Single Implants and Buccal Bone Grafts in the Anterior Maxilla: Measurements of Buccal Crestal Contours in a 6-Year Prospective Clinical Study

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ABSTRACT

Background: Patients provided with buccal bone grafts seem to lose a substantial part of the graft in the short term.

Purpose: To measure long-term changes in buccal and proximal tissue volumes after local bone grafting and single implant treatment.

Materials and Methods: Eight of 10 originally treated male patients were followed up for 6 years after treatment with buccal bone grafts in the central incisor region. After a healing time of 6 months, a two-stage implant surgery procedure was performed followed by single crown placement. Clinical photographs and impressions were taken prior to the surgical interventions and after crown placement and at first and fifth annual checkups. The photographs were analyzed with regard to papilla regeneration by means of a clinical papilla index. The models were used to measure the clinical length of teeth and tooth movements adjacent to the implants. Changes in buccal crest volume during the study period were measured by means of optical scanning of obtained study models.

Results: Papillae volume increased significantly ($p < .05$) during the first year, thereafter showing a slow further increase during the 4 following years. Three of the patients (38%) presented small movements of their adjacent central incisor in a vertical or palatal direction of less than 1 mm during the follow-up period. All patients showed resorption during the first year after grafting ($p < .01$), in which three patients (38%) had lost basically all of increased volume at second surgery. After abutment or crown placement, all patients showed an increased volume ($p < .01$), followed by an average reduction during the first year, reaching a significant level in the apical part of the crest ($p < .05$). Thereafter, a relatively stable average situation was observed during the following 4 years, with individual variations, however.

Conclusion: Local bone grafting seems to create sufficient bone volume for implant placement after 6 months, but individual variations in resorption pattern make the grafting procedure unpredictable for long-term prognosis. Instead, the abutment and the crown seem to play a more important role for building up and maintaining the buccal contour in the coronal part of the crest long term.

KEY WORDS: local bone grafts, papilla, resorption, single implants, tooth movements

Loss of teeth often results in resorption of the alveolar bone from the buccal aspect. This leaves a concavity that may compromise later implant treatment, thereby significantly compromising the esthetic outcome of the treatment. To deal with this problem, several procedures have been suggested to restore the alveolar process to allow for correct placement of the implants in edentulous areas.[1–18]

Autogenous bone blocks have been used in many studies, showing encouraging short-term results with regard to graft and implant survival.[9–18] In a recent study, we showed that labial bone grafts allowed for better placement of the implants and an improved esthetic result at the time of crown placement.[18] Accordingly, we showed that the buccal contour increased significantly in the edentulous area following bone grafting, allowing for optimal implant placement

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6 months later. However, we also showed significant bone resorption during the first year after grafting, followed by an increase in the buccal tissue volume after second-stage surgery and sequel crown placement. A slow further reduction in the buccal contour was thereafter reported during the 2 following years, raising the question of whether the remaining increase in volume after the grafting would persist in the long term.

The aim of this study was to measure changes in the buccal contour of the alveolar crest in bone-grafted areas up to 6 years after grafting has taken place and to report the 5-year clinical outcome of the simultaneously performed single implant treatment.

MATERIAL AND METHODS

Patients and Clinical Procedures

This is a prospective 6-year follow-up study on patients treated with single implant restorations after local bone grafting in the upper central incisor region. The patients have been accounted for in more detail in an earlier publication.[18]

Inclusion criteria were that the patients should be missing one central incisor in combination with having a labial bone defect, necessitating a local bone graft before placing a single implant in the edentulous area. From the start, 10 male patients were consecutively included into the study group.[18] Two of these patients failed to show up for the final checkup after 6 years and were consequently excluded. The remaining 8 patients presented a mean age of 26.3 years (SD 5.5 years) at the time of grafting, with ages ranging between 21 and 36 years. They were all healthy, had no ongoing medication, and were nonsmokers.

The healing time after tooth loss or extraction ranged from 1 to 33 months, with an average healing time of 17 months (SD 10.6 months) before the grafting procedure was performed.[18] Resin-bonded temporary restorations were used for six of the patients between the treatment stages from tooth extraction to insertion of the final implant crown restoration. The remaining two patients were using removable partial dentures during this period.

The bone grafting protocol was carried out on an outpatient basis under local anesthesia (2% Xylocain-Adrenalin®, AstraZeneca, Södertälje, Sweden) and oral sedation (Halcion®, Pharmacia Sverige AB, Sweden). After an incision in the vestibule, a bone block of about 1×2 cm was harvested from the symphysis region of the mandible.[12,14,18] This graft was placed with the buccal cortical layer outward and secured by means of microscrews to the buccal cortex of the alveolar crest in the recipient area of the maxilla (Figure 1). Bone particles were packed around the block graft to fill out empty spaces. After soft tissue closure, the area was allowed to heal for an average of 27 weeks (SD 3.9 weeks) before implants were placed according to a standardized two-stage surgical protocol.[18,19]

At the time of single implant placement, one Mk II and seven standard Brånemark System® implants (Nobel Biocare AB, Göteborg, Sweden) were placed according to standard surgical procedures.[18,19] The implants were allowed to heal for an average of 32 weeks (SD 9.0 weeks) before standard healing abutments were attached (Nobel Biocare AB). Final impressions were made directly at implant level by means of an implant transfer coping (Nobel Biocare AB) about 2 weeks after abutment surgery. Porcelain-fused-to-metal single crowns were cemented to CeraOne® single abutments (Nobel Biocare AB) at an average of 5 weeks (SD 1.6 weeks) after abutment surgery.[18] Seven of the crowns, provided with palatal access holes,[18,20] were cemented extraorally to the abutment and then connected to the implant, whereas the remaining crown was cemented intraorally.[18,20] After one postinsertion clinical checkup, the patients were scheduled for annual control appointments after 1, 2, 3, and 5 years, respectively.

Measurements and Registrations

Measurements and registrations have been accounted for in more detail in an earlier publication.[18] Clinical

Figure 1 Clinical situation with local bone graft secured by means of miniscrews in the right central incisor area.

photographs were taken at the different stages of the treatment and at the annual examinations. The clinical photographs at placement of the crowns and during follow-ups (first and fifth years) were used to analyze size changes in the soft tissue papillae, adjacent to the single implant restorations, by means of a papilla index described by Jemt.[21]

Intraoral apical radiographs were taken at abutment connection, at crown placement, and after the first, third, and fifth years in function. The radiographs were analyzed with regard to the presence of pathology, signs of mechanical complications, and marginal bone level changes in relation to the fixture/abutment junction (FAJ).

At follow-up appointments, clinical evaluation involved assessments of the condition of the peri-implant mucosa, the stability of implants and crown restorations, and any signs of problems or complications related to the treatment.

Impressions for study casts were included in the follow-up protocol.[18] Care was taken that the study casts well reproduced the buccal vestibulum of the upper anterior jaw. Impressions were made prior to the bone grafting procedure ($n = 8$). Four patients showed up with loose resin-bonded prostheses 4 to 5 weeks after grafting had taken place. For these patients, casts were also made at this early stage ($n = 4$). According to the protocol, casts were then made prior to implant insertion ($n = 8$), before abutment connection ($n = 8$), and at the time of crown placement ($n = 8$). One patient failed to show up for the first annual checkup ($n = 7$), but all patients were examined and casts were made at the final fifth annual examination ($n = 8$). These study casts were used for measurements of the clinical length of the upper anterior teeth (measured with a digital caliper to the closest 0.1 mm). They were also used for assessments of possible tooth movements close to the implant restorations and for measurements of buccal mucosa contours of the jaw in the grafted area by means of the scanning technique described below.

For measurements of changes in the mucosa volume, the study casts were placed in an optical three-dimensional scanner (Atos, GOM International AG, Widen, Switzerland), as has been accounted for in more detail.[18] The scanner measured the surfaces of the models by projecting different light fringe patterns onto the object, which were recorded by two video cameras. The pixels from the images of the two cameras were then calculated to three-dimensional coordinates with a calculated three-dimensional accuracy of 150 to 200 microns for this setup.

The first study cast, made prior to bone grafting, was used as the reference for the other casts.[18] Accordingly, the three-dimensional images of the other models were, one by one, superimposed onto the reference model in the computer. Thereby, sagittal planes could be placed through the central part of the edentulous area of the central incisor, presenting the tissue contour of the reference model in relation to the different follow-up models.[18] A horizontal reference line was placed in the computer through the estimated gingival/crown margin of the digitalized model at crown placement. Parallel lines were placed in an apical direction with an interline distance of 2 mm, thereby creating sections of 2 mm–wide areas at various levels of the crest.[18] Via the computer, the lines were then orientated in the same positions for all of the models using the reference model as a base. The area created between two of the lines and the contour of the reference model and the superimposed model at the different follow-up situations were measured in square millimeters.[18] These areas were referred to as ''volume,'' and changes between these were compared throughout the study period, indicating changes in volume.

Statistics

Changes in volumes between the different stages of treatment were tested by means of the Wilcoxon signed rank test. Significant tests were two-tailed and conducted at the 5% significance level.

RESULTS

It was generally more difficult to establish a good fit between teeth than implant crowns and the palatal contour of the different measurements (Figure 2, A and B).

The patients exhibited sufficient amounts of bone for implant placement, but the bone volume at the implant head level was macroscopically found to be reduced at the time of abutment connection compared with at the time of implant placement. No complications were observed in relation to the bone grafting, in relation to the implant insertion protocols, or during the follow-up period. However, some patients showed various levels of oral hygiene maintenance during the follow-up period.

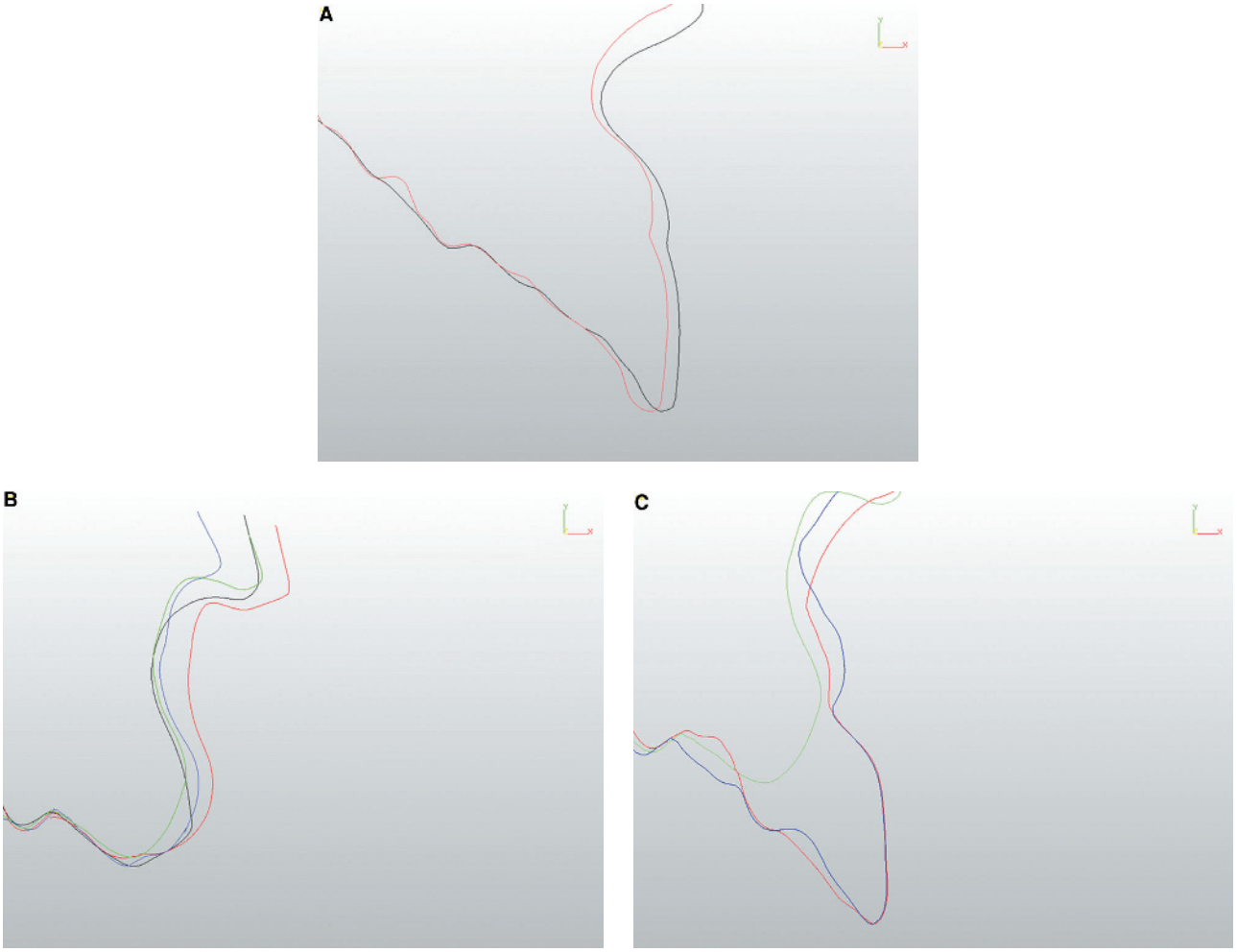

Figure 2 *A*, Sagittal presentation of the contour of the crest in the midsection of the left central incisor tooth in a 31-year-old male patient (patient G) before the grafting procedure (*black line*) and 6 years later (*red line*). Notice the palatal movement of the tooth (0.7 mm), which has caused a corresponding reduction in the volume of the crest, apical to the crown-mucosa margin. *B*, Sagittal presentation of the contour of the crest in the midsection of the edentulous area of the right central incisor of the same patient (patient G) at the time before the grafting procedure (*black line*), 5 weeks after grafting (*red line*), before implant placement 6 months later (*blue line*), and before abutment placement (*green line*). The increased contour showed a maximum horizontal volume of 2.2 mm 5 weeks after grafting (*black-red lines*). The contours at the time of abutment connection and before grafting (*black-green lines*) coincide, indicating that the increased volume is lost. *C*, Sagittal presentation of the contour of the crest in the midsection of the edentulous area of the right central incisor (patient G) at the time before abutment connection (*green line*), at the time of crown placement (*blue line*), and 5 years later (*red line*). Notice the increased volume after crown placement (*green-blue lines*) and the coronal reduction in the volume during the 5-year follow-up (*red-blue lines*). Notice also the good fit between the red and blue lines for the ancylotic implant crown compared with *A*, where the adjacent tooth has moved.

No signs of pathology or mechanical complications were observed in the radiographs obtained during the study period. Bone levels were, on average, 1.2 mm (SD 0.40 mm) below the FAJ at crown placement. At the first and fifth annual checkups, the marginal bone levels were, on average, 1.4 mm (SD 0.58 mm) and 1.5 mm (SD 0.56 mm) below the FAJ, respectively. The corresponding intraindividual bone loss was, on average, 0.2 mm (SD 0.23 mm) and 0.3 mm (SD 0.24 mm) from crown placement to the first and fifth annual examinations, respectively. The bone loss ranged within the group from 0 to 1.7 mm after 5 years of clinical function.

The papilla index scores ranged from 0 to 2 at the time of crown placement and from 1 to 3 at the follow-up appointments. The increase in papillae size reached a significant level from placement to first year at both the mesial and distal sides ($p < .05$). Thereafter, only an insignificant ($p > .05$) further increase in papilla volume could be observed during the remaining follow-up period.

TABLE 1 Measurements of the Clinical Length of Implant Crowns, Anterior Incisors, and Right Canine Teeth

	Mean (SD) Crown Length (mm)				
	Right Canine	Adjacent Lateral Incisor	Implant Crown	Central Incisor Tooth	Contralateral Lateral Incisor
Before grafting	10.3 (1.41)	9.0 (1.41)		10.3 (0.92)	8.9 (1.57)
Crown placement	10.3 (1.36)	9.2 (1.69)	11.0 (0.95)	10.3 (0.72)	9.0 (1.53)
First annual appointment	10.2 (1.58)	9.8 (1.09)	11.0 (1.17)	10.5 (0.85)	9.0 (1.72)
Fifth annual appointment	10.4 (1.46)	9.4 (2.04)	11.1 (1.20)	10.4 (1.01)	9.0 (1.71)
Distribution of teeth with regard to change in mm, from crown placement to fifth annual appointment					
> + 0.9		2			
+0.6 to +0.9			2	1	1
+0.3 to + 0.5	1		1	1	
± 0.2 mm	6	5	3	5	4
−0.3 to −0.5	1	1	2	1	3

Implant crowns to central incisors, $p < .05$ at crown placement.
Adjacent lateral incisor, $p < .01$ between before grafting and first annual appointment.

The measurements of the length of the clinical crowns are presented in Table 1. Implant crowns were longer than the contralateral central incisor teeth, reaching a significant difference level at the time of placement of the implant crowns ($p < .05$). The length of the permanent teeth showed small average variations between the different observation stages, however, with a weak trend of developing longer clinical crowns during the study period. The lateral incisors adjacent to the implant crown, however, showed a significant increase in their clinical length from before the grafting procedure to the first annual checkup ($p < .01$).

Buccal volumes at the different stages of treatment in relation to the initial buccal contour at the implant site (before grafting) are given as mean values in Table 2 and as mean overall values for all individual patients in Table 3. It can be observed that the mean buccal contour was significantly increased before implant placement ($p < .01$) compared with before bone grafting (see Table 2). Thereafter, the mean buccal contour was

TABLE 2 Mean (SD of mean) Volume (mm^2) Measured from before Grafting to the Different Stages of Treatment

	Mean Area (Volume) at Different Stages of Treatment (mm^2)						
Level of Crest below Crown Margin (mm)	Before Grafting ($n = 8$)	Early Healing ($n = 4$)	Before Implant ($n = 8$)	Before Abutment ($n = 8$)	Crown Placement ($n = 8$)	After 1 Year ($n = 7$)	After 5 Years ($n = 8$)
Coronal							
0–2	0	3.35 (1.03)	2.17** (1.19)	1.17** (1.50)	3.62** (1.43)	3.40 (1.35)	3.58 (1.54)
2–4	0	5.27 (1.48)	3.78** (1.45)	2.40* (1.84)	4.62** (1.72)	3.48 (1.32)	3.65 (1.34)
Apical							
4–6	0	6.85 (1.52)	5.30** (1.68)	3.12** (2.11)	5.14** (2.26)	3.47* (1.33)	3.47 (1.58)
Total							
0–6	0	15.5 (3.85)	11.3** (3.78)	6.7** (5.34)	13.4** (5.16)	10.4 (3.47)	10.7 (4.09)

The measurements are given for different levels of the crest and as a total measurement for the different stages.
Comparing the volume between crown placement and 5 years of clinical follow-up showed a significant reduction in the mid- (2–4 mm; $p < .05$) and apical part (4–6 mm; $p < .01$) of the crest.
Statistical change in volume compared with the preceding observations, $*p < .05$, $**p < .01$.

TABLE 3 Measured Volume at the Different Stages of Treatment for Individual Patients

	Mean Area (Volume) at Different Stages of Treatment (mm^2)						
Patient	Before Grafting	Early Healing	Before Implant	Before Abutment	Crown Placement	After 1 Year	After 5 Years
A	0		13.7	8.1	15.7	14.4	9.9
B	0	21.1	13.9	13.7	19.4	12.5	13.9
D	0	13.8	13.2	7.1	10.4	7.2	6.7
E	0	14.4	11.6	0.6	3.8	6.4	5.7
F	0		3.6	−0.5	9.8	9.2	8.8
G	0	12.6	8.5	2.4	14.7	8.1	8.8
J	0		15.2	12.1	18.6	14.8	17.6
K	0		10.2	10.0	14.6		14.0
Mean	0	15.5	11.3	6.7	13.4	10.4	10.7
SD	0	3.85	3.78	5.34	5.16	3.47	4.09

The measurements are given as a mean for the three levels from 0 to 6 mm.

significantly reduced up to the time of abutment surgery ($p < .05$–$p < .01$), followed by a significant increase in the mean volume at crown placement ($p < .01$). Only small changes in the mean values were observed after crown placement, reaching a significant level of reduction ($p < .05$) for the apical part of the crest (4 to 6 mm apical of the crown/mucosa junction) after 1 year in function (see Table 2).

Compared with before abutment surgery, slightly more tissue volume was present at the termination of the study at the apical part of the crest (4–6 mm; $p > .05$), whereas significantly more tissue was present at the midpart (2–4 mm; $p < .05$), and much more volume was present at the coronal part of the crest (0–2 mm; $p < .01$). A similar pattern was observed for the situation between before implant surgery and the termination of the study, indicating less volume present at the apical part of the crest (4–6 mm; $p < .05$) and more volume present at the coronal part of the crest (0–2 mm; $p < .01$) at the end of the study.

The buccal contour showed individual patterns of increase after grafting and crown placement, as well as individual levels of reduction in the volume during healing after implant surgery and crown placement (see Table 3). Even though all patients showed an increased buccal volume before implant placement, three of the patients (38%) had basically lost all of this volume increase at the time of abutment surgery (see Figures 2B and 3A), whereas others still had an obvious increase in volume present (Figures 4, 5A, and 6). Thereafter, again, all patients showed an increase in volume in association with abutment surgery and sequel crown placement (see Figures 2C, 3B, 4, 5B, and 6). This increase was, on average, more or less maintained during the following 5 years in the coronal part of the crest, whereas a more pronounced reduction in the volume was observed in the apical part (see Figures 4 and 5B). Two patients showed almost a complete loss of the increased apical volume (see Figures 2C and 3B). Another three patients had an increase in buccal volume of 2.0 to 3.5 mm in a buccal direction after 6 years, all along the buccal contour of the entire crest down to at least 10 mm below the crown-mucosa margin (see Figures 5B and 6).

DISCUSSION

In accordance with other studies,[14,16] the present report clearly showed that it was possible to establish a substantial initial increase in bone volume by means of local autogenous bone grafting of maxillary central incisor single tooth gaps, thereby allowing for optimal implant placement (see Table 3). However, also in accordance with earlier reports,[14,22] a significant reduction in the created tissue volume was observed already during the early healing and before implant placement. A further significant reduction in the volume continued during the following half-year before abutment connection. After abutments and crowns had been placed, all patients showed a significant increase in tissue volume in the grafted area, almost of the same magnitude as after grafting.[18] After an initial reduction, this increase seemed to be stable in volume during the

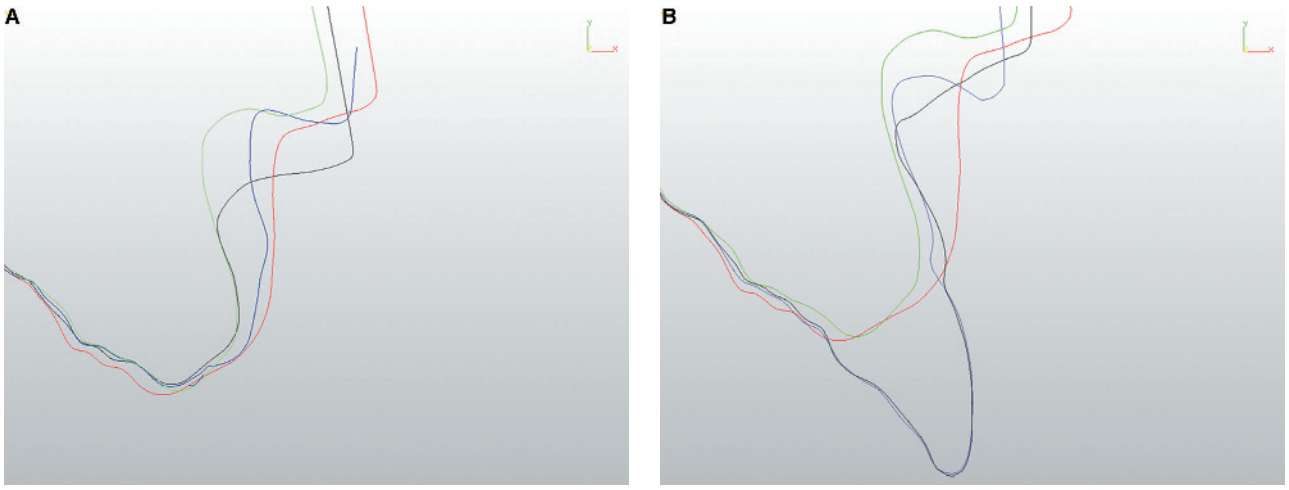

Figure 3 *A*, Sagittal presentation of the contour of the crest in the midsection of the edentulous area of the right central incisor (patient E) at the time before grafting (*black line*), 3 weeks after grafting (*red line*), before implant placement (*blue line*), and before abutment connection (*green line*). Notice the loss of increased buccal contour at the time of abutment connection, where the contour before grafting and before abutment surgery coincides. *B*, Sagittal presentation of the contour of the crest in the midsection of the edentulous area of the right central incisor (patient E) at 3 weeks after grafting (*red line*), before abutment connection (*green line*), at the time of crown placement (*blue line*), and 5 years after crown placement (*black line*). Notice the obvious resorption of the graft (reaching 3.8 mm in a horizontal direction), the increase in volume at crown placement, and the relatively stable situation between crown placement and the 5-year follow-up (*blue-black lines*). Notice also that the buccal volume has increased after crown placement at the crown margin (owing to poor oral hygiene).

following 5-year period. Consequently, bone grafting seems to be of restricted value for long-term buildup of the crest for esthetic reasons. Instead, the placement of abutments and crown restorations per se seemed to have a more profound and long-lasting effect on the maintenance of the buccal and coronal volume of the crest. Using custom-made abutments would presumably provide even better support for the tissue compared with the standard abutment components that were used in this study.[20]

An individual pattern of response to the grafting procedure could be seen in the present group. In some patients, the buccal volume increase disappeared more or less completely up to abutment connection surgery (see Figures 2B and 3A), whereas in others, the increased volume remained almost intact throughout the study (see Figure 6). Consequently, individual variations (see Table 3) existed in the resorption and remodeling patterns in this group of patients. It is also of interest to note that even in those patients in whom there had been a complete loss of increased volume before abutment connection (38%), these patients still showed almost the same amount of buccal volume increase after abutment or crown placement. This increase could even remain more or less the same over the years independent of how the bone remodeling had turned out during the first year (see Figures 2C and 6). It is also of interest to notice that two (possibly three) patients seemed to have maintained their increase in buccal volume at the termination of the study, attributed rather to the early bone grafting than to the later added volume after abutment or crown placement (see Figures 5B and 6). Accordingly, a major part of the

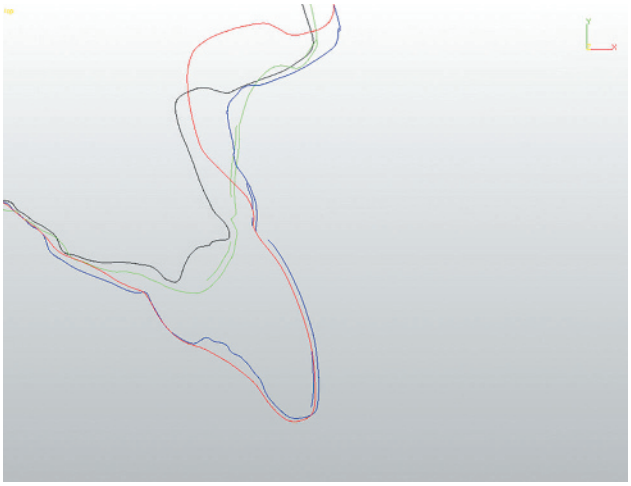

Figure 4 Sagittal presentation of the contour of the crest in the midsection of the edentulous area of the left central incisor (patient A) at the time before grafting (*black line*), before abutment connection (*green line*), at crown placement (*blue line*), and 5 years later (*black line*). Notice the increase in volume at crown placement and the continuous reduction in the volume in the apical part of the crest. Still, an obvious amount of increased volume is present after 6 years.

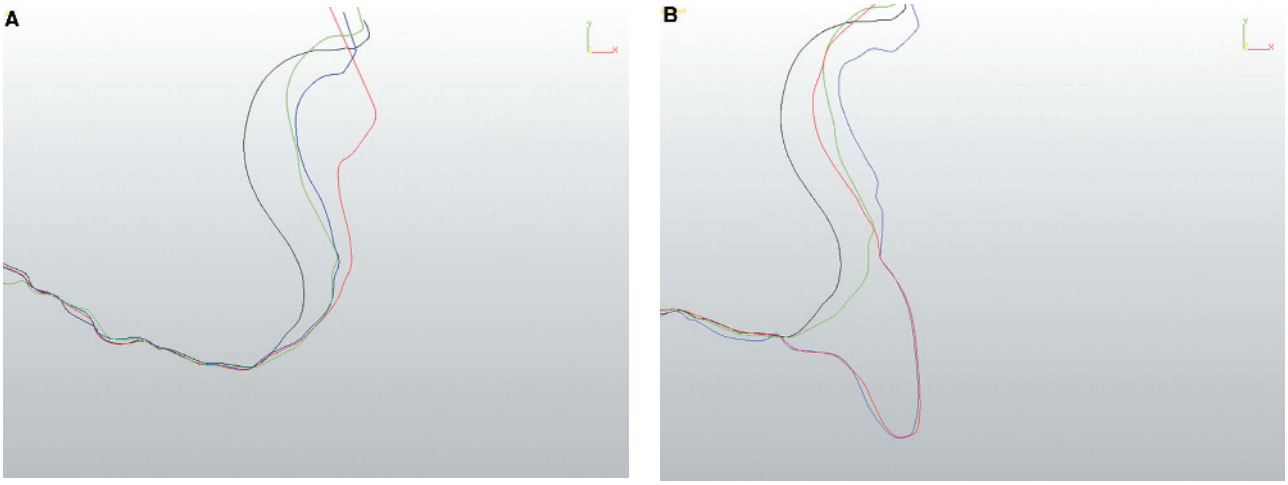

Figure 5 *A*, Sagittal presentation of the contour of the crest in the midsection of the edentulous area of the left central incisor (patient B) at the time before grafting (*black line*), 4 weeks after grafting (*red line*), before implant surgery (*blue line*), and before abutment connection (*green line*). Notice that even though resorption has taken place, an increased volume is still present at the abutment connection (*black-green lines*). *B*, Sagittal presentation of the contour of the crest in the midsection of the edentulous area of the left central incisor (patient B) at the time before grafting (*black line*), before abutment connection (*green line*), at crown placement (*blue line*), and 5 years later (*red line*). Notice the increased volume at crown placement and the resorption during the following 5 years. Notice also that an increased volume is still present after 6 years (*black-red lines*), reaching a thickness of 1.8 mm.

graft may have remained up to 6 years after grafting in some patients. However, in two patients, a specific decrease in the apical volume took place, indicating bone resorption during the last 4 years. Consequently it may also be possible to experience remodeling of bone grafts more than 2 years after grafting has been performed (see Figures 4 and 5B).

Even though resorption was observed, the present grafting procedure has shown that it is possible to increase the buccal volume in the edentulous single gap area (see Table 2). However, when comparing the clinical length of the implant crown with the contralateral central incisor, it was observed that the implant crown was significantly longer than the permanent tooth. This indicates that grafting may restore some of the buccal volume that is lost after tooth extraction, but it seems to be much more difficult to build up the crest also in a vertical dimension. The problem with maintenance of the vertical height can be reflected in the significant increase in the clinical length of the adjacent lateral incisor that took place from the grafting procedure to the first annual checkup after crown placement ($p < .01$). The risk of mucosal recession at the adjacent teeth owing to several surgical interventions is obvious and should be considered when planning for local grafts.

In summary, it was found that bone grafting of single tooth gaps could create good initial bone volumes for implant placement. The patients showed obviously different patterns of resorption and remodeling after grafting, and it was not possible to observe a consistent response in the group. All patients showed a significant increase in buccal volume after abutment or crown placement, which, after some initial shrinkage,

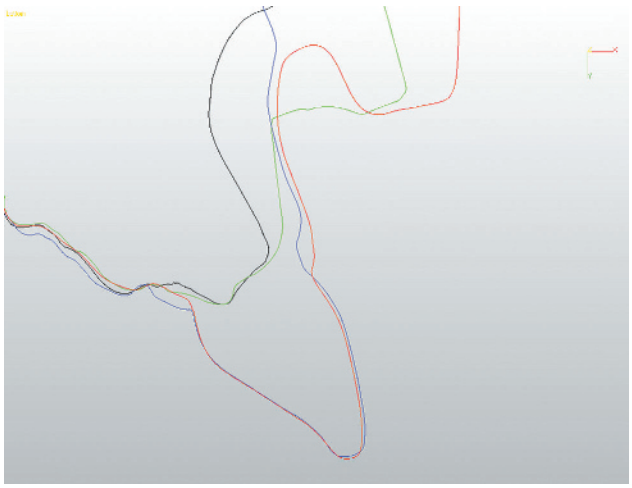

Figure 6 Sagittal presentation of the contour of the crest in the midsection of the edentulous area of the right central incisor in a 21-year-old male patient (patient K) at the time before grafting (*black line*), before abutment connection (*green line*), at crown placement (*blue line*), and 5 years later (*red line*). Notice the increased volume at crown placement, the slightly reduced volume after crown placement, and that an obvious amount of increased volume is still present after 6 years. The persistent increase in the buccal contour within the coronal 10 mm area of the crest varied from 2.2 to 3.4 mm.

in many patients was maintained in the coronal part during the follow-up period. Furthermore, several patients showed reduced volume in the apical part of the crest after crown placement, indicating further slow resorption of the graft. It was also observed that the local bone grafting failed to restore the crest in a vertical direction, resulting in significantly longer clinical implant crowns compared with the contralateral incisors. Eventually, it was observed that, besides resorption, other reasons for change in buccal volumes might be present in the long term (see Figure 2A). However, the prevalence and impact of these tooth movements should be analyzed in other studies.

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