THE EFFECT OF IMMEDIATE IMPLANT PLACEMENT ON ALVEOLAR RIDGE PRESERVATION: RADIOGRAPHIC RESULTS OF A RANDOMIZED CONTROLLED CLINICAL TRIAL COMPARING THESE TWO TREATMENT MODALITIES AND NATURAL HEALING AFTER TOOTH EXTRACTION

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ABSTRACT
Aim: to radiographically evaluate the effect of simultaneous implant placement plus alveolar ridge preservation (ARP) as compared to ARP or spontaneous healing (SH) on vertical and horizontal bone dimensional changes after 4 months of healing.
Materials and methods: thirty patients requiring extraction of one upper or lower single-rooted tooth or premolar were randomly assigned to: immediate implant placement +ARP (IMPL/DBBM/CM), ARP (DBBM/CM) or SH. Cone Beam Computer Tomography (CBCT) scans, performed before tooth extraction and after 4 months, were superimposed in order to asses: changes in ridge height at the buccal and lingual aspect; changes in ridge width at three levels (1mm, 3mm, 5mm)
Results: No statistically significant differences between the groups were observed for the vertical bone resorption on the buccal and the lingual side, while significant differences were found between SH group (-3.37 ± 1.55 mm.; -43.2 ± 25.1%) and both DBBM/CM (-1.56 ± 0.76 mm.; -19.2 ± 9.1%) and IMPL/DBBM/CM (-1.29 ± 0.38 mm. ;-14.9 ± 4.9 %) group in the horizontal dimension at the most coronal aspect.
Conclusion: a preservation technique, with or without immediate implant placement, reduces the horizontal bone morphological changes that occur, mostly in the coronal portion of the buccal bone plate following tooth extraction, when compared to spontaneous healing.

CLINICAL RELEVANCE
Scientific rationale for the study: no human study has ever compared simultaneous implant placement+ARP to ARP alone and to spontaneous healing. Hence, the question that remains unanswered is whether simultaneous implant placement+ARP may influence bone modelling and remodelling as compared to ARP or to spontaneous healing.

Principal findings: in the horizontal dimension at the most coronal aspect minor dimensional changes were observed in DBBM/CM and IMPL/DBBM/CM groups compared to major changes observed in SH group

Practical implications: immediate implant placement in post-extraction sites plus an ARP technique may be a viable option, to reduce hard tissue morphological changes and treatment time.

INTRODUCTION

It is well known that following the loss of a tooth, severe hard and soft-tissue alterations may take place at the affected site (Pietrokovski & Massler, 1967; Schropp et al., 2003), resulting in a subsequent reduction of both vertical and horizontal ridge dimensions (Araujo & Lindhe, 2005; Discepoli et al., 2013; Van der Weijden et al., 2009; Tan et al., 2012). In many occasions, these bone dimensional changes do not allow either appropriate pontic fabrication or correct placement of endosseous implants.

Over the past 20 years, several surgical procedures, grouped under the term of "alveolar ridge preservation" (ARP), have been introduced, aiming to maintain the existing soft and hard tissues as well as a stable ridge volume, to simplify subsequent treatment procedures and optimize functional and esthetic outcomes (Hämmerle et al., 2012). A recent controlled clinical study (Jung et al., 2013) with a 6 month follow-up evaluated different techniques for ARP. The authors concluded that the application of a demineralized bovine bone mineral (DBBM) with 10% collagen into an extraction socket, covered either with a collagen matrix or an autogenous soft tissue graft, resulted in less vertical and horizontal changes compared with spontaneous healing or the use of b-tricalcium phosphate particles alone without primary closure. Moreover, a conspicuous number of systematic reviews on this topic have confirmed the efficacy of ARP in preventing post-extraction dimensional changes of the alveolar ridge (Ten Heggler et al., 2011; Vignoletti et al., 2012; Horvath et al., 2012; Vittorini Orgeas et al., 2013; Mardas et al., 2010; MacBeth et al., 2017, Avila-Ortiz et al., 2019). However, when ARP techniques are performed before implant placement, this treatment modality requires a minimum of three to six months before implant insertion (De Risi et al., 2015, Avila-Ortiz et al., 2019), prolonging treatment time and needing a second surgical procedure for implant insertion.

Immediate implant placement (IIP) in fresh extraction sockets was introduced, in order to reduce exposure of patients to surgery and may limit physiological bone resorption (Schulte & Heimk, 1976, Lazzara et al. 1989). However, IIP may not always provide successful clinical outcomes (Lang et al., 2012, Tonetti et al., 2017) and it is well known nowadays that this surgical protocol fail to prevent the horizontal and vertical ridge alterations (Vignoletti & Sanz, 2014, Vignoletti et al., 2012; Araujo et al., 2005). This may result in impaired esthetics (Evans & Chen, 2008, Tonetti et al., 2017) such as marginal soft tissues recessions, especially when affecting the buccal side of maxillary sites in patients with a high smile line (Cosyn et al., 2012,) .

In order to improve the aesthetic outcomes and attenuate the bone dimensional changes several techniques have been proposed, such as flapless protocols, immediate provisionalization, connective tissue grafting, GBR techniques or filling of the gap with a bone replacement graft (Chen & Buser, 2014). Although no consensus exists on the efficacy of regenerative techniques at the time of immediate implant placement (Clementini et al., 2015), results from a very recent clinical trial demonstrated that placing a bone replacement graft in the marginal gap between the implant and the buccal bone plate significantly reduced (approximately 0.5 mm) the horizontal dimensional changes of the buccal bone after IIP in fresh extraction sockets. (Sanz et al., 2017).

The body of evidence on the treatment of extraction sockets indicates that ARP is an effective technique to reduce the physiological bone dimensional changes that occur after tooth extraction when compared to spontaneous healing (Avila-Ortiz et al., 2019). Nevertheless, very limited human evidence is available comparing immediate implant placement to spontaneous healing. Data from preclinical studies demonstrated that both horizontal and vertical buccal bone resorption occurs after immediate implant placement when compared to spontaneous healing (Araujo et al., 2005), and these morphological changes seems to be more pronounced with immediate implant placement

(Discepoli et al., 2015). On the other hand, it is clinically well known that immediate implant placement alone fails to prevent the physiologic resorption of the bone crest (Botticelli et al., 2005, Clementini et al. 2015), however this process may be reduced to some extent through grafting the gap (Chen et al. 2007, Sanz et al., 2017, Clementini et al. 2015). Whether this reduction is similar to the reduction provided by ARP is still unknown, since up-to-date no human study has ever compared simultaneous implant placement+ARP to ARP alone and to spontaneous healing. Hence, the question that remains unanswered is whether simultaneous implant placement+ARP renders different results in term of radiographic bone changes as compared to ARP and spontaneous healing.
Thus, the aim of this randomized controlled clinical trial was to evaluate the effect of simultaneous implant placement+ARP (test treatment) as compared to ARP (control treatment) or spontaneous healing (negative control) on bone dimensional changes after 4 months of healing post-extraction. The primary objective was to radiographically evaluate the horizontal dimensional changes in mm., whereas the secondary objective was to evaluate the horizontal dimensional changes in percentage and the vertical dimensional changes in mm. and percentage.

MATERIALS & METHODS

Study design
This study was a prospective controlled, randomized, clinical investigation according to the CONSORT statement (http:/www.consort-statement.org/). All procedures and materials were approved by the local ethical 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)

Sample size
To calculate the number of patients to be treated, summary statistics (mean and standard deviation) reported by Jung et al. (2013) were used for the variable HW-1C, respectively for the control group (mean=-3.3, sd=2) and DBBM-C/CM (mean=-1.2, sd=0.8). The effect size resulted equal to 1.4 and this value 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. This resulted in 10 subjects for each group.

Population
Participants were selected on a consecutive basis among patients of the Dental Clinic at University Vita Salute San Raffaele, Milan, Italy between January 2016 and January 2018. Patients agreed to participate in the study by signing a written informed consent, in full accordance with the ethical principal of Declaration of Helsinki on experimentation involving human subjects, as revised in 2008.
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 inter proximal 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).

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 treatment of malignancy.
- Pregnant patient or intended to get pregnant or currently nursing.
- Patients taking medications or having treatments with an effect on healing in general (e.g. steroids, large doses of antiinflammatory drugs, bisphosphonates).

Randomization process and allocation concealment

Randomization was performed using a computer-generated list by someone not involved in other aspects of the study. Allocation concealment was performed by opaque continuously numbered sealed envelopes that were opened after tooth extraction and assessment of the integrity of the bone plates.

Treatment procedures

A full thickness envelope flap including the mesial and distal tooth was performed, and the tooth was extracted with great care to preserve the buccal bone plate and the surrounding soft and hard tissues. Granulation tissue was carefully removed with hand instruments and sterile saline rinses were performed. After assessment of the integrity of the bone plates, patients were randomly assigned to **(Figure 1):**

- Test group (IMPL/DBBM/CM): immediate implant placement, plus a collagenated bovine bone mineral grafted into the gap up to the buccal bone crest, sealed with a collagen porcine matrix at the soft tissue level.
- Control group (DBBM/CM): collagenated bovine bone mineral grafted into the socket up to the buccal bone crest, sealed with a collagen porcine matrix at the soft tissue level.
- Negative control group (SH): spontaneous healing.

More specifically, in IMPL/DBBM/CM group an immediate implant (TTi WINSIX®, Biosafin, Ancona, Italy) with prosthetically driven placement was performed positioning the platform 1 mm subcrestally respect to the most apical crest, in accordance with the guidelines described by the company. After implant placement and closure cap insertion, a bone substitute material (Geistlich Bio-Oss Collagen; Geistlich Pharma AG, 6110 Wolhusen, Switzerland) was placed in the gap formed between the implant surface and the hard tissue walls of the extraction socket. Grafting was performed to the level of the palatal and lingual bone crest. Subsequently, after flap replacement, the soft tissue borders were de-epithelialized and a collagen porcine matrix (Geistlich Mucograft Seal; Geistlich Pharma AG, 6110 Wolhusen, Switzerland) was adapted to seal the graft and the implant using single interrupted resobable sutures.
In DBBM/CM group a bone substitute material (Geistlich Bio-Oss Collagen; Geistlich Pharma AG, 6110 Wolhusen, Switzerland) was placed in the extraction socket to the level of the palatal and lingual bone plate. Subsequently, after flap replacement, the soft tissue borders were de-epithelialized and a collagen matrix (Geistlich Mucograft Seal; Geistlich Pharma AG, 6110 Wolhusen, Switzerland) was adapted to seal the graft using single interrupted resorbable sutures.
In SH group flap was repositioned with interrupted resorbable sutures and the coagulum within the socket was left for spontaneous healing.
Patients were instructed to rinse twice a day (starting the day after surgery) with 0.2% chlorhexidine and received antibiotics (Augmentin 1g) for 6 days and analgesic medication (Ibuprofen 600 mg) if needed. All patients were recalled at 7 days for suture removal. Patients then followed their individual maintenance program according to the individual periodontal and caries risk assessment. Four months post-extraction, all patients were recalled for a follow-up in order to schedule the following therapies.

Clinical measurements

Full-mouth plaque score (FMPS) (O'Leary, Drake, & Naylor, 1972), full-mouth bleeding score (FMBS) (Muhlemann & Son, 1971) and keratinized tissue height (KTH), measured from the most coronal extension of gingival margin to the mucogingival line, were recorded with a periodontal probe (PCP UNC 15, Hu-Friedy) at baseline and 4 months. Moreover, gingival thickness (GT) was assessed at baseline and 4 months, as described in Clementini et al. 2018. All clinical measurements were made by a single blinded calibrated examiner (A.A.).

Radiographic measurements

Before treatment procedures, a cone-beam computed tomography (CBCT) scan was performed using a 3D exam (NewTom VGi evo, QR S.r.l., Verona), following the producer's prescriptions: resolution of 0.2 mm, scan time: 15 s, exposure time: 1.8 s. After four months post-extraction, all selected patients underwent to a second CBCT scan with the same settings as described above.

To calculate CBCT measurements a similar approach as the one proposed by Jung et al. (2013) was adopted. Firstly, in the baseline data set the distance from the mesial and/or distal bone crest was calculated in the axial section, and subsequently the cross section was selected passing through the pulp canal of the involved tooth. The CBCT performed 4 months after tooth extraction was selected by the same procedure, considering the distance from the mesial and/or distal bone crest previously calculated. Then a computer-assisted (GeoGebra GmbH, Wolfauer Str 90, 4040 Linz, Austria) superimposition of the original DICOM (Digital Imaging and Communications in Medicine) data of the two CBCT scans was done in areas where no changes had taken place during the 4 months (e.g. the cranial base in the maxilla or the lower border and angle in the mandible respectively). Varying the degree of transparency of the sections, DICOM data of the two CBCT scans were manually checked in order to assure a perfect match. Finally the measurements were computed on the selected scans at baseline and at 4 months, by means of reference the following points and lines defined and drawn in the baseline image **(Figure 2)**

- Four reference points: the point representing the radiographic apex of the tooth (Apical Central Point, ACP) and the point representing the cusp of the tooth (Coronal Central Point, CCP). In cases where the crown of the tooth was missing or in cases of bicuspids, a segment was traced using 2 points (the most coronal and buccal point and the most coronal and lingual point of the tooth) and the centre of this segment was taken as the coronal reference point; two points representing respectively the most coronal buccal (Coronal Buccal Point, CBP) and the most coronal lingual (Coronal Lingual Point, CLP) portion of the buccal and lingual bone plates.
- Eleven reference lines, subsequently drawn, as follows: a vertical central line (VCL), in the center of the socket, which crosses the apical (ACP) and coronal (CCP) central reference points; a vertical buccal line (VBL) and a vertical lingual line (VLL), parallel to the VCL and crossing respectively the most coronal point of the buccal (CBP) and lingual (CLP) bone crest; the buccal bone crest line (BCL_B) and the lingual bone crest line (BCL_L) connecting respectively the most coronal point of the buccal (CBP) and lingual (CLP) bone crest and perpendicular to VCL; the horizontal lines, perpendicular to the VCL drawn in precedence at 1, 3, 5 mm and parallel to the straight lines passing through CBP (BCL_B) and CLP (BCL_L). .

With respect to these reference points and lines, the following measurements were performed in mm.:

• thickness of the buccal and lingual bone plate at three levels (1 mm, 3mm and 5mm), only at baseline;

• vertical ridge height, measured at the buccal and lingual site, at baseline and 4 months;

• mid-buccal and mid-lingual horizontal ridge width, measured at 1 mm, 3 mm, 5 mm below respectively the CBP and CLP, at baseline and 4 months.

In addition, the following dimensional changes over time, based on the measurements performed at baseline and at 4 months, were assessed and expressed both in percentages and in mm:

- changes in ridge height at the buccal and lingual aspect;
- changes in ridge width at three levels (1mm, 3mm, 5mm) respectively of the whole ridge, from the middle of the ridge to the buccal bone crest and from the middle of the ridge to the lingual bone crest.

All superimpositions of CBCT images and measurements of morphological changes were made by a single calibrated examiner (W.C.), who superimposed and measured, 24 hours apart, baseline and 4 months CBCT images of 3 different cases not included in the study. Intraclass coefficient correlation (Bliese, 2000) was 0.9891839.

<u>Data analysis</u>

Descriptive statistics were provided for all the measures collected in the study. To test whether treatment groups were different, Kruskal-Wallis test, i.e., the non-parametric counterpart to standard ANOVA, followed by post-hoc analysis (Dunn's pairwise test and Bonferroni's adjustment of p-values), has been applied for comparison of differences between groups.

All the analyses were performed using R statistical software (R Development Core Team, 2016). In all the analyses, the significance threshold was set at 0.05.

RESULTS

The study population consisted of 32 subjects that were screened for participating in this clinical trial from 2015 to 2018. Of these patients, two were excluded due to a loss of buccal bone plate after tooth extraction. A total of 30 subjects were finally recruited, randomized and included in the clinical trial: 10 allocated to the SH group (negative control), 10 allocated to DBBM-CM group (control), 10 allocated to IMPL/DBBM-CM group (test), respectively. Hence, a total of 30 subjects were included in the analysis **(Figure 3).**

No significant differences between treatment groups were found at the baseline (**Table 1)** regarding age, gender, smoking status, tooth position, presence of both mesial and distal tooth, reason for extraction, FMPS, FMBS, KTH, GT, and thickness of the crest.

Clinical outcomes

All treated sites healed uneventfully, and no post-operative complications were recorded. No significant differences were assessed at 4 months follow up for FMPS, FMBS, KTH and GT in the three study groups. Slight but not significant differences were observed for KTH (-0.4 mm.) and GT (+0.35 mm.) for SH group, while no differences were observed for DBBM/CM group and IMPL/DBBM/CM group.

Radiographic outcomes

Dimensional alterations in mm. and percentage that occurred during healing for all sites are reported in **Table 2.**

<u>Horizontal dimensional changes.</u>

Horizontal changes were not significantly different between DBBM/CM group and IMPL/DBBM/CM group at 1 mm below the coronal crest, while significant differences were found between SH group and both DBBM/CM and IMPL/DBBM/CM group. At the most coronal aspect, ridge width decreased 3.37 ± 1.55 mm (-43.2 ± 25.1%) in the SH group, while DBBM/CM and IMPL/DBBM/CM groups presented a ridge reduction of 1.56 ± 0.76 mm (-19.2 ± 9.1%) and 1.29 ± 0.38 mm (-14.9 ± 4.9 %) respectively.

Analyzing horizontal changes at the buccal (mid-buccal) and lingual (mid-lingual) aspect, significant differences were found at 1 and 3mm below the crest of the buccal side between SH group and both DBBM/CM and IMPL/DBBM/CM groups: a reduction of 2.45 ± 1.29 mm (at 1mm) and 1.92 ± 1.99 mm (at 3mm) was revealed for SH group, while a change of -0.91 ±0.43 mm (at 1 mm.) and -0.53 ± 0.44 mm (at 3 mm.) was shown in DBBM/CM group and a change of -0.99 ± 0.21 mm (at 1 mm.) and -0.70 ± 0.33 mm (at 3 mm.) in IMPL/DBBM/CM group. Significant differences at the lingual aspect were found at 1 mm below the crest between SH group (-24.03 ± 22 %) and IMPL/DBBM/CM group (-5.99 ± 6.18 %). **(Figure 4)**

Vertical changes

No statistically significant differences between the groups were observed for the vertical bone resorption on the buccal and the lingual side. **(Figure 5)**.

DISCUSSION

The present study demonstrated that the insertion of an immediate implant does not affect the outcomes of the alveolar preservation technique. Even if an implant is inserted, the effectiveness of the alveolar preservation technique is guaranteed, at least in terms of linear bone reduction measured using DICOM data. Furthermore, this surgical protocol (with or without the insertion of an immediate implant) seems to limit hard tissue morphological changes that occur when an extraction site is left to heal spontaneously after a flap procedure.

Spontaneous healing

In this study a marked resorption of the alveolar ridge was observed at 4 months when this was left to heal spontaneously after a flapped procedure, revealing a horizontal change of 3.37 ± 1.55 mm (43.2 ± 25.1%) and a vertical change of 0.8 ± 1.1 mm (12 ± 17%) at the buccal aspect. These data are in agreement with those of a very recent similar radiographic study by Jung et al. (2013), in which a horizontal change of 3.3 ± 2 mm (43.2 ± 26.8%) and a vertical change of 0.5 ± 0.9 mm (5.5 ± 9.8%) at the buccal aspect was revealed after 6 months when the alveolar ridge was left to heal spontaneously after a flapless procedure.

The scientific literature has amply demonstrated in humans how, after the extraction of a tooth, significant changes occur in ridge size both horizontally and vertically (Pietrokovski & Massler, 1967; Schropp et al., 2003). A very recent systematic review demonstrated a horizontal dimensional reduction of 3.79 ± 0.23 mm. (29–63%) and a vertical bone loss at the buccal aspect of 1.24 ± 0.11 mm. (11–22%) at 6 months. (Tan et al., 2012).

In this study further analysis of mid-buccal and mid-lingual changes revealed that at 4 months vertical and horizontal resorption were more pronounced on the buccal (vertical: 0.8 ± 1.1 mm.; horizontal: 2.45 ± 1.29 mm.) than the lingual (vertical: 0.2 ± 0.3 mm.; horizontal: 0.98 ± 0.93 mm.) aspect, thus shifting the center of the crest towards a more palatal position. This observation is in agreement with preclinical studies by Araujo & Lindhe (2005), Fickl et al. (2008) and Discepoli et al. (2013) in which observed morphological changes were more significant at the buccal than the palatal/lingual aspects.

On the other hand, similarly to results from clinical trials in which radiographic analysis was performed at different levels below the alveolar crest (Jung et al., 2013; Kerr et al., 2008), this study demonstrated a relative decrease in horizontal ridge reduction as the distance from the alveolar crest increased, despite differences in the surgical method (flapped in this study, flapless in Jung et al., 2013 and Kerr et al., 2008) . Different changes between the two cortices (buccal and palatal/lingual aspects) and at different heights (1-, 3-, 5mm.) below the crest may be explained by differences in thickness of the alveolar crest at baseline: although the sample size in the present study is insufficient to perform a statistical analysis, it seems that the thicker the crest the smaller the dimensional alteration. This resorption pattern may be due to the presence of bundle bone, in which the periodontal ligament fibers of a tooth invest, and which is lost following tooth extraction as it is a tooth-dependent structure. In pre-clinical studies from Araujo & Lindhe (2005) and Discepoli et al. (2013) it was observed that thin crestal regions (high resorption rate) were made up exclusively of bundle bone while the thick regions (low resorption rate) were comprised of a combination of bundle bone and lamellar bone.

Relatively large thickness of the marginal crest at baseline (buccal:1.17 ± 0.39 mm.; lingual: 1.99 ± 1.05 mm.) and site selection (mostly premolars) may explain the discrepancy with respect to the amount of crestal resorption between this study and results from Araujo et al. (2015), in which a vertical change of 3.6 mm. (35.8%) at the buccal site and 1.4 mm. (13.4%) at the palatal site were reported. In that article the study sample was mostly composed of anterior teeth, and further analysis of their data disclosed that the reduction in the buccal bone plate was more pronounced in the anterior than in the premolar regions. As demonstrated by Januario et al. (2011) from a radiographic study, about 50% of the coronal (5 mm) portion of the buccal bone wall in maxillary incisors and canines is <0.5 mm wide, with an average of 0.6 mm wide.

ARP

The observations in the present study established that the placement of a bone substitute material (DBBM) in the fresh extraction socket, covered by a collagen matrix, reduced vertical and horizontal ridge resorption. This is in agreement with data reported by Jung et al. (2013), in which both vertical and horizontal resorption were limited by the placement of DBBM, covered by a collagen matrix, in the fresh extraction socket, despite the fact that in that study a flapless approach was performed.

This is also in agreement with a number of recently published systematic reviews on ARP procedures (Ten Heggler et al., 2010; Vignoletti et al., 2012; Horvath et al., 2012; Vittorini Orgeas et al., 2013; Mardas et al., 2010; MacBeth et al., 2017) which conclude how no bone substitute material and/or membrane is able to completely preserve the alveolar ridge after tooth extraction, but may limit buccal plate resorption to a certain extent.

Findings from the present study revealed that mid-buccal horizontal changes 1 mm (0.91 ±0.43 mm.), and 3 mm (0.53 ± 0.44 mm) below the marginal crest have been the ones which benefited the most from ARP procedure. This means, in agreement with Araujo et al. (2008), that graft material apparently promoted de novo hard tissue formation showing a radiographic appearance different from that of a cortical plate but maintaining the dimensions of the hard tissue wall. This is particularly true for sites made up exclusively of bundle bone, therefore regions with a very thin bone crest.

ARP + Immediate implant placement

In the present work no statistically significant difference resulted from the comparison between test group (IMPL/DBBM/CM) and control group (DBBM/CM), indicating that the preservation of bone volumes is quite similar in sites where the implant was inserted and in the sites where only ARP was performed.

When an implant was inserted simultaneously to an ARP procedure after flapped tooth extraction, horizontal mean changes at 1 mm. below the marginal crest were 1.29 ± 0.38 mm (14.9 ± 4.9 %) with changes at buccal aspect of 0.99 ± 0.21 mm (26.80 ± 7.07 %). These data are completely in agreement with a recent work by Sanz et al. (2016), aimed at evaluating differences in dimensional alterations of the ridge after 4 months between immediate implants and immediate implants associated with regenerative procedures. Reporting a bucco-lingual dimensional change (1 mm below the crest) in grafted sites of 1.3 (11%) and a reduction of the buccal cortical bone of 1.1 mm. (29%), they demonstrated that placement of DBBM in the void between the implant and the walls of the fresh extraction socket somewhat counteracted the contraction of the buccal hard tissue plate that normally occurs during healing.

Similar data were also presented in a radiographic study by Degidi et al. (2013), in which the mean reduction in the distance between implant surface and outer surface of buccal bone crest was 0.88 ± 0.51 mm (29.3%) after 1 year of a flapless immediate implant placement with simultaneous grafting of the buccal gap with DBBM and immediate restoration. Analyzing the height of the marginal buccal crest, the authors reported a mean reduction of 0.76 ± 0.96 mm., that is similar to 0.6 ± 0.4 mm. of vertical dimensional alteration obtained in this study at the buccal site when an immediate implant and an ARP procedure were simultaneously performed.

These data seems to confirm the trend towards better outcomes with the combined use of regenerative techniques observed in a clinical trial by Chen et al. (2007) and by a recent systematic review (Clementini et al., 2015) on dimensional changes after immediate implant placement with or without simultaneous regenerative procedures. In IMPL/DBBM/CM group of the present study a flapped procedure was performed and the inserted implant was not immediately restored. The use of a flapless procedure or an immediate restoration, as the placement of a soft-tissue graft or the use of a platform-switching implant-abutment connection should further be investigated in well- designed clinical trials, since there are indications of their potential benefit in maintaining ridge volume after tooth extraction.

Due to the small sample size, this randomized controlled clinical trial was not able to identify correlations between some prognostic factors (i.e. thickness of the buccal bone plate at baseline, tooth location) and the radiographic outcomes (Ferrus et al., 2010; Tomasi et al., 2010). The short follow up period (4 months) of a radiographic analysis is another limit of this study since it does not allow an evaluation of the real benefits for patients of limiting morphological changes after tooth extraction: the necessity and the amount of a ridge augmentation procedure for the following implant placement, the occurrence of soft tissue dehiscence at longer follow up and patient related outcomes (overall treatment time, number of surgical procedures, esthetic satisfaction) should be radiologically and clinically evaluated after a minimum of 6-12 months after definitive prosthetic restoration.

Despite this, the present study is able to make important clinical considerations with some practical implications and these findings may allow for future investigations.

CONCLUSION

The present study demonstrates that after a flapped extraction of a tooth, vertical and horizontal changes of the alveolar ridge occur, regardless of whether alveolar ridge preservation is performed. This happens despite the placement of an implant simultaneously with the ridge preservation procedure. However, a preservation technique, with or without immediate implant placement, reduce the horizontal bone morphological changes that occur, mostly in the coronal portion of the buccal bone plate, when compared to spontaneous healing. For this reason, immediate implant placement in post-extraction sites plus an ARP technique may be a viable option, to reduce hard tissue morphological changes and treatment time.

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Figure 1. Baseline CBCT, intra-operative view and 4 months post-surgery CBCT representative of the 3 treatment modalities. 1) Spontaneous healing: (a) baseline, (b) intra-operative, (c) 4 months. 2) DBBM-CM site: (d) baseline, (e) intra-operative, (f) 4 months 3) IMPL / DBBM-CM site: (g) baseline, (h) intra-operative, (i) 4 months.

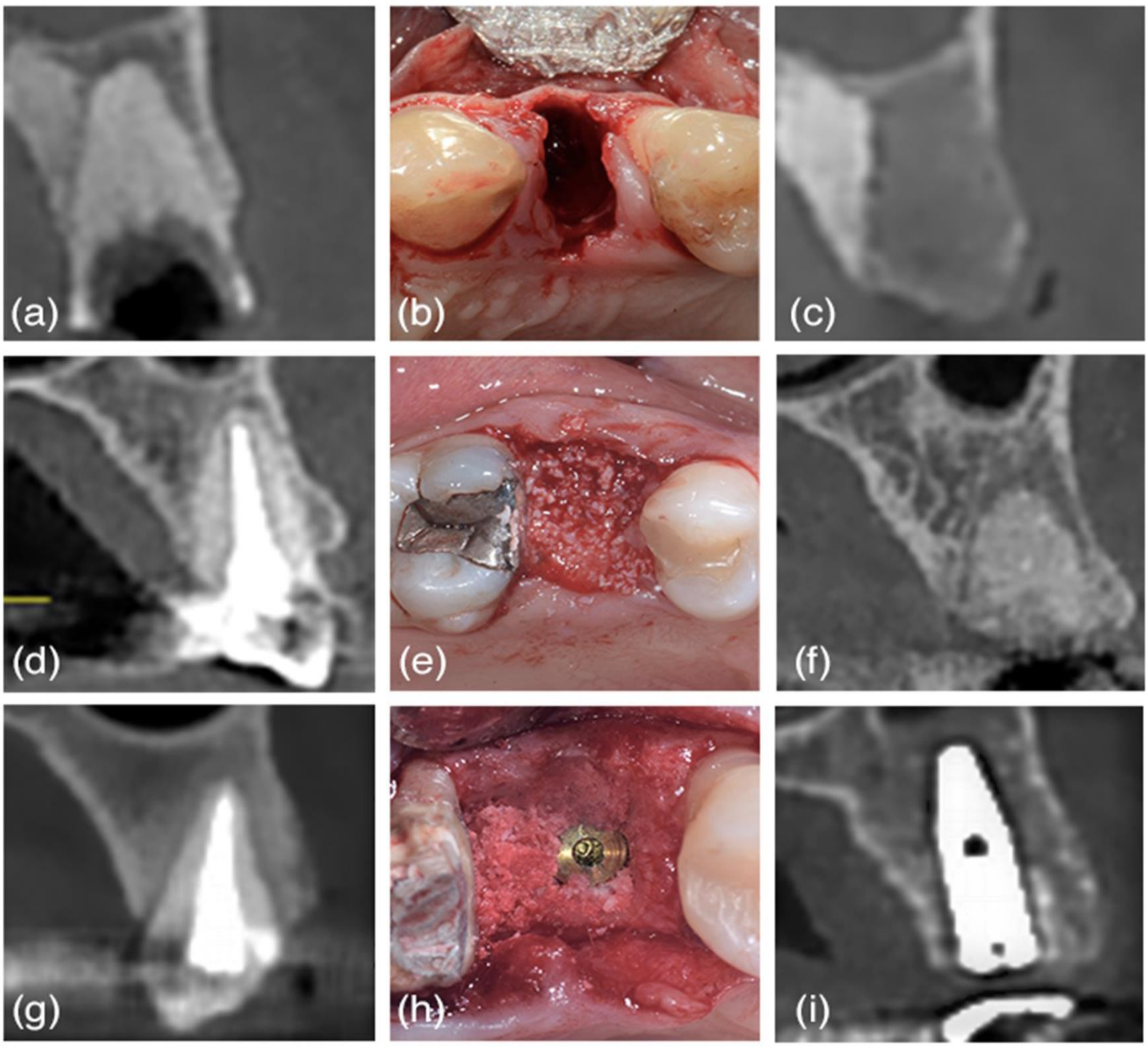

Table 1. Baseline demographic, clinical and radiographic data of included patients.

Baseline characteristics	**SH**	**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
Smokers	3	4	3
Maxilla/Mandible	8/2	6/4	8/2
Anterior/Premolars	5/5	5/5	6/4
Presence of both mesial/distal tooth	9	9	9
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)
GT (mm)	1.40(0.57)	1.30(0.59)	1.30(0.42)
Thickness 1 mm Buccal (mm)	1.17(0.39)	1.33(0.25)	1.34(0.45)
Thickness 3 mm Buccal (mm)	1.21(0.55)	1.35(0.48)	1.37(0.94)
Thickness 5 mm Buccal (mm)	1.59(0.41)	1.71(1.30)	1.64(0.90)
Thickness 1 mm Lingual (mm)	1.99(1.054)	2.43(1.64)	2.05(1.30)
Thikness 3 mm Lingual (mm)	2.38(0.91)	2.89(1.78)	3.08(1.81)
Thickness 5 mm Lingual (mm)	3.02(1.58)	4.12(2.16)	4.34(2.32)

Table 2. Calculated statistical differences for changes in ridge height and width over 4 months among the three treatment modalities.

Dimensional changes	SH	DBBM-CM	IMPL / DBBM-CM	Kruskal-Wallis (p-value)	Pairwise comparisons		
					SH vs. DBBM-CM	SH vs. IMPL / DBBM-CM	DBBM-CM vs. IMPL / DBBM-CM
Vertical buccal (mm)	-0.83(1.14)	-0.31(0.33)	-0.56(0.38)	0.3444			
Vertical lingual (mm)	-0.21(0.31)	-0.32(0.47)	-0.50(0.58)	0.4658			
Vertical buccal (%)	-10.60(14.00)	-3.94(4.79)	-6.26(4.64)	0.4181			
Vertical lingual (%)	-2.15(3.23)	-3.58(4.72)	-4.98(5.83)	0.4586			
Horizontal 1 mm (mm)	-3.37(1.55)	-1.56(0.71)	-1.29(0.38)	**0.0008**	**0.0133**	**0.0011**	1
Horizontal 3 mm (mm)	-2.41(1.97)	-1.07(0.69)	-0.99(0.48)	0.0534			
Horizontal 5 mm (mm)	-1.88(1.55)	-0.96(0.61)	-0.92(0.59)	0.1858			
Horizontal 1 mm (%)	-43.23(25.05)	-19.21(9.18)	-14.92(4.85)	**0.001**	**0.0213**	**0.0011**	1
Horizontal 3 mm (%)	-30.62(28.60)	-12.27(8.56)	-10.78(5.64)	0.0738			
Horizontal 5 mm (%)	-23.12(20.69)	-10.44(7.13)	-9.51(6.44)	0.1349			
Mid buccal 1 mm (mm)	-2.45(1.29)	-0.91(0.43)	-0.99(0.21)	**0.0001**	**0.0003**	**0.0014**	1
Mid buccal 3 mm (mm)	-1.92(1.99)	-0.53(0.44)	-0.70(0.33)	**0.0292**	**0.0342**	**0.1461**	1
Mid buccal 5 mm (mm)	-1.43(1.35)	-0.56(0.44)	-0.53(0.31)	0.0833			
Mid buccal 1 mm (%)	-54.96(20.99)	-25.96(11.01)	-26.80(7.07)	**0.0004**	**0.0009**	**0.0034**	1

Mid buccal 3 mm (%)	-41.51(26.45)	-15.76(13.86)	-19.22(9.44)	**0.0335**	**0.056**	**0.095**	1
Mid buccal 5 mm (%)	-38.771(28.16)	-16.90(15.21)	-14.87(8.78)	0.047	0.1262	0.076	1
Mid lingual 1 mm (mm)	-0.98(0.93)	-0.64(0.40)	-0.29(0.29)	0.0825			
Mid lingual 3 mm (mm)	-0.55(0.59)	-0.53(0.29)	-0.29(0.26)	0.1061			
Mid lingual 5 mm (mm)	-0.45(0.45)	-0.40(0.25)	-0.38(0.39)	0.9741			
Mid lingual 1 mm (%)	-24.03(22.07)	-14.47(9.65)	-5.99(6.18)	**0.0308**	1	**0.031**	0.2061
Mid lingual 3 mm(%)	-14.30(15.87)	-10.29(6.51)	-5.20(4.74)	0.1163			
Mid lingual 5 mm (%)	-10.88(12.61)	-7.00(4.60)	-6.44(7.08)	0.7421			

Figure 2. Consort diagram showing the study design

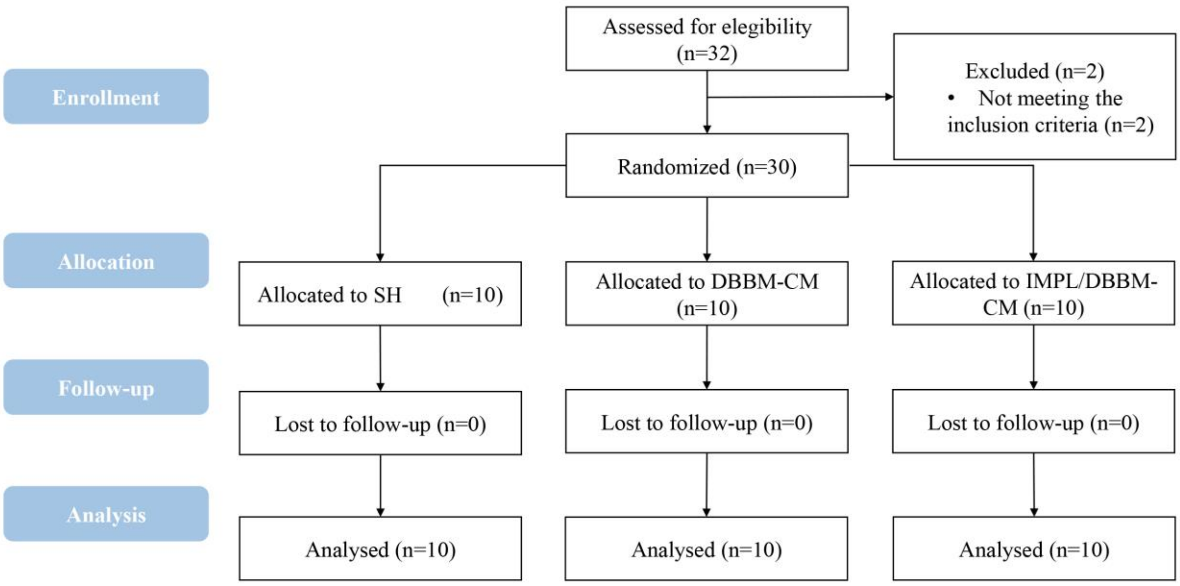

Figure 3. Bone changes measurements. ACP: apical central point. CCP: coronal central point. BCP: buccal coronal point. LCP: lingual central point.

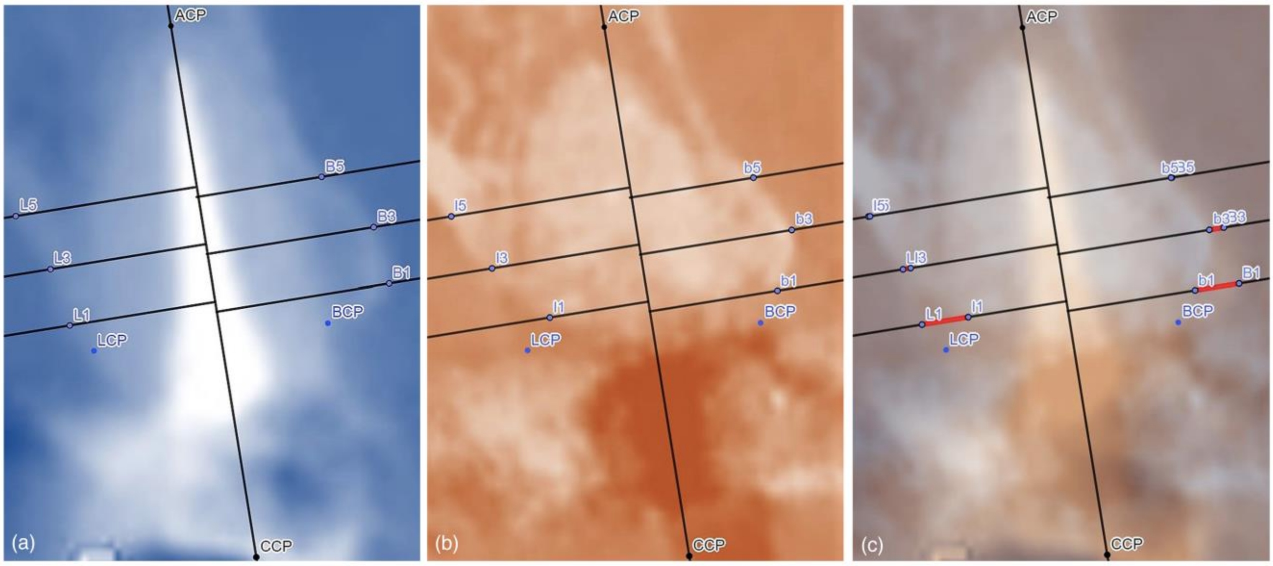

Figure 4. Changes in ridge width (mm) at buccal and lingual aspects over 4 months based on cone-beam computed tomography (CBCT) measurements.

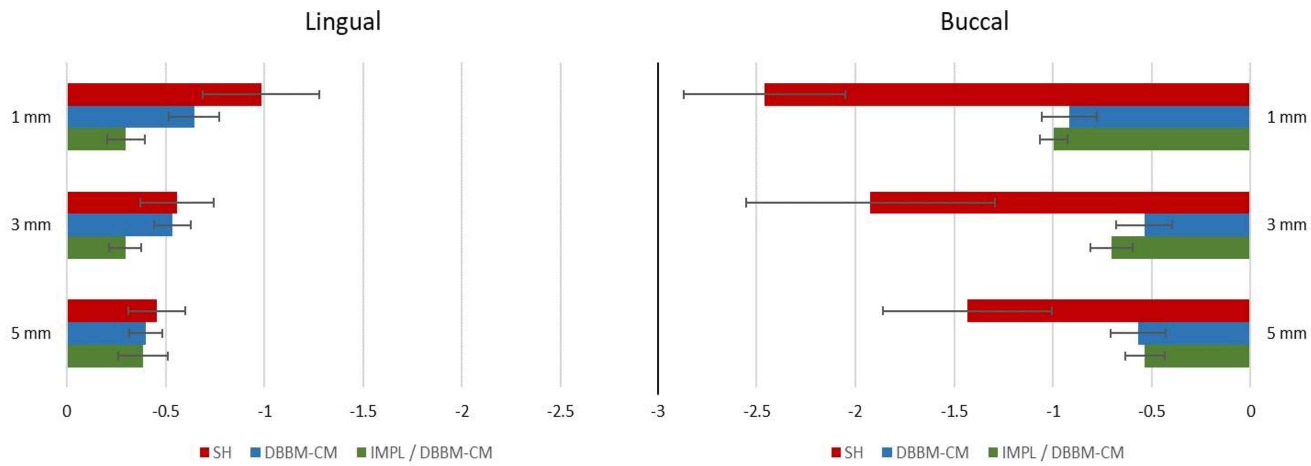

Figure 5. Changes in ridge height (mm) over 4 months based on cone-beam computed tomography (CBCT) measurements.