suture removal and 6 months following surgery.

All teeth were grouped according to their initial (preoperative) and final (6 months postsurgery) reactions to CO_2:

- Group A (pos-pos): positive reaction to CO_2 throughout the study
- Group B (pos-neg): positive reaction to CO_2 before surgery, but negative reaction at the 6-month follow-up
- Group C (neg-neg): negative reaction to CO_2 throughout the study

Statistical Analysis

The risk for permanent changes in tooth sensitivity and the average number of affected teeth per patient following bone harvesting were calculated using the CO_2 test values. A potential significant change of the number of unaffected teeth after treatment was evaluated using the exact Friedman test (StatExact, Studio Version 6.2.0; Cytel Software, Cambridge, MA).

Flux values (LDF measurements) before surgery and at the 6-month follow-up were compared for the mandibular right and left canines, lateral incisors, and central incisors separately, using nonparametric analysis for longitudinal data.[17] Initially, all 6 tooth categories were analyzed together, regardless of their reaction to the CO_2 test values. The software used was SAS 9.1 (SAS Institute, Cary, NC). The data analysis was done exploratively; thus, no Bonferroni correction for multiple testing was applied.

Flux values were compared between groups A, B, and C using the Kruskal-Wallis test (2-sided exact/Monte Carlo). To analyze differences within groups A to C over the 3 different time points (preoperative, postoperative, and 6-month follow-up), a 2-sided exact Friedman test was used. Bonferroni adjustment for multiple testing was applied (StatExact, Studio Version 6.2.0).

The significance level chosen for all statistical tests was $P \leq .05$.

RESULTS

The 20 patients comprised 13 women and 7 men with a mean age of 43 years (range, 21 to 65 years). In all patients, all anterior mandibular teeth (incisors and canines) were present and could be thermally tested preoperatively (n = 120). One hundred five teeth showed a positive reaction to CO_2, whereas 15 teeth tested negative (in 4 patients with a mean age of 52.5 years). None of these negative teeth had been endodontically treated.

Preoperative flux measurements (LDF) did not differ significantly between positive and negative teeth (Table 1). Across the different tooth types (canines vs lateral incisors vs central incisors), no significant differences were found for preoperative flux measurements (Table 2). However, when analyzed for effects over time, the mandibular left central incisor and the mandibular right lateral incisor showed a significant decrease ($P < .05$) of pulpal blood flow from preoperative to follow-up flux measurements.

At the 6-month follow-up evaluation, 93 teeth reacted positively to CO_2 again (group A). Twelve of the teeth that reacted positively preoperatively (11.4% of 105) exhibited a negative reaction (group B), and 15 teeth remained negative throughout the study (group C) (Table 3).

The postoperative and 6-month flux measurements showed clearly lower values for negative teeth (groups B and C) compared to positive teeth (group A) (Table 3). Group B demonstrated a statistically significant decrease of pulpal blood flow over the 3 time points. Groups A and C presented no significant changes; however, group C did not reach the level of significance due to the Bonferroni adjustment (Table 3). For postoperative and follow-up flux values, there were statistically significant differences between group A and groups B and C (Table 3).

The changes of flux measurements over time and per group are shown in Fig 4. Flux changes from preoperative to postoperative measurement were generally greater than flux changes from postoperative to 6-month follow-up measurements in groups B and C, whereas no such difference was seen in group A.

Table 1 Preoperative Flux Measurements in Perfusion Units (PU)

	Mean	SD	Range
CO_2 positive (n = 105)	7.72	2.80	1.5 to 15.3
CO_2 negative (n = 15)	7.25	4.61	1.8 to 15.8

Table 2 Preoperative and Follow-up Flux Measurements in PU per Group of Teeth (n = 120)

	Right mandible						Left mandible					
	Canine (n = 20)		Lateral incisor (n = 20)		Central incisor (n = 20)		Central incisor (n = 20)		Lateral incisor (n = 20)		Canine (n = 20)	
	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD	Mean	SD
Preoperative flux	7.69	3.40	8.59[a]	3.69	7.16	2.83	7.52[b]	2.76	7.10	2.69	7.93	3.03
Follow-up flux (after 6 months)	5.46	2.23	4.78[a]	1.97	6.14	3.24	5.92[b]	3.42	5.87	2.20	8.34	3.15

[a,b]Statistically significant difference ($P < .05$).

Table 3 Flux Measurements in PU per Group at 3 Time Points (n = 120)

	Group A (n = 93)		Group B (n = 12)		Group C (n = 15)	
	Mean	SD	Mean	SD	Mean	SD
Preoperative flux	7.83	2.79	6.88[a,b]	2.91	7.25	4.61
Postoperative flux	7.30[1,2]	3.53	4.71[1,a]	3.34	4.80[2]	3.99
Follow-up flux (after 6 mo)	6.71[3,4]	2.65	3.56[3,b]	1.89	4.23[4]	3.45

A = positive-positive, B = positive-negative, C = negative-negative.
[1–4]Statistically significant differences between groups A to C ($P < .005$).
[a,b]Statistically significant differences over time ($P < .005$).

Five of 20 patients (25%) presented with sensitivity changes of 1 or more mandibular anterior teeth at the 6-month follow-up. A significant number ($P < .01$) of the teeth that initially reacted positively to CO_2 demonstrated a negative reaction at the 6-month follow-up. An average of 0.6 teeth per patient remained negative at the 6-month follow-up.

DISCUSSION

The present clinical study evaluated and compared vitality testing by means of LDF to sensitivity testing by means of carbon dioxide snow (CO_2). In 20 patients undergoing bone harvesting from the symphysis, the mandibular canines and incisors were evaluated preoperatively, postoperatively (suture removal), and 6 months postsurgery.

At the initial examination, LDF measurements did not differ between CO_2-positive teeth (n = 105) and CO_2-negative teeth (n = 15). One explanation might be that aging teeth with sclerotic or partially obliterated pulp canals would respond negatively to thermal testing but still have some vascular supply, as documented by the LDF measurements. Although Ikawa et al[18] have demonstrated age-related changes of the pulpal blood flow measured by LDF, they could still record flux signals in all study participants. While young individuals (age < 20 years) had perfusion units from 2 to 6, elderly patients (age > 60 years) had perfusion units from 0.5 to 3. These findings are in agreement with a decrease of blood vessels and a reduction of the size and volume of the pulp with age.[19,20] On the other hand, the increase in calcified tissue may negatively affect pulpal blood flow measurements made with LDF by reducing the penetration of the laser beam.[21]

In the present study, teeth reacting positively to CO_2 at the 6-month follow-up showed only a slight decrease of pulpal blood flow postoperatively and during the follow-up period of 6 months (Fig 4). In contrast, teeth with a negative reaction to CO_2 at the 6-month follow-up as well as teeth testing negative throughout the study demonstrated a marked (although only statistically significant in group B) decrease in flux measurements postoperatively compared to preoperatively, and an additional slight decrease over time from the postoperative to the 6-month examination. Therefore, the present study demonstrated a correlation of the flux measurements to the changes of pulp sensitivity over time for teeth of group B.

Similar flux values were reported in a study[22] evaluating blood flow of premolar teeth under different pulpal conditions using the same LDF device used in the present study. Initial PU values of 11.2 dropped to 4.8 following extraction, induction of an ischemic pulp by cutting off the root apex, and replantation of the tooth. Analogous findings were also reported for traumatized teeth in which LDF measurements were compared to other clinical and/or radiographic diagnostic examinations.[22] Several studies have provided data to identify teeth at risk for pulp necrosis following tooth injury to initiate or postpone endodontic treatment.[6,9,23] In an animal study with reimplanted immature dog teeth, LDF diagnosis of vital teeth was correct in 74% of cases and LDF diagnosis of nonvital teeth was correct in 95%, with radiographic and histologic determination of revascularization.[24]

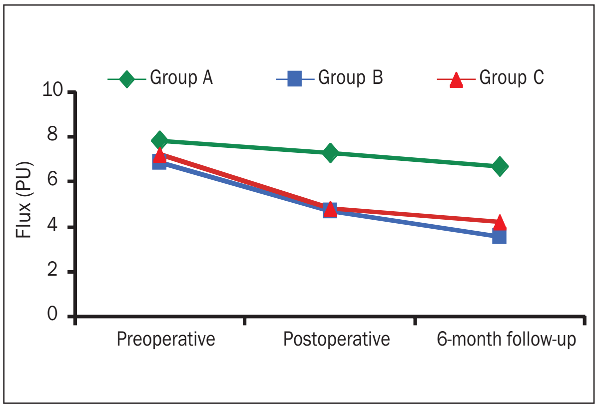

Fig 4 Flux measurements in PU by group.

It is difficult to analyze the results of group C (teeth with a preoperative negative reaction to CO_2), since these teeth showed a similar but insignificant decrease of pulpal blood flow over time compared to group B (Fig 4). The most logical explanation would be that these teeth underwent disruption of the vascular supply following bone harvesting similar to the teeth of group B. One can speculate that the surgeon, who was not blinded to the preoperative data, and who was aware of the preoperative negative reaction, may have tended to go closer with the bone cuts to these teeth than to teeth with a preoperative positive reaction to CO_2.

Since all groups of teeth showed a decrease of flux over the study period (Fig 4), the harvesting procedure in the symphysis appears to interfere with the vascular supply of the anterior mandibular teeth. The vascular supply of the anterior mandibular teeth is provided by *Rami dentales* from the anterior portion (ie, *Arteria incisiva*) of the *Arteria alveolaris inferior*. In addition, lingual anastomoses exist between the *Arteria incisiva* and the *Arteria sublingualis* via the *Rami interincisivi*, and with the *Arteria profunda linguae* via the *Ramus supragenoideus*.[25,26] Removal of corticocancellous bone blocks in the mental area might damage these blood vessels, depending on the posterior (length) and lingual extension (depth) of the donor site and on the distance to the apices of the adjacent teeth. In an animal experiment, Neukam et al[27] showed with microangiography that a minimum distance of 8 mm is required to preserve the blood supply of the anterior mandibular teeth following block osteotomy in the symphysis.

However, while sensitivity changes of anterior mandibular teeth are a frequent finding following bone harvesting in the symphysis, only a single case of pulp necrosis due to complete vascular damage has been reported.[2] For the individual patient, tooth sensitivity changes, whether temporary or permanent, are a nuisance; therefore, avoidance of this outcome must be addressed during treatment planning. A recent prospective clinical study[28] over a 1-year period showed a nearly complete recovery of sensitivity changes of anterior mandibular teeth following bone harvesting in the symphysis. However, 13 teeth in 30 patients had a negative reaction at the 6-month follow-up, comparable to 12 teeth in 20 patients in the present study. Extending the follow-up period to 1 year might yield more resolution, as shown by an earlier study by von Arx et al[28] in which only 1 tooth remained negative at the 1-year follow-up. Since only 7 of 20 patients complied with the 1-year follow-up in the present study, it was decided to include only LDF measurements up to 6 months after surgery.

The introduction of LDF in daily practice must be critically appraised. The equipment is expensive, and the LDF procedure is technique-sensitive and time-consuming.[6] The position of the patient may influence the flux measurements. Pulpal perfusion was found to be significantly higher in a supine compared to a standing or sitting position.[29] LDF may yield false-positive flux measurements in endodontically treated teeth.[9,30] Movement (whether caused by a distressed patient, a nonfixed probe, or a mobile tooth) or measurement of gingival blood flow may corroborate the detection of pulpal blood flow using LDF.[31,32] In contrast, false-negative flux measurements may be explained by the absorption or reflection of the laser beam due to irregular enamel surfaces, composite fillings, or changes of tooth color and dental hard tissues.[33] It has also been demonstrated that tooth morphotype has a significant effect on pulpal blood flow measurements using LDF, which explains intra- and interindividual variations of LDF measurements for different types of teeth.[34]

In a recent experimental study, the ability of the current generation of laser Doppler flowmeters to reliably assess the vitality of teeth was questioned due to contamination with back-scattered light from nonpulpal tissues, such as gingival and periodontal tissues.[35] The same authors also cast doubt on the use of nonvital teeth as controls, since the optical properties of pulp and dentin may change after pulp death, affecting the amount of light transmitted to tissues outside the tooth. LDF was used purely as an experimental tool in the present study.

CONCLUSIONS

In the present study, pulpal blood flow measurements using LDF demonstrated a decrease of flux over time in anterior mandibular teeth following bone harvesting in the symphysis. A significant change of flux was observed for teeth that initially reacted positively to CO_2 but showed a negative reaction at the 6-month follow-up. The study demonstrated a relatively high risk of pulp sensitivity changes, with 12 initially positive teeth in 20 patients testing negative to CO_2 at the 6-month follow-up (0.6 tooth per patient). Patients must be fully informed about the risk of pulp sensitivity changes and incomplete resolution over time.

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