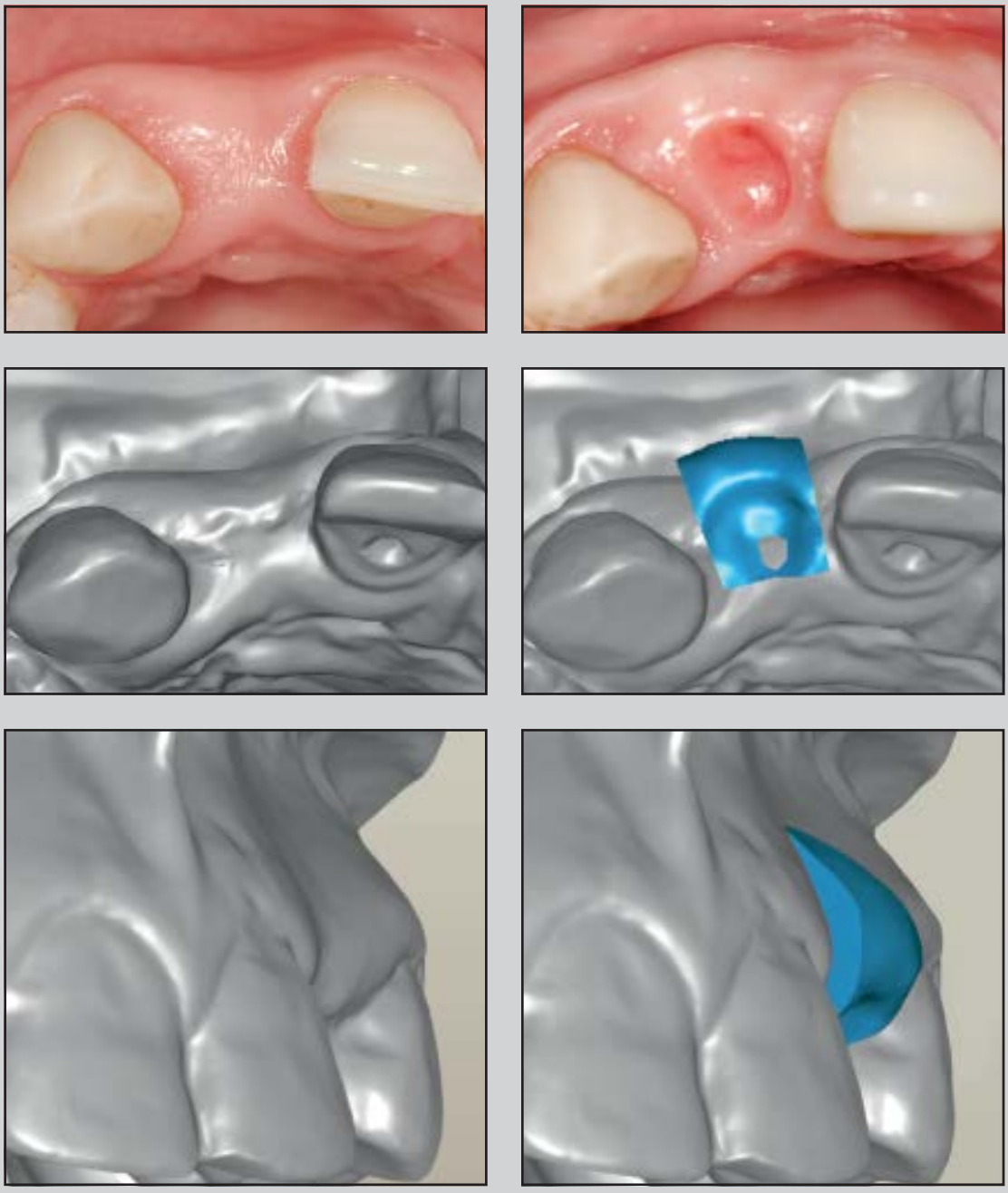

Quantitative Three-Dimensional Methodology to Assess Volumetric and Profilometric Outcome of Subepithelial Connective Tissue Grafting at Pontic Sites: A Prospective Pilot Study

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The aim of this study was to describe a technique for the assessment of soft tissue volumetric and profilometric changes. The technique has been applied at the alveolar contour of mild to moderate horizontal ridge defects after soft tissue augmentation at pontic sites. A quantitative three-dimensional (3D) analysis based on laser scanning was used for the measurement of volume gain and horizontal changes of alveolar profile 5 months after a subepithelial connective tissue graft using a pouch approach in five patients. All the surgical sites healed uneventfully. A mean soft tissue volume increase of 35.9 mm³ was measured 5 months after the grafting procedure. The linear measurements showed that, in the area where the augmentation was performed, the distance between the preoperative vestibular profile and the postoperative one ranged from 0.16 to 2 mm. The described quantitative measurements based on 3D laser scanning appear to be an effective method for assessment of soft tissue changes in future studies. Additionally, within the limitation of a small sample size, the present data suggest that the investigated surgical technique can be considered when corrections of mild to moderate alveolar horizontal ridge atrophies at maxillary lateral incisor edentulous gaps are necessary.
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The amount of bone resorption following the extraction of a tooth is substantial.[1] Compared to the original width, the orofacial dimension reduces by approximately 30% during the first 3 months of healing and by 50% after 12 months.[2] An animal model showed how marked osteoclastic activity leads to resorption of the crestal region of both the buccal and the lingual bone walls.[3,4]

Due to this physiologic process of bone resorption, defects ranging from loss of root prominence to loss of crest width and height may arise. As a result, an esthetic compromise might occur when a fixed prosthesis is planned, especially in the anterior zone.

Different techniques have been proposed to enhance the alveolar contour of an edentulous segment that is to be restored with a pontic. In the treatment of mild or moderate horizontal ridge defects[5] soft tissue reconstruction seems sufficient. On the other hand, severe defects may require several surgical procedures or hard tissue augmentation.[5–7]

Subepithelial connective tissue grafting appears to be superior in terms of volume gain, esthetics, and long-term stability compared with full-thickness free gingival grafts.[8] Nevertheless, little information is available regarding a combination of this type of graft with a minimally invasive pouch procedure without vertical incisions.

Soft tissue measurement is receiving increasing attention in the evaluation of treatment outcomes.[9] Although traditional methods such as photographs, direct visual assessment, and transgingival probing have limitations due to reduced accuracy, practicability, and clinical indications, emerging laser scanning technology allows easier and quantitative three-dimensional (3D) assessment of soft tissue changes following therapy.[9]

The aim of this prospective pilot study was to report a method to assess changes in soft tissue volume and profile by quantitative 3D volumetric analysis based on laser scanning. In particular, the method will be applied to evaluate the outcome of a pouch procedure combined with a subepithelial connective tissue graft in the region of missing maxillary lateral incisors.

Method and materials

Five consecutive patients presented with a missing maxillary lateral incisor and a fully healed edentulous gap (Figs 1a and 1b). Patients were treated from May 2010 to May 2012 by a single operator. The treatment plan aimed at delivering a prosthesis incorporating an ovate pontic in the lateral incisor position. After the diagnostic phase, confirming the presence of a moderate horizontal facial resorption of the edentulous area corresponding to Seibert Class I,[10,11] the need for ridge contour augmentation was determined. Conversely, no need for vertical augmentation was identified. Such anatomical conditions have been described as being best treated by a subepithelial connective tissue graft in conjunction with a horizontal pouch technique to enhance the horizontal volume at the deficient site.[12]

All recruited patients met the following inclusion criteria: *(1)* awareness of dental esthetics, *(2)* no probing pocket depths greater than 4 mm, *(3)* no bleeding on probing, *(4)* no tooth mobility greater than Miller Class I,[13] and *(5)* no plaque accumulation at the two teeth adjacent to the edentulous gap.

All patients agreed to the planned procedure and signed an informed consent form.

Surgical technique

A horizontal partial-thickness crestal incision was made and extended facially and apically to create a recipient pouch through the entire length of the deficiency. The incision avoided the gingival sulcus of the adjacent teeth. A subepithelial connective tissue graft of dimensions adequate to the defect was obtained from the palate according to the single-incision palatal harvest technique[14] (Fig 1c). The graft was introduced inside the pouch, and one nonresorbable single suture was used to anchor its position at the recipient site. Extra stitches were used to close the pouch (Figs 1d and 1e). Patients rinsed with a 0.2% chlorhexidine solution twice a day for 30 seconds during the first 10 days, and 500 mg mefenamic acid was administered three times a day for at least 4 days. Patients were prescribed 500 mg amoxicillin once a day for 7 days. Sutures were removed 7 days after surgery, and teeth were professionally cleaned. Recall sessions occurred at 1, 3, and 5 months after surgery and included periodontal examination, professional tooth cleaning, and photographic documentation.

Surgically corrected ridge defects were protected from chewing by either a provisional fixed partial denture or a provisional removable prosthesis. The dimensions of all provisional pontics were reduced to compensate for any inflammatory swelling of the augmented area during the first week of wound healing, thus avoiding any potential compression. The study protocol required postponing conditioning of the augmented ridge for the initial 5 months. Subsequently, conventional procedures for tissue conditioning at the pontic site were started (Figs 1f to 1h).

Volumetric assessments

Polyvinyl siloxane impressions (Express 2, 3M Espe) were taken before soft tissue augmentation and after a period of 5 months. An experienced laboratory technician who was aware of the study purpose fabricated a

Fig 1a *Preoperative intraoral view. A mild to moderate defect is present in the edentulous gap.*

Fig 1b *Preoperative occlusal view. The area must be prepared to receive the planned pontic restoration and to compensate for the soft tissue defect.*

Fig 1c *Connective tissue graft is obtained from the palate using a single incision approach.*

Fig 1d *Minimally invasive surgical pouch procedure.*

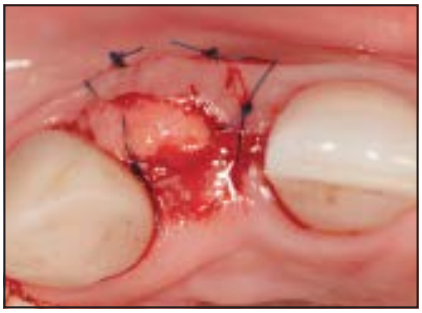

Fig 1e *Single sutures are used to secure the graft in the pouch. Observe partial exposure of the connective tissue graft.*

Fig 1f *Occlusal postoperative view after tissue conditioning. Notice how the augmentation favored the ovate pontic design.*

Fig 1g (left) *One-week follow-up evaluation after the cementation of an adhesive partial denture to replace the lateral incisor and a laminate veneer in the canine position. (Courtesy of Giovanna Vaglio, DMD.)*

Fig 1h (right) *One-year follow-up evaluation. Increased height of the papilla adjacent to the ovate pontic can be observed when compared with Fig 1g.*

dental cast from each impression. Casts were then scanned with a three-dimensional (3D) laser scanner (D250, 3Shape). The .stl files obtained from each model subsequently were transferred to a digital shape sampling and processing software for re-elaboration of 3D models from the 3D scan data (Geomagic Studio, Geomagic; Figs 2a to 2g). For each patient, presurgical and postsurgical models were superimposed, based on a procedure that relies on best matching of manually selected surfaces. Therefore, on each model, at teeth mesial and distal to the edentulous space, vestibular and palatal surfaces of similar extension were selected. The software was then able to perform an automatic alignment and superimposition in one coordinate system of the two models, based on the best match of these selections. Best-fit alignment used 300 randomly selected points to get an initial orientation. Next, the

Fig 2a *Digital preoperative model after scanning and importing to the software.*

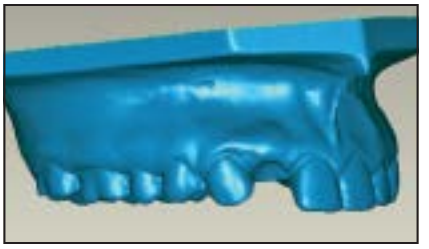

Fig 2b *Five-month postoperative digital model.*

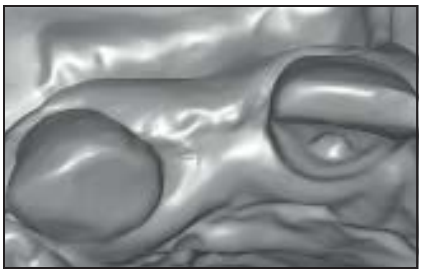

Fig 2c *Occlusal view of the scanned preoperative model.*

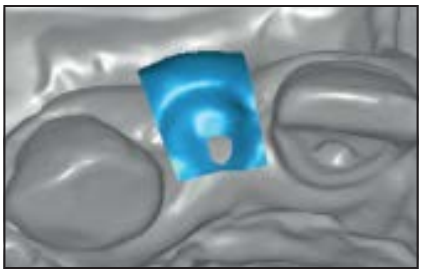

Fig 2d *Occlusal view of the soft tissue volume gain superimposed to the preoperative model.*

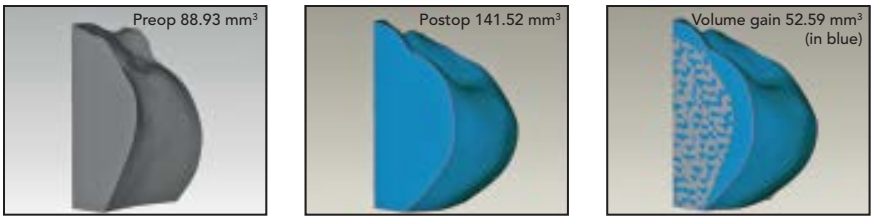

Fig 2e (left) *Preoperative (preop) volume at a patient's region of interest. This area of interest differed from patient to patient but was constant for each patient over the two time points evaluated.* (center) *Corresponding postoperative (postop) volume.* (right) *Superimposition of both volumes. The increase of ridge contour is noticeable (solid blue).*

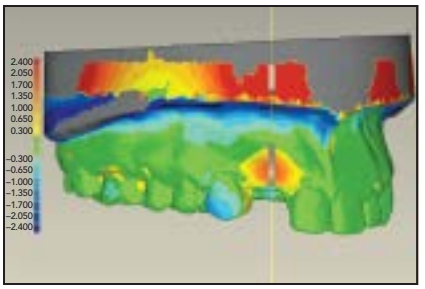

Fig 2f *Digital model obtained after superimposition. Green areas represent perfect model alignment and superimposition. The evaluated surgical area showed volumetric changes as evident from the color scale. The range from yellow to red represents different sizes of volume increase, while from light to dark blue represents a decrease in volumes. Note change in color in the area receiving the grafting. The plane where the two models are subjected to the two-dimensional comparison is also visible in the middle of the edentulous gap .*

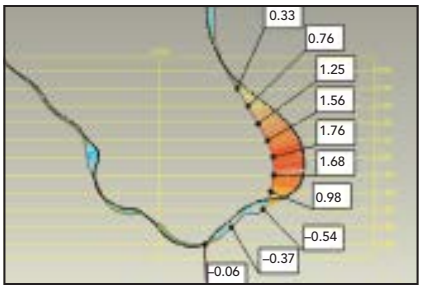

Fig 2g *Two-dimensional comparison of the superimposed models on the middle of the edentulous gap, perpendicular to the alveolar crest. The linear distance between the pre- and postoperative soft tissue profile was measured in mm. Such measurements, beginning at the top of the crest, were repeated each mm for 10 mm in an apical direction.*

sample size was automatically increased to 1,500, and a further fine adjustment was performed to achieve the final alignment (see Fig 2f). The merged models were then saved as a .wrp file and assessed with inspection software for graphic comparison of digital models (Geomagic Qualify, Geomagic). Prior to measurements, the presurgical model was set as reference, while the postsurgical model was set as test. For each patient, in order to assess the augmentation outcome, an area of interest at the vestibular aspect of the edentulous gap was defined, and the volume change at this area was evaluated (see Figs 2c to 2e). Because of the individual anatomical variation in each patient, the area of interest differed slightly from patient to patient, but it was identical for each patient over the two time points evaluated. In addition, for each superimposed set of models two-dimensional labiopalatal sections were obtained in the middle of the edentulous gap, perpendicular to the alveolar crest. Subsequently, the linear distance between the preoperative and postoperative soft tissue profile was measured and, beginning at the top of the crest, was repeated each mm for 10 mm in an apical direction (see Fig 2g).

Statistical analysis

Straightforward descriptive statistics were used to present the changes in the soft tissue profile before and after surgery.

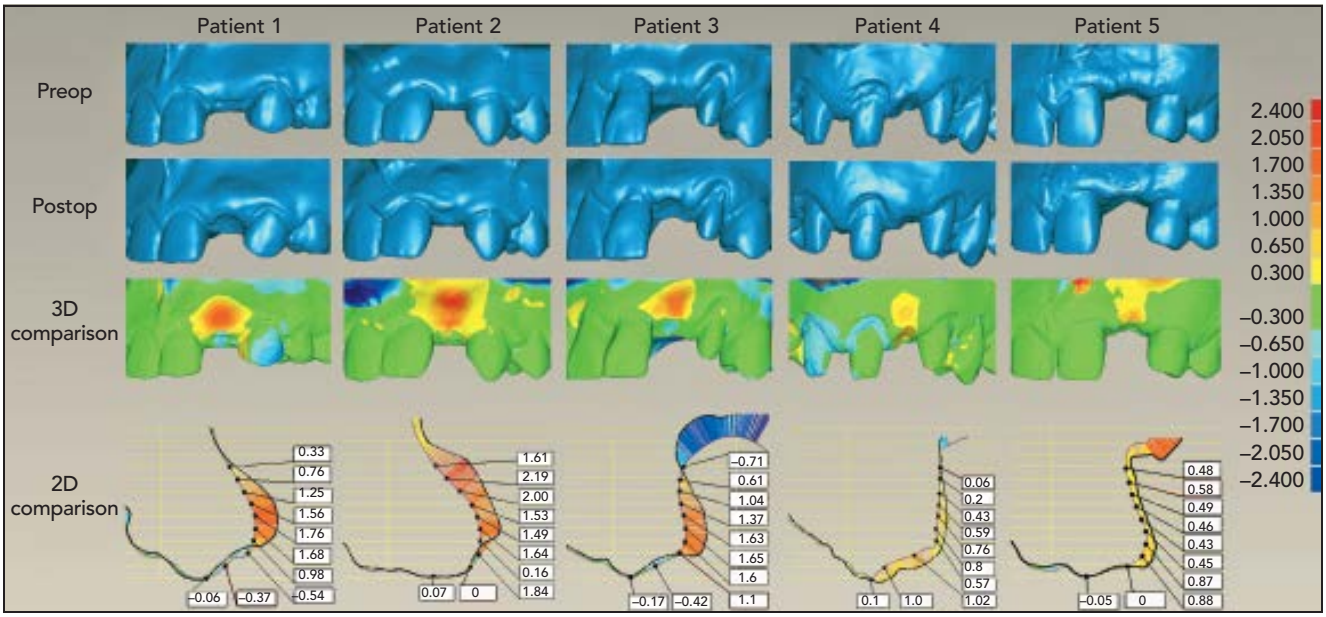

Fig 3 *Details of the preoperative (preop) and postoperative (postop) models showing the area subjected to soft tissue augmentation. Model superimposition and two-dimensional (2D) section evaluating the middle of the edentulous gaps are also shown. Note that for display purposes images have been mirrored; however, both right and left incisors were included.*

Results

All surgical sites healed uneventfully and received the planned restoration, and the patients were satisfied with the esthetic outcome. Five months after the grafting procedure the mean soft tissue volume increase was 35.9 mm^3 (range: 12.8 to 52.59 mm^3). A gain in soft tissue volume was registered for all the patients (Table 1 and Fig 3); however, in one patient this gain was minimal. The linear measurements displaying the distance between the preoperative and postoperative vestibular profiles are shown in Table 2 and Fig 3. Measurements were divided to distinguish changes in the 5 mm directly involved in the graft from the first few millimeters apical and coronal to it. The distance between the preoperative vestibular profile and the postoperative one ranged from 0.16 to 2.00 mm in the grafted area (see Table 2 and Fig 3).

Table 1 **Labial volume (mm^3) measured before and 5 months after placement of the subepithelial connective tissue graft**

Patient	Preoperative	Postoperative	Volume increase
1	88.93	141.52	52.59
2	204.88	254.22	49.34
3	135.25	171.85	36.60
4	172.24	200.62	28.38
5	276.00	288.80	12.80
Mean	175.46	211.40	35.94
SD	70.87	59.97	16.20

Discussion

Volumetric analysis of oral tissues has evolved from rough visual inspection[12,15,16] to more complicated optical projection analysis based on the Moiré method[7] and recently to 3D evaluation based on laser scanning technology.[17–19] The accuracy of the scanner employed in this study was ±6 μm, and its repeatability was ±10 μm. It was judged suitable for application in the digital manufacturing workflow of fixed dental prostheses.[20] It also seems of interest that the data provided by the scanner were evaluated entirely by commercially available software. In fact, linear and volumetric analysis by laser scanning has been, even

Table 2 **Linear measurements (mm) showing the distance between the preoperative and postoperative vestibular profiles**

	Patient 1	Patient 2	Patient 3	Patient 4	Patient 5	Mean	SD
Crestal area							
1	–0.06	0.07	–0.17	0.10	–0.05	–0.02	0.11
2	–0.37	0.00	–0.42	1.00	0.00	0.04	0.57
3	–0.54	1.84	1.10	1.02	0.88	0.86	0.87
Augmented area							
4	0.98	0.16	1.60	0.57	0.87	0.84	0.53
5	1.68	1.64	1.65	0.80	0.45	1.24	0.58
6	1.76	1.49	1.63	0.76	0.43	1.21	0.58
7	1.56	1.53	1.37	0.59	0.46	1.10	0.53
8	1.25	2.00	1.04	0.43	0.49	1.04	0.64
Apical area							
9	0.76	2.19	0.61	0.20	0.58	0.87	0.77
10	0.33	1.61	–0.71	0.06	0.48	0.35	0.84

recently, considered limited to university studies.[9] However, hardware and software for such analysis might become increasingly accessible in the future. The accuracy of the software used has been tested by the US National Institute of Standards and Technology (NIST) and the German physical and technical standardization organization (PTB). The results of NIST tests showed that the software was accurate to less than 10^{-4} µm in position and radius and 10^{-4} arcseconds (1/36,000 of a degree) in angle of tilt compared with the official reference values.[21] PTB stated that the software was accurate to less than 0.1 µm in length and 0.1 arcseconds in angle compared with the official reference value.[22]

Although several techniques have been described for pontic site augmentation,[12,15,23,24] there is limited information in the current literature concerning the results of these different procedures.[25] A possible reason for this lack of data is the number of limitations when quantitatively assessing soft tissue topography intraorally by conventional means.[9]

The outcome of the horizontal pouch technique here assessed by quantitative 3D volumetric measurements clearly showed a soft tissue volume gain 5 months after the surgical procedure. Quantitative measurements first focused on the evaluation of the volume change at the esthetically relevant area. However, from a clinical point of view, these volumetric changes are difficult to interpret, and this volume could also be gained in an area that has no benefit for the final prosthetic appearance. Therefore, it seemed of interest to measure the horizontal gain in millimeters between the pre- and postoperative ridge contours. For this reason, a plane was defined to vertically intersect the superimposed models at the most deficient ridge areas (see Fig 2f). Two-dimensional profile changes were then evaluated for 10 mm, starting at the top of the edentulous ridge. It seems that the augmentation resulting from the horizontal pouch technique is concentrated from the fourth to the eighth millimeter. Regardless of the somewhat localized augmentation achieved here, an ovate pontic could be created in all five cases evaluated (see Fig 3). The finding that the first 3 mm remained mostly unchanged after the procedure is due to the localization of the pouch incision and seems to be in agreement with Garber and Rosenberg, who proposed this technique only in cases of horizontal ridge defects.[12] The horizontal contour gain in the present study ranged from 0.16 to 2 mm in the fourth to eighth millimeter area, which corresponds to the area where the augmentation focus was concentrated. The relatively modest augmented volume in patient 5 could be explained by the limited thickness of the connective tissue obtainable from the hard palate[26] and by the pouch design. Presurgical examination of the soft tissue palate thickness by means of transmucosal sounding to assess the graft availability is highly recommended. In cases of limited thickness, a different donor site should be evaluated (eg, tuberosity area). Also, the limited extension of the horizontal incision and the absence of vertical releasing incisions restricted the displacement of the recipient pouch. Therefore, the present data seems to confirm that the technique is adequate for corrections of mild to moderate Class I[10,11] alveolar ridge deformities at single-tooth edentulous gaps.

The volumetric evaluation performed in this study is noninvasive, free of radiation, and does not require much equipment; it can be easily performed with a laser scanner and suitable software. On the other hand, as a drawback, some inaccuracy might be incorporated during the impression procedure as well as during cast fabrication. Direct digital impressions by an intraoral scanner could eliminate the need for a plaster cast and thus overcome such drawbacks, making the entire assessment of the soft tissue anatomy more easily applicable in the clinical setting. With continuous advancements in digitized dental workflows, it is foreseeable that the described technique of comparison of intraoral contours and volumes may find various other uses and be applied to data derived from direct digital impressions or 3D bone models generated by cone beam computed tomography.

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