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The effect of immediate implant placement on alveolar ridge preservation compared to spontaneous healing after tooth extraction: Soft tissue findings from a randomized controlled clinical trial

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Abstract

Aim: To compare soft tissue dimensional changes and relative differences in soft and hard tissue volumes 4 months after single-tooth extraction and three different treatment modalities: spontaneous healing (SH) and alveolar ridge preservation by means of a deproteinized bovine bone mineral and a collagen matrix, with (IMPL/DBBM/CM) or without (DBBM/CM) immediate implant placement.

Materials and Methods: STL files from study casts obtained at baseline and after 4 months were matched to calculate buccal soft tissue linear and volumetric changes. DICOM files from CBCTs were superimposed to STL files allowing the evaluation of soft tissue thickness at baseline and 4 months.

Results: Mean horizontal reduction accounted for 1.46 ± 0.20 (SH), 0.85 ± 0.38 (DBBM-CM) and 0.84 ± 0.30 IMPL/DBBM-CM, with no statistical differences. Soft tissue thickness had a significant mean increase of 0.95 for SH group, compared to a non-significant mean decrease for DBBM-CM (0.20) and IMPL/DBBM-CM groups (0.07).

Conclusion: A preservation technique with DBBM-CM, with or without immediate implant placement, did not reduce the horizontal linear and volumetric changes at the buccal soft tissue profile significantly at 4 months after tooth extraction when compared to spontaneous healing. This is due to a significant increase in soft tissue thickness in spontaneously healing sites.

KEYWORDS
alveolar ridge preservation, immediate implant placement, soft tissue changes, STL file, tooth extraction

ClinicalTrials.gov ID: NCT03422458

1 | INTRODUCTION

Dimensional changes observed after tooth extractions not only relate to changes in bone morphology but also to those occurring at the surrounding soft tissue architecture (Pietrokovski & Massler, 1967). Marked alterations of the soft tissue after tooth extraction have been described in the past. Schropp et al. (2003) observed a loss of volume in the horizontal dimension that seems to amount to 5–7 mm within the first 12 months, approximately corresponding to 50% of the original width of the alveolar crest.

This may jeopardize the functional and aesthetic outcome of any dental treatment following tooth extraction: both tooth replacement with an implant-supported fixed prosthesis and a traditional fixed partial denture with a pontic.

Different systematic reviews have confirmed the efficacy of an alveolar ridge preservation (ARP) technique in preventing post-extraction dimensional changes in the alveolar ridge (Ten Heggeler et al. 2011; Vignoletti, Matesanz, et al., 2012; Vittorini Orgeas et al., 2013, Horvath et al., 2013; De Risi et al., 2015, MacBeth et al., 2017; Clementini et al., 2015, Avila-Ortiz et al., 2019), and very recently, a consensus report on this topic (Tonetti et al., 2019) stated that an ARP with an application of a bone grafting material attenuates the physiological dimensional changes that typically follow tooth extraction.

However, clinical research related to dimensional change after tooth extraction has mainly focused on the biology of bone, while the impact of soft tissue healing on bone modelling and dimensional changes in post-extraction sites have received little attention. The investigation of soft tissue volumetric changes in future RCTs was strongly recommended in the latest consensus report on the management of the extraction sockets and timing of implant placement (Tonetti et al., 2019).

In recent years, the introduction of soft tissue volumetric analysis using optical scanning and STL image superimposition has allowed the evaluation of changes in tissue contours around teeth and implants (Benic et al., 2012). This validated technique showed a high reproducibility and an excellent accuracy for measuring volumetric changes with a measurement error below 10 mm (Mehl et al., 1997; Windisch et al., 2007).

Different studies utilized this methodology to investigate the impact of different treatment strategies aimed to counteract dimensional changes after tooth extraction.

Thalmair et al. (2013) investigated soft tissue contour changes after tooth extraction and different alveolar ridge preservation (ARP) surgical procedures. The authors demonstrated that the use of a xenogenic bone substitute, with or without a free gingival graft, was not able to entirely compensate for the alveolar ridge reduction. Covering the orifice of the extraction socket using a free gingival graft, with or without application of a filler material, was able to somewhat limit the post-operative external contour shrinkage. Another clinical trial on different ARP techniques (Jung et al., 2013) revealed less bone loss in grafted sites compared with extraction alone. Despite that, no significant soft tissue contour changes were observed (Schneider et al., 2014), which implies that soft tissue changes do not seem to completely follow the changes at the alveolar bone level and there are thicker soft tissues in non-grafted sites.

In recent years, the superimposition of DICOM data from CBCT and STL methodology gave insights in experimental and clinical research to better understand the dynamics of tissue healing in a three-dimensional way. Furthermore, this technology allowed to discern the hard and soft tissue inter-play and the reciprocal role that they may have (Sanz-Martin et al., 2017; Sanz-Martin, Encalada, et al. 2019; Sanz-Martín, Permuy, et al., 2018). Chappuis et al. (2015), evaluating the fate of buccal soft and hard tissues 8 weeks after extraction and before delayed implant placement, observed that soft tissue profile did not follow the pronounced resorption pattern of the underlying bone anatomy. The authors reported a 7.5-fold increase in soft tissue thickness after tooth extraction in patients with a thin biotype and concluded that a rapidly resorbing thin buccal plate favoured soft tissue ingrowth and therefore increased soft tissue thickness.

Very recently, Clementini et al. (2019) investigated the effect of immediate implant placement on alveolar ridge preservation when compared to alveolar ridge preservation alone or spontaneous healing of the socket. Based on radiographic linear measurements from CBCT, the authors demonstrated the effectiveness of the alveolar ridge preservation technique, independently of the insertion of the implant, on the reduction of the hard tissue dimensional changes that occurred after spontaneous healing of a tooth extraction. The presence of baseline three-dimensional hard (CBCT) and soft tissue (STL) data allows for the possibility of studying the dynamic changes in tissues over time, so the aim of this report was to compare soft

Clinical relevance

Scientific rationale for the study: The impact of dimensional soft tissue alterations in post-extraction sites has received little attention in clinical research. Moreover, the relative contribution of the soft and hard tissues to the total volume and their mutual inter-play is poorly understood.

Principal Findings: Alveolar ridge preservation, with or without immediate implant placement, reduced labial soft tissue dimensional changes 4 months after tooth extraction when compared with spontaneous healing. However, differences between treatment modalities were not statistically significant. Soft tissue thickness had a significant increase after 4 months of spontaneous healing.

Practical Implications: On a soft tissue level, treatment modality may be considered less critical in terms of contour alterations than focusing on the preservation of alveolar bone. Spontaneous healing provides an increased amount of keratinized mucosa. Future research with longer follow-up may assess if this would have an impact on type 2, 3 or 4 implant placement.

tissue dimensional changes 4 months after single-tooth extraction and to compare the relative differences in soft and hard tissue volumes following 3 different treatment modalities: spontaneous healing (SH) and alveolar ridge preservation with (IMPL/DBBM/CM) or without (DBBM/CM) immediate implant placement.

2 | MATERIALS AND METHODS

2.1 | Study design

This report is based on a prospective controlled, randomized, clinical study (Clementini et al., 2019) performed according to the CONSORT statement (http://www.consort-statement.org/). The study and relative procedures and materials were approved by the local ethics committee (REF: 14-034, 24/07/2015) and monitored following the Good Clinical Practice. The trial was registered at http://www.clinicaltrials.gov/ (REF: NCT03422458).

2.2 | Population

The study population consisted of subjects seeking care at the Dental Clinic of San Raffaele Hospital, Vita-Salute University, Milan, Italy, between January 2016 and January 2018. All patients signed a written informed consent, according to the ethical principal of Declaration of Helsinki on experimentation involving human subjects, as revised in 2008.

2.2.1 | Inclusion criteria

- Adult patients (>18 years old) requiring extraction (for caries, fracture, prosthetic reasons) of one upper or lower single-rooted tooth (incisor, canine) or premolar.
- Presence of adjacent (mesial and/or distal) natural teeth.
- The presence of an intact extraction socket (evaluated after a flapped tooth extraction), with a coronal margin of the buccal bone crest that deviated ≤1 mm from the coronal margin of the lingual bone crest and ≤3 mm from the mesial and/or distal interproximal bone crest (evaluated on the pre-operative CBCT).
- Systemically healthy patients not smoking more than 10 cigarettes/day.
- Patients with adequate oral hygiene (FMPS <25%) and periodontal health (FMBS <10% and absence of PPD >4 mm with BoP) (Lang & Bartold, 2018).

2.2.2 | Exclusion criteria

- Uncontrolled diabetes (HbA1c > 7), osteoporosis or any other systemic or local disease or condition that would compromise post-operative healing.
- Patients with a history of malignancy, radiotherapy or chemotherapy for the treatment of malignancy.
- Pregnant patient or intending to become pregnant or nursing at the time of study inclusion.
- Patients taking medications or having treatments with an effect on healing in general (e.g. steroids, large doses of anti-inflammatory drugs, bisphosphonates).

2.3 | Sample size

Sample size was calculated in a previous report (Clementini et al., 2019) published by the authors. Ten subjects for each group were included, based on data from Jung et al. (2013) for the variable HW-1C, respectively, for the spontaneous healing group (−3.3 ± 2) and DBBM-C/CM group (−1.2 ± 0.8). The effect size of 1.4 was used to determine the sample size based on a two-independent sample Mann–Whitney test (two-tailed) with a significance level alpha set equal to 5% and power equal to 80%. GPower software, v. 3.1, was used.

2.4 | Randomization process and allocation concealment

A person not involved in the study prepared a computer-generated randomization list. After tooth extraction, an opaque sealed envelope was opened and the allocation in one of the three groups accomplished.

2.5 | Treatment procedures

Details of the surgical procedures are reported in Clementini et al., 2019. In brief, after the elevation of a full-thickness flap and atraumatic tooth extraction with granulation tissue removal, the integrity of the bone plates was assessed and patients were randomly assigned to:

- Test group (IMPL/DBBM/CM): immediate implant placement (TTi WINSIX®, BioSAFin, Ancona, Italy), plus a collagenated bovine bone mineral (Geistlich Bio-Oss Collagen; Geistlich Pharma AG, 6110 Wolhusen, Switzerland) grafted into the gap up to the buccal bone crest, sealed with a collagen porcine matrix (Geistlich Mucograft Seal; Geistlich Pharma AG).
- Control group (DBBM/CM): collagenated bovine bone mineral (Geistlich Bio-Oss Collagen; Geistlich Pharma AG, 6110 Wolhusen, Switzerland) grafted into the socket up to the buccal bone crest, sealed with a collagen porcine matrix (Geistlich Mucograft Seal; Geistlich Pharma AG).
- Negative control group (SH): spontaneous healing.

Patients were provided with oral hygiene instructions (rinsing twice a day, starting the day after surgery, with 0.2% chlorhexidine) and drug prescriptions (1 g of Augmentin twice a day for 6 days and Ibuprofen 600 mg, if needed, for analgesic use). When requested, a temporary crown (a mesial or distal cantilever of an adjacent pre-existing temporary crown or a Maryland bridge) was delivered without any direct contact with the soft tissues, in order to not interfere with the healing process.

Sutures were removed 7 days after the surgical procedures. Patients then followed their individual maintenance programme according to the individual periodontal and caries risk assessment. Four months after the surgery, all patients were recalled for a follow-up.

2.6 | Clinical measurements

The following clinical parameters were assessed by a single-blinded calibrated examiner (A.A.): full-mouth plaque score (FMPS) (O'Leary et al., 1972), full-mouth bleeding score (FMBS) (Muhlemann & Son, 1971) and keratinized tissue height (KTH) were recorded with a periodontal probe (PCP UNC 15, Hu-Friedy) at baseline and 4 months. Moreover, tissue thickness (TT clinical) was assessed at baseline and 4 months, as described in Clementini et al., 2018.

2.7 | STL image acquisition

For each patient, dental impressions were obtained using a polyether impression material (Impregum™ Penta™, 3 M ESPE Dental Products, Seefeld, Germany) at two different time points: after tooth extraction at the end of the surgical procedure (Baseline, BL) and 4 months after surgery (4 M). Afterwards, cast models were made with dental stone (Zeus Stone®, Zeus®, Industria Zingardi S.r.l., Novi Ligure, Italy) and optically scanned using a 3D scanner (CEREC Omnicam, Dentsply Sirona, York, PA, United States) in order to be digitized for creating stereolithography (STL) files.

2.8 | Soft tissue linear and volumetric measurements

STL file superimposition and soft tissue dimensional change measurements were performed by one calibrated and blinded examiner (V.C.), adopting a methodology similar to the one reported by Sanz-Martín, Encalada, et al. (2019). BL and 4 M STL files of each patient were superimposed and matched using a digital volume comparison software program (SMOP, Swissmeda AG, Zurich, Switzerland) (Figure S1). After importing the STL files of dental models (BL and 4 M) to the software, the matching of STL files was made by defining corresponding point pairs from the occlusal tooth surfaces of the BL and 4 M digital models and then the software automatically aligned the models.

Superimposed STL files were used to assess linear and volumetric soft tissue dimensional changes which occurred after 4 months of healing following the three different treatment modalities (IMPL/DBBM/CM; ARP DBBM/CM; and SH):

- Linear soft tissue contour changes were assessed on the superimposed models using the cross section representing the mesio-distal centre of the edentulous crest, in order to carry out linear measurement. Using an image analysis software program (ImageJ, National Institutes of Health, Maryland, USA), three parallel lines were drawn at 1, 3 and 5 mm below the most coronal point of soft tissue contour at BL and horizontal linear measurements were performed. The linear horizontal soft tissue contour changes were calculated by subtracting the horizontal measurement of the alveolar soft tissue width at BL to the 4 M measurement and were expressed in mm (total horizontal 1, 3, 5 mm). The linear buccal soft tissue contour changes were calculated by measuring the horizontal linear distance between the buccal soft tissue contour at BL to 4 M and were expressed in mm (buccal horizontal 1, 3 and 5 mm).
- Volumetric buccal soft tissue changes were analysed with the same software program used for STL files superimposition (SMOP, Swissmeda AG, Zurich, Switzerland), manually selecting a well-defined area on the surface corresponding to the BL cast, after superimposing BL and 4 M digital models. According to Schneider et al. (2014), this area was delimited apico-coronally by the gingival margin and the mucogingival line and mesio-distally by the middle of inter-dental papillae. Subsequently, the software automatically computed the mean linear distance in mm (MD) and the volume change in mm^3 (volume) between BL and 4 M buccal surfaces of the selected area.

2.9 | Soft tissue thickness measurements (DICOM–STL image superimposition)

STL file of the soft tissue profile at BL and 4 M was superimposed to the DICOM files of the hard tissue, respectively, at BL and 4 M using the same software program used for STL files superimposition (SMOP, Swissmeda AG, Zurich, Switzerland), as described in Sanz-Martin et al., 2017; Sanz-Martin, Encalada, et al. 2019; Sanz-Martín, Permuy, et al., 2018. Using an image analysis software program (ImageJ, National Institutes of Health. Maryland, USA), a common vertical axis was selected for both the BL and 4 M cross-sectional images; then, the buccal tissue thickness was assessed by measuring the distance between the buccal bone and the buccal soft tissue profile perpendicularly to the vertical axis at 1, 3 and 5 mm below the most coronal point of soft tissue contour at BL and 4 M (TT digital 1, 3 and 5).

All superimpositions of CBCT and STL images and measurements of were made by a single calibrated examiner (V.C) who superimposed and measured, 24 h apart, baseline and 4 months images of three different cases not included in the study.

2.10 | Statistical analysis

Observed values were summarized by means and standard deviations. In order to assess soft tissue linear and volumetric differences among groups, a one-way ANOVA allowing for different variances was used. In order to assess differences within groups, a paired t test was performed. At the same manner, the soft tissue thickness changes at 4 months with respect to the baseline measurements were investigated in each treatment group. All *p*-values were then adjusted for false discovery rate (FDR). All the analyses were performed using R statistical software (R Development Core Team, 2016). The significance threshold was set at 0.05.

3 | RESULTS

From January 2015 to January 2018, a total of 30 subjects were recruited, randomized and included in this clinical trial: 10 allocated to the SH group, 10 allocated to DBBM-CM group and 10 allocated to IMPL/DBBM-CM group, respectively (Figure S2).

No significant differences between groups were observed when analysing baseline characteristics (Table 1). Clinical outcomes were reported in Clementini et al., 2019.

3.1 | Soft tissue linear changes

Table 2 reports data on linear soft tissue dimensional changes at 1, 3 and 5 mm apical to the most coronal soft tissue margin (Figure 1). All groups demonstrated a horizontal reduction in the dimensions of the bucco-lingual tissue contours. Although a tendency towards less reduction was observed in the two test groups, no statistically significant differences were observed. A similar trend was observed at the buccal aspect, although a statistically significant change was observed at 5 mm. The reduction at this level was 1.66 ± 0.26 mm. 1.02 ± 0.31 mm, and 0.85 ± 0.26 mm in SH, DBBM-CM and IMPL/DBBM/CM group, respectively (Figure 2).

3.2 | Soft tissue volumetric changes

Soft tissue volumetric changes at the buccal aspect are reported in Table 2. All groups showed a volumetric reduction in both mean linear distance (MD) and volume changes (Figure 3). Differences between groups were not significant, despite a tendency to a minor reduction was observed for the two test groups.

3.3 | Soft tissue thickness changes (DICOM–STL image superimposition)

Only tissue thickness at 3 and 5 mm could be assessed, due to the absence of bone at 1 mm below the most coronal point of soft tissue contour (Figure 4). After 4 months of healing, at 3 mm the soft tissue thickness demonstrated a significant mean increase of 0.95 ± 0.24 mm for SH group ($p < 0.05$), whereas test groups demonstrated a non-significant decrease. Differences in soft tissue thickness changes at 3 mm between control and test groups were statistically significant, with SH group resulting in higher tissue increase than DBBM/CM ($p < 0.05$) and IMPL/DBBM/CM ($p < 0.05$) groups. No differences were observed at 5 mm (Table 3). A cumulative frequency of tissue thickness in the three groups is presented in Table S1.

4 | DISCUSSION

This randomized clinical study reported on the soft tissue volumetric changes occurring after three different surgical procedures performed at the time of tooth extraction: spontaneous healing (SH) and alveolar ridge preservation, with (IMPL/DBBM/CM) or without (DBBM/CM) immediate implant placement.

TABLE 1 Baseline demographic and clinical data of included patients

Baseline characteristics	Spontaneous healing	DBBM-CM	IMPL/ DBBM-CM
Age (years)	50.5 (12.2)	55.5 (11.6)	52.5 (7.5)
Male/female	7/3	4/6	3/7
Maxilla/mandible	8/2	6/4	8/2
	5/5	5/5	6/4
Reason for extraction (endo/fracture/ prosthetic/root resorption)	5/1/4	5/2/2/1	4/3/2/1
FMPS (%)	15.3 (1.3)	15.1 (1.9)	14.9 1.5)
FMBS (%)	8.9 (0.4)	8.3 (0.6)	8.6 (0.5)
KTH (mm)	2.70 (1.25)	3.70 (0.95)	4.00 (1.41)
TT clinical (mm)	1.40 (0.57)	1.30 (0.59)	1.30 (0.42)
Ridge width 1 mm	10.97 (0.94)	10.97 (0.77)	10.94 (0.49)
Ridge width 3 mm	14.10 (0.72)	13.85 (1.50)	13.48 (1.38)
Ridge width 5 mm	15.87 (0.70)	14.00 (1.01)	15.26 (2.02)

Abbreviations: FMBS, full-mouth bleeding score; FMPS, full-mouth plaque score; KTH, keratinized tissue height; TT clinical, tissue thickness clinically measured.

TABLE 2 Linear and volumetric soft tissue changes over 4 months among the three treatment modalities

Changes	Spontaneous healing Mean (SD)	DBBM-CM Mean (SD)	IMPL/ DBBM-CM Mean (SD)	*p*-value
Buccal horizontal 1 mm	−1.50 (0.23)	−0.80 (0.27)	−0.72 (0.23)	0.20
Buccal horizontal 3 mm	−1.48 (0.29)	−0.83 (0.29)	−0.75 (0.26)	0.20
Buccal horizontal 5 mm	−1.66 (0.26)	−1.02 (0.31)	−0.85 (0.27)	0.006
Total horizontal 1 mm	−2.60 (0.32)	−1.60 (0.27)	−1.66 (0.25)	0.13
Total horizontal 3 mm	−2.79 (0.31)	−1.42 (0.30)	−1.55 (0.48)	0.16
Total horizontal 5 mm	−3.21(0.34)	−1.94 (0.26)	−1.91 (0.26)	0.16
MD (mm)	−1.46 (0.20)	−0.85 (0.38)	−0.84 (0.30)	0.89
Volume (mm^3)	42.57 (17.36)	33.99 (9.55)	32.50 (11.69)	0.86
Area (mm^2)	40.31 (11.74)	39.60 (9.53)	39.95 (8.84)	1

Note: MD: mean linear distance between the two STL surfaces.

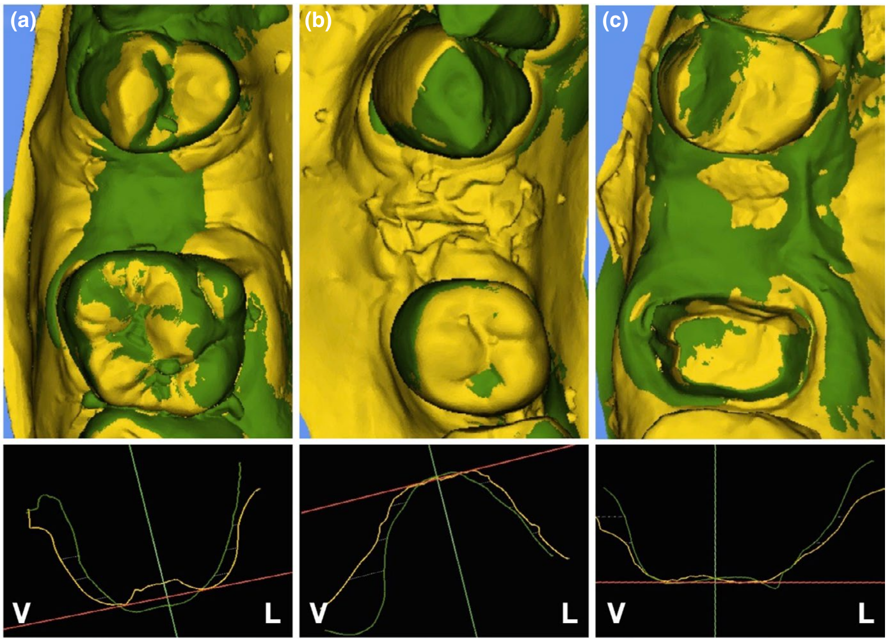

FIGURE 1 Occlusal view of superimposed models and linear measurements of soft tissue changes. (a) Spontaneous healing, (b) DBBM-CM and (c) IMPL/DBBM-CM

Linear and volumetric measurements using STL data demonstrated that after 4 months a more pronounced reduction in the ridge contour for spontaneous healing compared to alveolar ridge preservation technique was found, irrespectively of the insertion of an immediate implant. Nevertheless, differences were not significant in the most coronal aspect. This should b interpreted as an effect of the small sample size of each group. The only statistically significant difference between test groups (ARP with or without immediate implant placement) and control group (natural healing) was observed for linear measurement 5 mm apical to the most coronal soft tissue margin at the labial site. This may be explained by the relative absence at this level of keratinized tissue that may compensate for hard tissue resorption (Chappuis et al., 2015).

Apart from this observation, no significant differences were found in linear and volumetric changes between test group and control group at the most coronal area. This is in accordance with a recent randomized control clinical trial (Thalmair et al., 2013) demonstrating that different alveolar ridge preservation techniques were not able to entirely prevent soft tissue contour alterations 4 months after tooth extraction. A possible explanation may be the mean thickness of the buccal bone wall at the extraction sites in this study, which was always greater than 1 mm. In a recent RCT comparing ARP with SH (Tomasi et al., 2018), grafting the socket with a

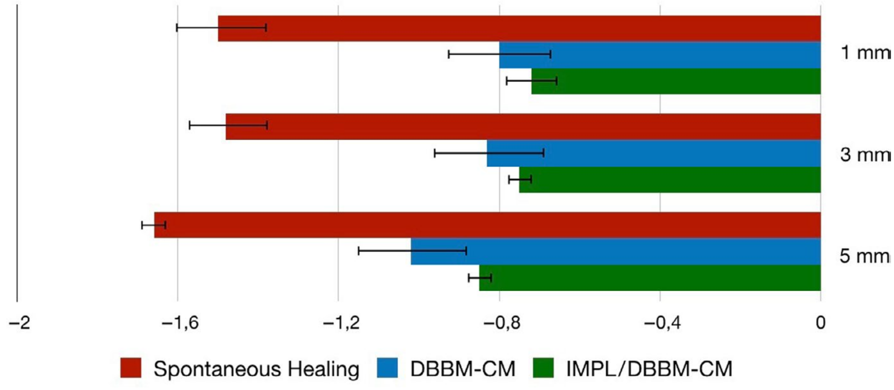

FIGURE 2 Linear changes in soft tissue contour (mm) at the buccal aspects over 4 months based on STL data

DBBM influenced the degree of ridge shrinkage only at sites where the buccal bone wall was thin (≤ 1 mm). Furthermore, the higher benefit of an ARP with socket grafting in sites exhibiting thin buccal bone (≤ 1 mm) has been also confirmed in the last consensus report and clinical recommendations of group 3 of the XV EWP on the management of the extraction socket and timing of implant placement (Tonetti et al., 2019).

Findings from STL analysis do not seem to follow previous radiographic results obtained from the same pool of patients. That study (Clementini et al., 2019) demonstrated the effectiveness of the alveolar ridge preservation technique, independently of the insertion of the implant, in reducing the hard tissue dimensional changes that occurred 4 months after spontaneous healing after extraction. Similarly, Schneider et al. (2014), comparing the effect of different techniques for ridge preservation with spontaneous healing on a soft tissue contour level, demonstrated that soft tissue changes do not seem to completely follow the changes at the alveolar bone level when recorded in the same group of patients (Jung et al., 2013). Based on these data, treatment modalities (ARP or SH) after tooth extraction may be considered less critical on the soft tissue level than on the hard tissue level. Hence, a cost–benefit ratio should be carefully evaluated when a bridge/pontic rather than an implant-supported prosthesis is planned. One possible explanation of different morphological alterations at soft and hard tissue level might be that in the radiographic studies the region of interest is located more apically (one, three and five millimetres from the initial alveolar crest) as

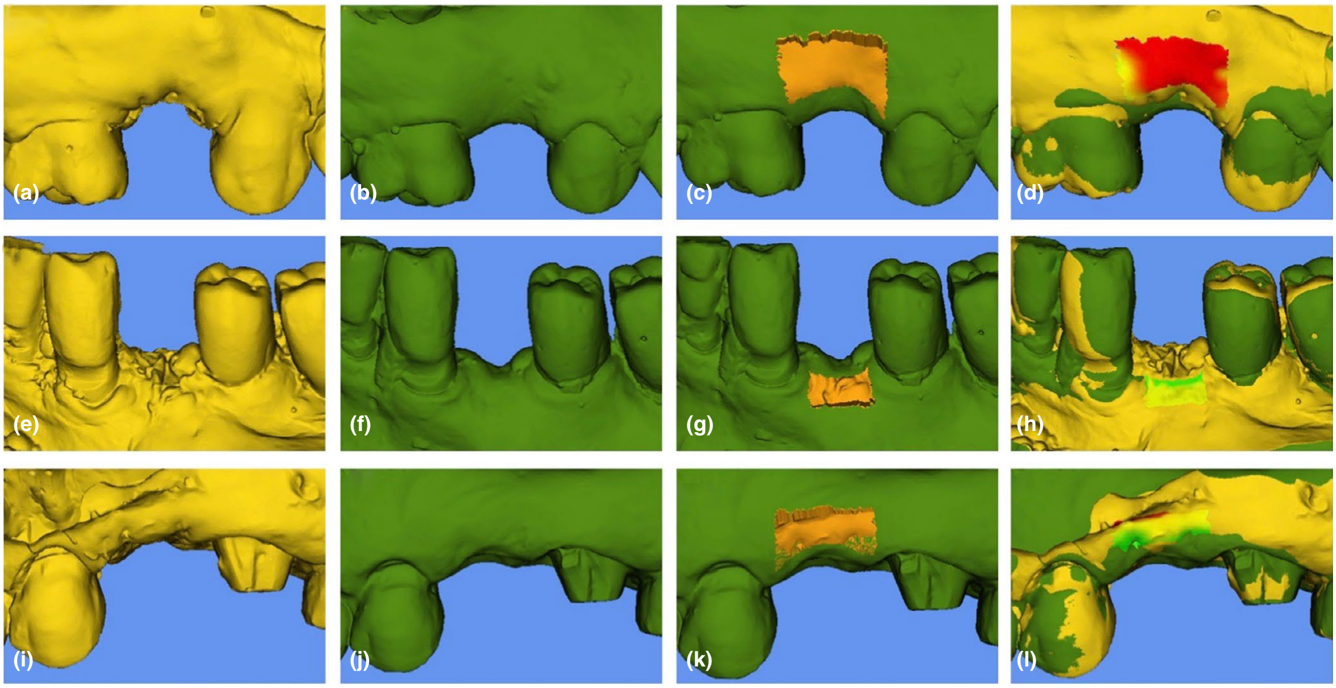

FIGURE 3 Volumetric analysis by superimposition of STL files. (1) Spontaneous healing site: (a) baseline, (b) 4-month healing, (c) superimposition showing loss of volume (orange) and (d) superimposition showing gradients of volumetric variations. (2) DBBM-CM site: (e) baseline, (f) 4-month healing, (g) superimposition showing loss of volume (orange) and (h) superimposition showing gradients of volumetric variations. (3) IMPL/DBBM-CM site: (i) baseline, (j) 4-month healing, (k) superimposition showing loss of volume (orange) and (l) superimposition showing gradients of volumetric variations

compared to the region of interest for soft tissue contour measurements. Another explanation could be the change in soft tissue thickness during the healing period, as shown by Chappuis et al. (2015), in which a significant spontaneous soft tissue thickening was observed after 8 weeks of healing both in thin and thick bone wall phenotypes.

The superimposition of baseline and 4-month three-dimensional hard (CBCT) and soft tissue (STL) data allowed for the possibility of studying the dynamic alterations of both tissues over time, even though this methodology may present limitations due to the difficulty of obtaining the same region of interest (ROI). Soft tissue thickness had a significant mean increase (+0.95) after 4 months for SH group at 3 mm, while no significant difference was found for DBBM-CM group and IMPL/DBBM-CM group. Hence, it appears clear that the more pronounced contraction of the bone crest observed at the natural healed ridge is compensated by an increase of the soft tissue thickness, at least over the 4-month observation period. It must be considered that after 4 months of healing of an extraction site a further modelling of the healing crest may be still expected and hence additional differences may appear after a longer healing period. Indeed, a radiographical study by Misawa et al.

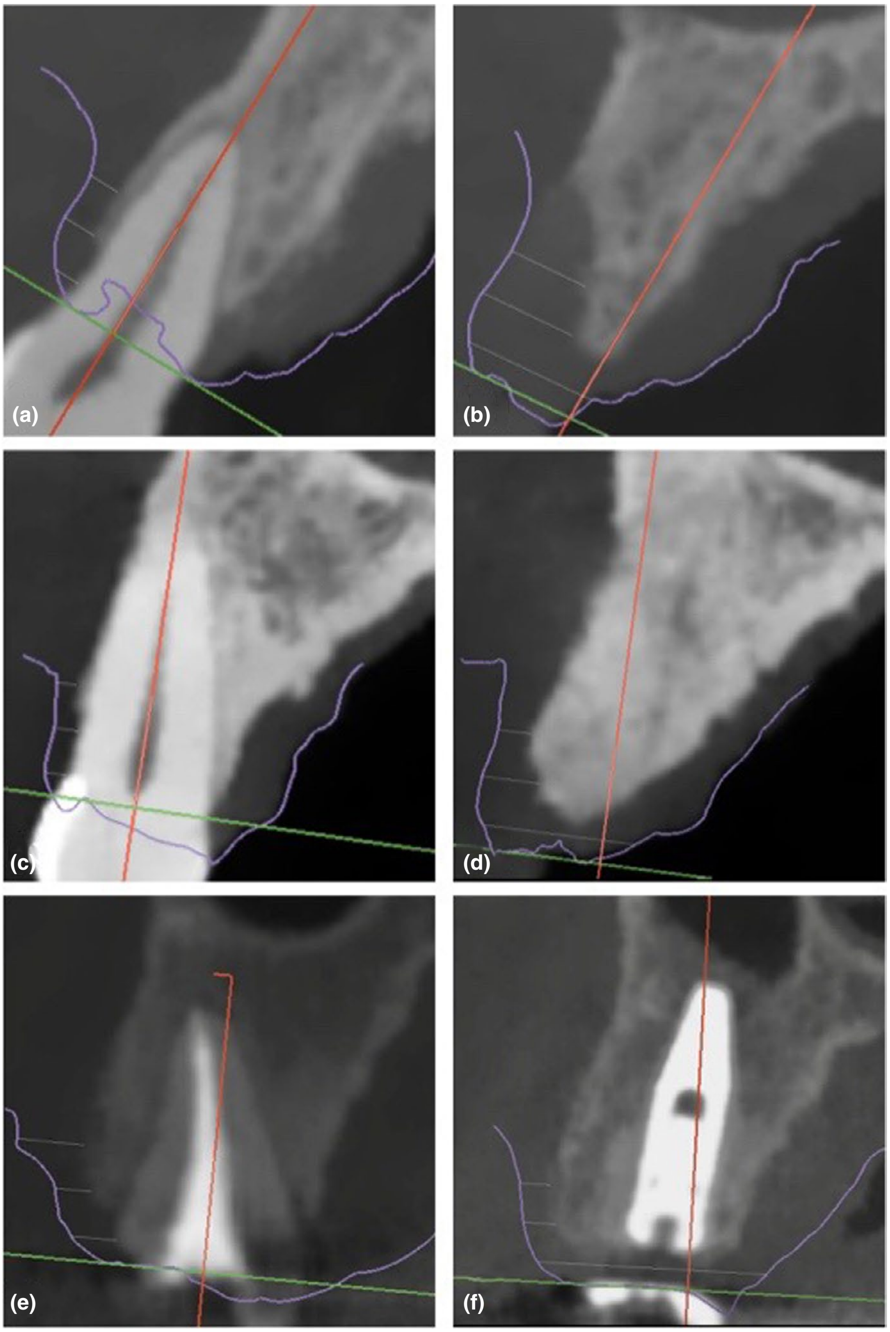

FIGURE 4 Superimpositions of hard and soft tissues (purple line) in the three treatment modalities. (1) Spontaneous healing site: (a) baseline and (b) 4-month healing. (2) DBBM-CM site: (c) baseline and (d) 4-month healing. (3) IMPL/DBBM-CM site: (e) baseline and (f) 4-month healing

TABLE 3 Baseline and 4-month follow-up linear soft tissue thickness (digitally measured) among the three treatment modalities

	Spontaneous healing			DBBM-CM			IMPL/DBBM-CM				
	BL mean (SD)	4 M mean (SD)	*p*-value	BL mean (SD)	4 M mean (SD)	*p*-value	BL mean (SD)	4 M mean (SD)	*p*-value	*p*-value inter-group BL	*p*-value inter-group 4 M
TT digital 1 mm.	1.69 (0.57)	n.r.	n.r.	1.65 (0.58)	n.r.	n.r.	1.66 (0.51)	n.r.	n.r.	0.89	n.r.
TT digital 3 mm.	1.30 (0.46)	2.25 (0.94)	0.01	1.20 (0.51)	1.00 (0.91)	0.75	1.22 (0.54)	1.15 (0.93)	0.87	0.66	0.01
TT digital 5 mm.	1.21 (0.53)	1.10 (0.73)	0.27	1.17 (0.63)	0.9 (0.71)	0.48	1.18 (0.64)	0.9 (0.72)	0.45	0.78	0.6

Abbreviations: 4 M, 4-month follow-up; BL, baseline; TT, tissue thickness.

(2016) demonstrated almost 30% resorption of the socket as compared to the healed crest after 1 year. On the contrary, according to Schropp et al. (2003) major tissue alterations occur within the first 3 months.

In this study, an alveolar ridge preservation with immediate implant placement showed a soft tissue morphological reduction of 0.72 mm after 4 months. This seems in agreement with a recent prospective case series study (Sanz-Martin et al., 2017; Sanz-Martin, Encalada, et al. 2019; Sanz-Martín, Permuy, et al., 2018), evaluating soft and hard tissue changes after a surgical protocol combining immediate implant, hard and soft tissue grafting and an immediate provisional restoration. The authors reported a horizontal tissue decrease of 0.66 mm at 6 months and 1.31 mm at 1 year. The longer follow-up period (1 year) reported in this study may explain the higher soft tissue thickness reduction, despite the use of a xenogeneic collagen matrix in conjunction with an immediate provisional restoration.

In our study, no differences were found between an alveolar ridge preservation with or without immediate implant placement. These findings clearly corroborate the absence of an impact of immediate implant placement on hard and soft tissue modelling and remodelling, as stated in different pre-clinical (Araujo et al., 2005, Caneva et al. 2010, De Sanctis et al., 2010, Vignoletti, Discepoli, et al., 2012, Discepoli et al., 2015), Vignoletti, & Sanz 2014 and clinical (Botticelli et al., 2004; Cecchinato et al., 2015; Sanz et al., 2010) studies. Although not statistically significant, minor soft tissue morphological changes were assessed comparing an alveolar ridge preservation with or without immediate implant and spontaneous healing. This seems in agreement with soft tissue findings from a pre-clinical study from Caneva et al. (2012), in which the use of DBBM particles and a collagen membrane during immediate implant placement contributed to preserve the alveolar process. Findings from this study clearly underline that the sparing effect on the bone volume is due to ridge preservation and not to the insertion of an immediate implant.

Different limitations in the methods of the present study may have affected the reported data. One of the limitations is the definition of baseline as the socket status after extraction. Despite this was considered in a recent study by Chappuis et al. (2015), it is well known that the extraction process itself may cause transient expansion of the bone and soft tissues. This may affect the results. The consideration of the baseline as the socket status before tooth extraction, as reported in various publications (Schneider et al., 2014; Thalmair et al., 2013, Sanz-Martín et al. 2019), may allow to more accurately compare changes. Another limitation of this study is the use of polyether material to create cast models, then optically scanned in order to be digitized for creating STL files. Although this method has been validated (Schneider et al., 2014; Thalmair et al., 2013, Sanz-Martin et al., 2017; Sanz-Martin, Encalada, et al. 2019; Sanz-Martín, Permuy, et al., 2018), the polyether material may cause compression of the soft tissues. Because there are more steps when using this method, this may increase the measurement error. The possibility to perform direct intra-oral scans to directly obtain STL files may overcome these problems.

In the last consensus report and clinical recommendations of group 3 of the XV EWP on the management of the extraction socket and timing of implant placement (Tonetti et al., 2019), five different options were proposed after tooth extraction to transition towards an implant-supported restoration: immediate implant placement (type 1) and alveolar ridge preservation (type 3* and type 4*) are performed at the time of tooth extractions, while three additional options are available following different degrees of natural healing after the extraction: early soft tissue healing (type 2), partial bone healing (type 3) and full bone healing (type 4). Results from this study seem to demonstrate that spontaneous healing may provide an increased amount of keratinized mucosa thickness. However, the short follow-up (4 months) of this study does not allow to clearly understand if implant placement at different stages of healing may benefit from an increased amount of keratinized mucosa thickness. This might improve flap manageability if bone augmentation procedures were to be required.

As suggested by Tonetti et al. (2019), future RCTs should compare the three treatment modalities after tooth extraction (immediate implant placement, alveolar ridge preservation, spontaneous healing) at a long-term follow-up. Furthermore, evaluation of aesthetics, implant-related outcomes, PROMs (morbidity and patient preference) and cost-effectiveness analyses are warranted. A larger population should be also recruited, to increase the statistical power of this clinical investigation.

5 | CONCLUSION

Four months after tooth extraction, horizontal linear and volumetric changes occur at the buccal soft tissue profile. No differences were observed between the two test treatments and spontaneous healing sites. This lack of difference is related to a significant increase in soft tissue thickness in spontaneous healing sites.

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CONFLICT OF INTEREST

The authors report no conflict of interests related to the study.

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SUPPORTING INFORMATION

Additional supporting information may be found online in the Supporting Information section.

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