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Immediate implant in the posterior region combined with alveolar ridge preservation and sealing socket abutment: A retrospective 3D radiographic analysis

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Abstract

Background: Customized sealing socket abutment (SSA) has been claimed to optimize the peri-implant hard and soft tissues in type 1 implant placement. However, the evidence to claim the benefits of this technique over the use a conventional healing abutment remains weak.

Purpose: The aim of this retrospective study was to provide a 3D-radiographic evaluation of hard tissues changes following immediate implant placement in molar sites combined to ARP technique and installation of SSA.

Materials and Methods: Baseline and follow-up (FU) CBCTs (from 1 to 5 years) of 26 patients were collected and included in the study. Baseline and FU CBCTs were superimposed and horizontal and vertical bone changes were assessed.

Results: A total of 26 patients and 27 implants were included. Horizontal bone remodeling was not significant in any of the measured areas except in the most cervical level, where a mean bone remodeling of 0.73 mm was found. Proximal and buccal vertical bone changes were not significant.

Conclusions: Within the limits of a retrospective study, dimensional alveolar ridge changes 1 to 5 years after immediate implant placement in molar sites with simultaneous ARP technique and installation of SSA seem to be very limited.

KEYWORDS

3D, alveolar ridge preservation, CBCT, immediate implant placement, molar site, radiological, sealing socket abutment

1 | INTRODUCTION

Replacement of a hopeless molar with a dental implant is one of the most frequent therapeutic modalities in implant dentistry[1] and this tooth replacement modality has shown predictable long-term outcomes with high survival rates and successful results.[2,3] Because of the increased interest in shortening the overall treatment time and in order to reduce the invasiveness of surgical interventions,[4] immediate implant placement (Type 1) was proposed by several authors and different surgical protocols have been explored.[5-7] Although immediate implant placement in molar areas has shown high survival rates of 96.6%[7] clinical data from literature remains limited. To add to that, immediate implant placement does not counteract the post extraction bone resorption as widely described in the literature[8-12] while alveolar ridge preservation (ARP) techniques with the use of space filling biomaterials have proven to significantly limit bone remodeling after extraction and preserve, at least partially, the contour of the alveolar ridge.[13] In addition, their long-term effectiveness was recently emphasized[14,15] Therefore, it is relevant to combine extraction and immediate implant with ARP procedures.[4]

Immediate implant placement and ARP techniques in the posterior region differ from the esthetic zone for several reasons[16-19] mainly because of anatomical differences. Thicker buccal bone in the posterior sockets leads to less pronounced ridge alterations.[16,17] However, type 1 implant placement in the posterior region requires to manage the large jump distance and insure primary closure of the socket.[18-20]

To cope with this anatomical consideration several authors have proposed using a customized abutment to seal the large molar socket after the immediate implant placement, and maintaining the original outline of soft tissues.[21-26] For instance, the Sealing Socket Abutment (SSA) technique introduced by Finelle et al. 2017 uses an individualized chairside-fabricated abutment following tooth extraction to seal the surgical area and to protect the bone grafting material from the oral cavity exposure as well. The overall survival rate of immediately placed implants in molar sites with SSA protocol was 100% with a follow-up of two years.[23] Based on a case series of 29 patients, this technique displayed no implant failure and healthy peri-implant soft tissue. More recently, the stability of the soft tissues outlines up to two years follow-up was demonstrated.[23] However, scientific knowledge related to this innovative approach remains limited and deserves further investigation. For example, the radiographic outcomes and its influence on hard tissue remodeling have never been explored.

The aim of the present retrospective study was to provide a 3D-radiographic evaluation of dimensional alterations of hard tissues at immediately placed implants in molar extraction sites combined with alveolar ridge preservation technique (ARP) and installation of a Sealing Socket Abutment (SSA).

What is known:

- Plenty studies suggest that the use of a customized healing abutment at immediate implant placement improves peri-implant tissues healing. Most of these studies are case series and suffered from a long-term follow-up.

What this study adds:

- This study is a retrospective 3D-radiographic analysis of hard tissues changes around implants immediately placed in molar sites at least 1-year after.

2 | MATERIALS AND METHODS

2.1 | Study design, study population and inclusion criteria

The study was conducted in full accordance with the declared ethical principles of the World Medical Association Declaration of Helsinki of 1975 (revised in 2008) and the protocol was approved by the institutional Ethical Committee of the University of Liège, Belgium The radiologic examinations (Cone Beam CT-CBCT) of 80 consecutive patients treated from December 2013 to August 2018 with the SSA technique by 2 experienced private dentists (G. F., A. P.) were examined to be potentially included in this retrospective radiological study. All patients for whom a baseline and a follow-up (FU) CBCT (up to 7 years after implant placement) could be retrieved were included in the study.

2.2 | Surgical procedure

The detailed surgical technique was reported in a previous article.[23] In brief, hopeless 1st or/and 2nd molars in the maxilla or the mandible were extracted with minimally traumatic procedure so as to preserve the integrity of the surrounding bony structure. Dental implants were placed in prosthetically driven position with or without the use of a surgical guide. Moreover, the remaining socket around the implant and slightly over the intact buccal bone were filled with a bovine-derived xenograft (Bio-Oss 0.5 g small particles, Geistlich pharma AG Wolhusen, Switzerland, Bio-Oss collagen block size of 50 mg, Geistlich pharma AG Wolhusen, Switzerland or Cerabone, granules 0.5-1 mm, 1×0,5 cc, Botisse Cerabone, Straumann, Basel, Switzerland). Following implant placement, SSA was fabricated and placed using either a conventional procedure using resin flowable composite increments to customize SSA around Ti-base abutment or a digital strategy though chairside CAD-CAM fabrication. Patients were advised to start antibiotics postoperatively (amoxicillin 500 mg/3 day or clindamycin 300 mg/4 day) for 7 days, to take paracetamol (maximum 4 g/day) for pain management and to rinse with chlorhexidine 0.15% (3/day) for 7 days. All implants were restored after 3 to 4 months with a screw-retained monolithic crown (Lithium Disilicate or Zirconia) bonded on a Ti-base (Variobase, Straumann) (Figure 1).

2.3 | Radiographic examinations

In order to accurately evaluate linear and volumetric changes of the alveolar ridge in immediate implant sites, a superimposing of the baseline and FU CBCTs was performed with a dedicated image processing and analysis software (MeVisLab, MeVis Medical Solutions AG Bremen, Germany) using rigid registration. The irradiation protocol was 10.0 mA, 90 kV and a slice thickness of 0.150 mm (Planmeca ProMax 3D Plus Tuusula, Finland).

3 | HARD TISSUE ANALYSES

The goal was to establish a reproducible and precise protocol so as to measure the rates of horizontal and vertical bone changes following the

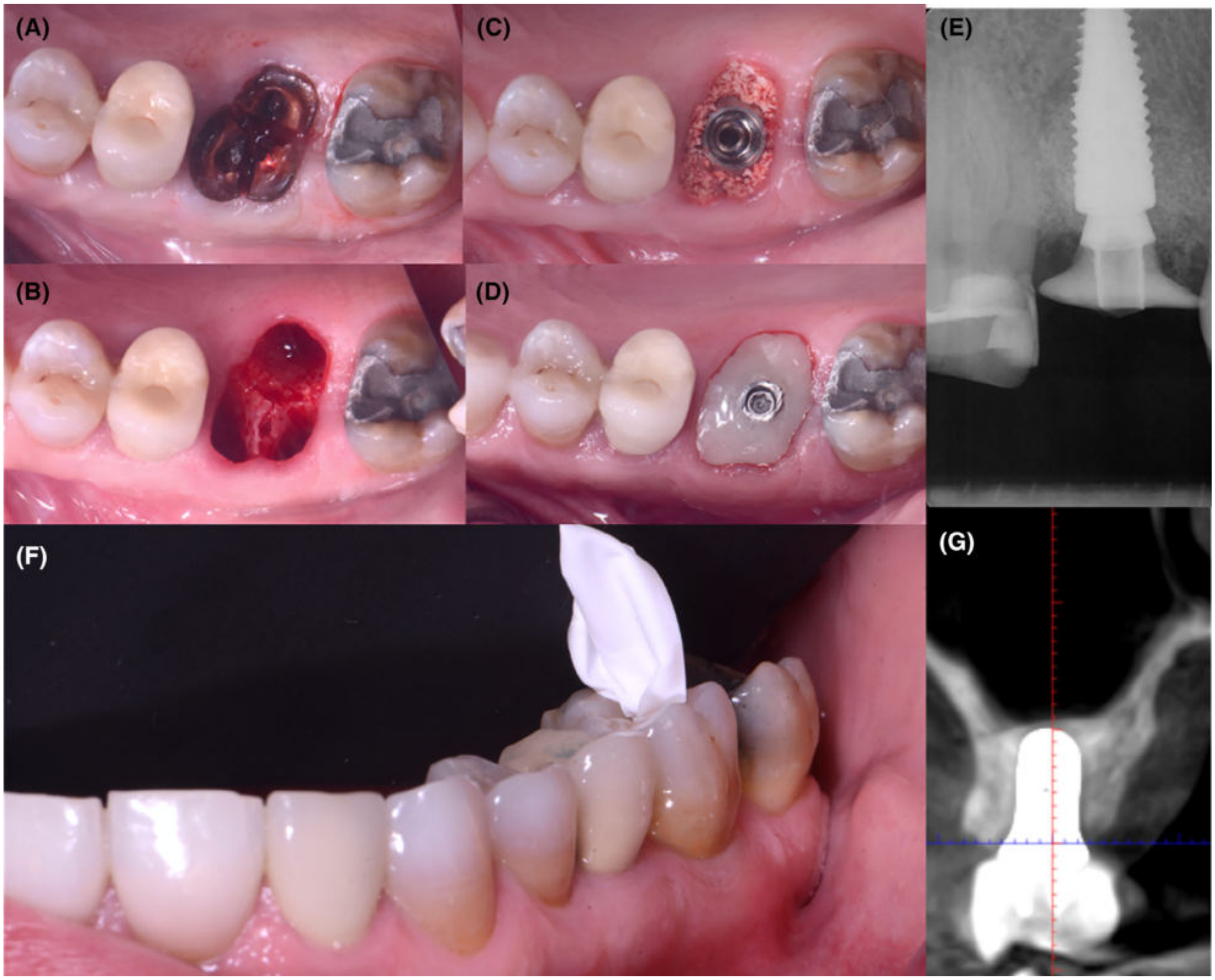

FIGURE 1 Surgical procedure. A, a hopeless right upper molar; B, after atraumatic extraction and optimal granulation removal; B,C, implant placement with simultaneous filling of the residual socket with biomaterials; D, preparation and installation of SSA; E, postoperative radiograph; F, crown delivery 3 months FU; and G, FU CBCT 2 years after

immediate implant placement procedure combined with ARP and SSA. Therefore, the radiologic datasets from baseline and follow-up were imported in DICOM format into the software to be matched and superimposed using rigid registration. All measurements were performed by two independent examiners (M.A. and B.K.). Primary outcomes were two types of linear measurements conducted horizontally and vertically.

3.1 | Horizontal bone changes (Figure 2a-d)

The horizontal bone changes were evaluated on a bucco-lingual/palatal cross-section in the implant midline. A horizontal reference line (RL) was defined at the level of the implant platform for bone level implants and below the machined collar for tissue level implants (Figure 2a). The horizontal width changes between the baseline and follow-up (FU) dataset were calculated at the RL and at −2 mm, −5 mm and −7 mm below this line, from the buccal to the lingual/palatal aspects. It was made possible to switch interactively from the baseline to the FU dataset and keep the exact same reformat with the measurements on the screen. Subsequently, observers could then adjust those measurements, which revealed horizontal width changes over time. In total four measurements (mm) were obtained for each implant.

Additional horizontal measurements were performed to evaluate hard tissue alterations above the RL. These horizontal measurements were made at 3 para-axial levels: 1 in the implant section (implant midline), 1 at the level of the mesial root and 1 at the level of the distal root (Figure 2b-d). The center of the mesial and distal roots was defined on the baseline CBCT and then the examiners switched to the FU CBCT to start the measurements. Consequently, a line was drawn from the most coronal and external margin of the alveolar ridge from the buccal to the lingual/palatal side. Measurements continued −1 mm and −2 mm below this line around the implant. Similarly, to previous measurements, it was possible to switch from baseline to FU CBCTs and calculate the horizontal bone changes of the alveolar crest

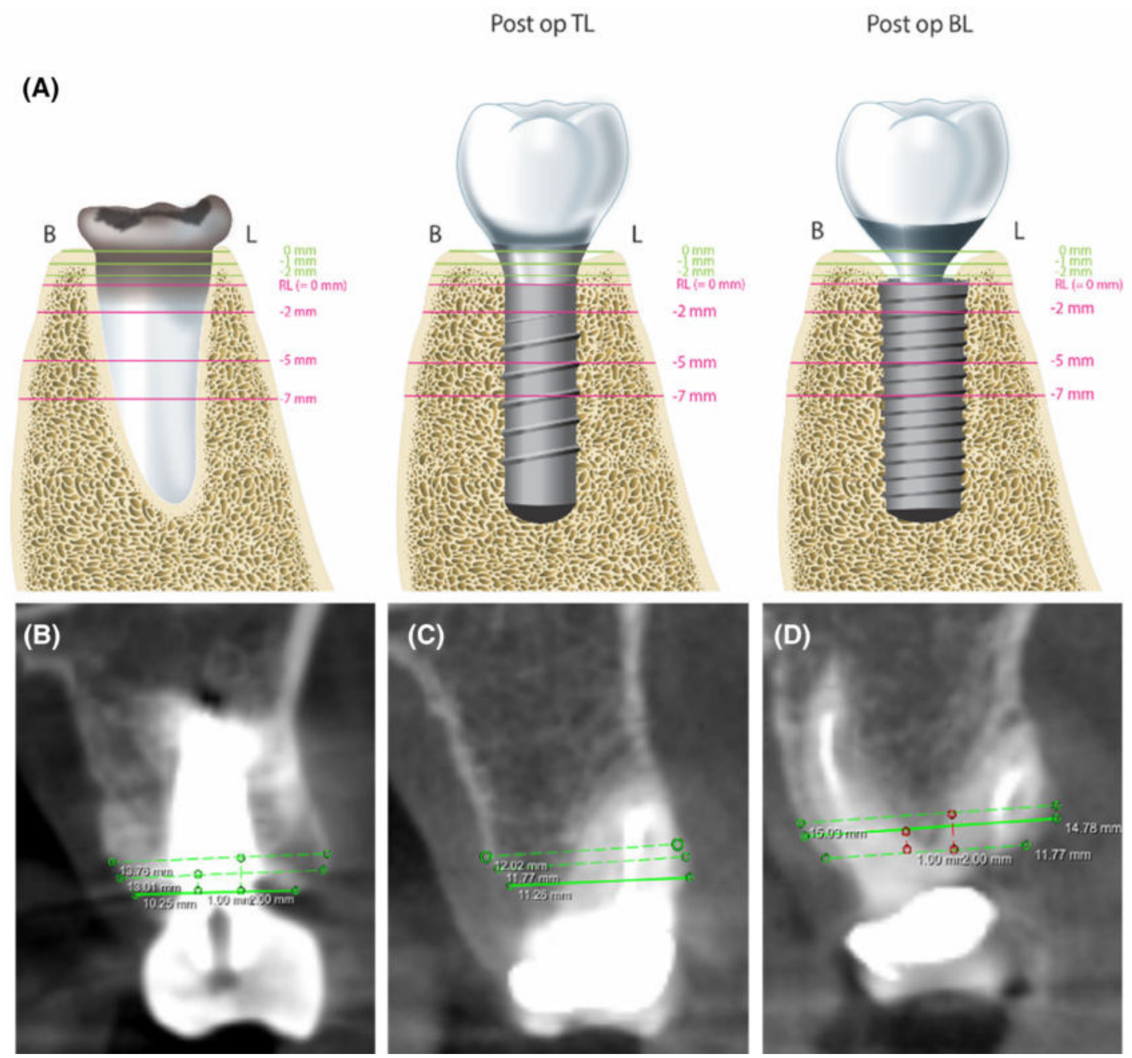

FIGURE 2 A, Horizontal bone measurements at the implant section below and above the reference line (RL), horizontal bone measurements above the RL, B, at the implant section, C, middle of mesial root, and D, middle of distal root

in the implant area. In total nine oblique measurements (mm) were obtained for each implant site.

3.2 | Vertical bone changes (Figure 3a,b)

Furthermore, vertical bone changes from baseline to FU CBCTs were assessed at the buccal plate in a similar fashion, at the implant section as well as mesially and distally at the contact points. Moreover, vertical bone measurements were performed in the middle of the alveolar bone crest at the proximal surfaces. Thus, in total 5 vertical measurements (mm) were obtained at each implant site.

3.3 | 3D volumes (Figure 3c)

Finally, bone volume around the implant was assessed using region growing algorithms and manual segmentation on all cross-sections. This algorithm selects grey values based on a chosen seed point (eg, cortical bone) and segments the grey values in the volume representing this bone density. Since automatic region growing will not completely segment out bone volumes, further manual segmentation occurred using coronal, sagittal and axial planes relative to the face. The region of interest (ROI) was determined again on the FU dataset: on the sagittal plane through the neighboring teeth, the bone volume was measured in a region limited by the contact points of the implant crown (mesial and distal limits) and seven mm apically from the alveolar crest; on the axial and coronal plane bone volume was measured from the buccal to palatal/lingual cortical bone. Since both datasets were registered, the exact same volume was available on the baseline dataset, cropping of course the tooth crown from the final volume. Segmentation first occurred on the FU-dataset and was then transposed to the preoperative dataset and then manually adjusted to minimize user dependency. After baseline and FU bone segmentation, the software calculated the bone volume around the tooth (BVPRE) and the implant (BVPOST) in mm^3 and percentages.

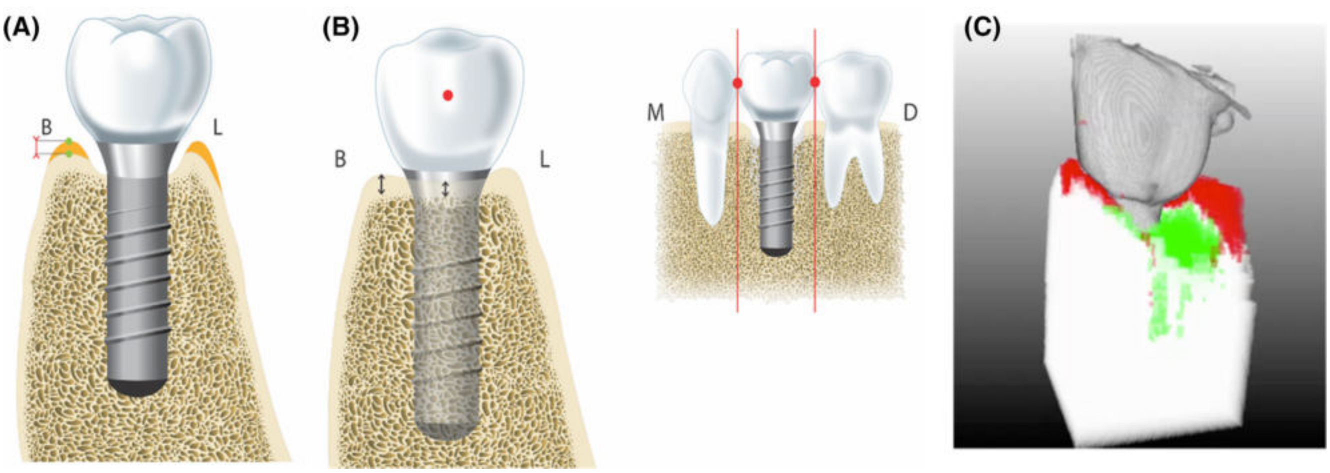

FIGURE 3 Vertical bone changes, A, at the buccal aspect at the implant section, B, at the buccal aspect and the middle of the alveolar crest at the contact points and C, bone volume

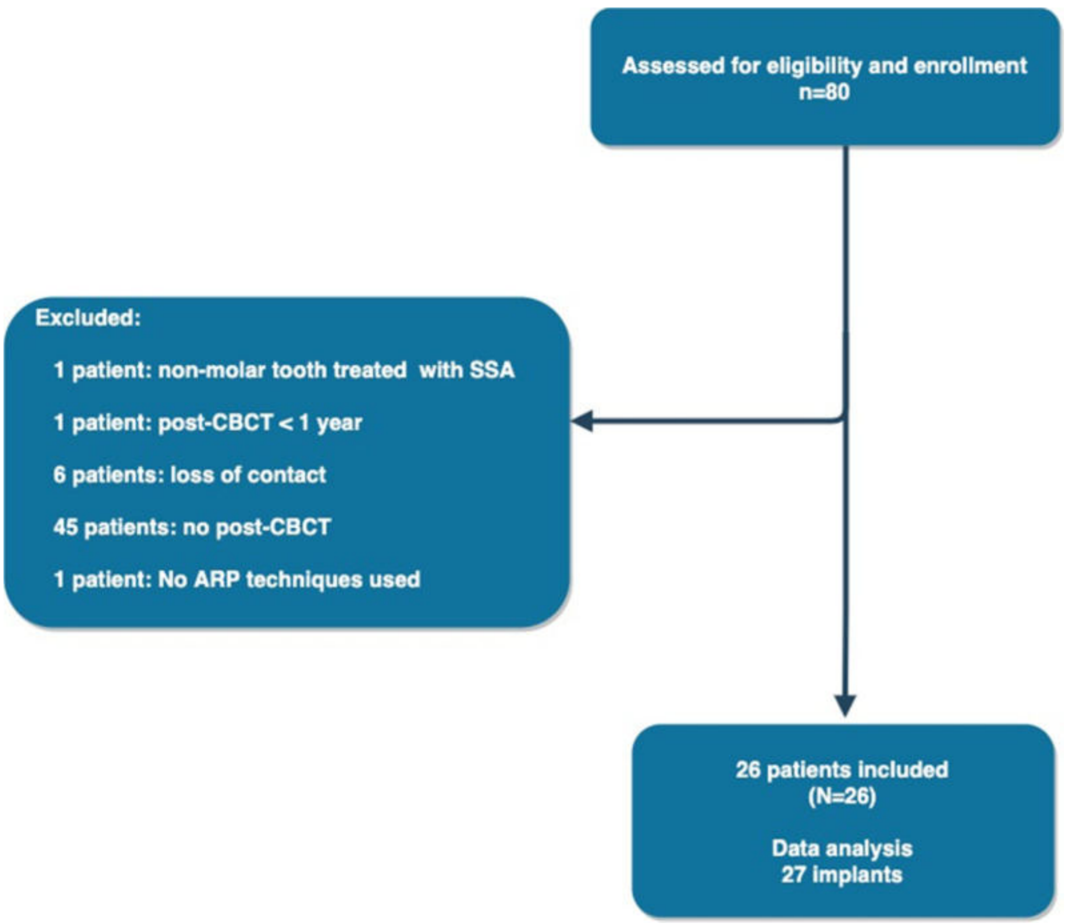

FIGURE 4 Flow chart

3.4 | Statistical analysis

The results were expressed as mean and standard deviation (SD), minimum and maximum for the continuous variables and as frequency tables (number/percent) for qualitative variables. The intraclass correlation coefficient (ICC) was used to test the agreement between the two independent examiners (M.A, B. K.) for each measurement. Each measurement was then averaged over both examiners. The change in measurement between baseline and 1-year follow-up was assessed by the paired Student *t* test and the Wilcoxon signed rank test. Linear mixed effect models were used to compare within patient evolutions between measurement levels.

TABLE 1 Patient and implant characteristics

Variable	N	Mean ± SD (range) Number (%)
Patient		
Age (years)	26	46.81 ± 11.19 (25–64)
Gender	26	
Male		10 (38.0)
Female		16 (62.0)
Implant		
Position	27	
16		8 (30.0)
26		3 (11.0)
36		7 (26.0)
37		2 (7.0)
46		7 (26.0)
Type	27	
Tissue level		13 (48.0)
Bone level		14 (52.0)
Brand	27	
Straumann		26 (96.3)
Nobel active		1 (3.7)
Implant length	27	
8 mm		10 (37.0)
10 mm		14 (52.0)
12 mm		3 (11.0)
Implant diameter	27	
4.3 mm		1 (3.7)
4.8 mm		26 (96.3)
SSA material	27	
Flow composite		12 (44.4)
PMMA, polymethyl methacrylate		14 (51.9)
PEEK, polyetheretherketone		1 (3.7)
Type of biomaterial	27	
Cerabone		18 (66.7)
Bio-oss collagen		7 (25.9)
Bio-oss		2 (7.4)

Moreover, bone changes according to the implant position in the mouth (maxilla/mandible), type of implant (bone/tissue level) were investigated using the unpaired Student *t* test and Kruskal-Wallis test. Subgroup analysis for implant placed in the maxilla/mandible and bone/tissue levels implants was assessed by the paired Student *t* test. Furthermore, the influence of the time interval of the FU-CBCT scan was explored for all measurements. Results were considered significant at the 5% level ($p < .05$). The calculations were performed with SAS version 9.4 (SAS Institute, Cary, NC).

4 | RESULTS

4.1 | Demographics and implant data

In total, the radiographic data of 80 patients were examined and baseline and follow-up (after at least 1 year) CBCTs could be retrieved in 26 patients (27 implants) (Figure 4). A total of 16 women (62%) and 10 men (38%) were included with a mean age of 46.81 ± 11.19 years old. The time interval between the baseline and the follow-up CBCTs was on average 27.5 ± 11.8 months (range: 12–50 months). Eleven implants were placed in the maxilla, sixteen in the mandible and thirteen tissue level along with fourteen bone level implants were used. The sites and implant related data are displayed in Table 1.

4.2 | Hard tissue analyses

The results collected from the 3D imaging measurements showed high reliability between the two examiners (ICC ranging between 0.790 and 0.967). Therefore, examiner measurements were averaged for each patient.

4.2.1 | Horizontal bone changes

The results showed that post extraction bone remodeling from baseline to a minimum of 1-year FU was not significant at the level or below the RL (Table 2). Moreover, the horizontal bone thickness in the most cervical area (above the RL) revealed to be equally stable, except at the 0 mm level where a mean bone loss of 0.73 ± 1.74 occurred (p = .039) and this corresponds to buccal horizontal bone loss of 48.75 ± 42.33%. Thus, the remodeling pattern was similar in the buccal and palatal aspects. Details are presented in Table 3.

TABLE 2 Horizontal bone changes below RL from baseline to FU (mean ± SD) (N = 26)

Bone level	Total horizontal change mm	Total horizontal change %	*p*-value
RL	0.33 ± 1.28	1.02 ± 18.93	.19
−2 mm	0.21 ± 0.75	1.37 ± 6.95	.16
−5 mm	0.17 ± 0.46	1.25 ± 3.57	.071
−7 mm	0.009 ± 0.37	0.28 ± 2.99	.90

TABLE 3 Horizontal bone changes above RL from baseline to FU (mean ± SD) (N = 26)

Localization	Bone level	Buccal change (mm) Mean ± SD	Buccal change % Mean ± SD	Palatal/lingual change Mean ± SD	Total horizontal change Mean ± SD	*p*-value
Implant section	0	0.34 ± 1.15	48.75 ± 42.33	0.39 ± 0.77	0.73 ± 1.74	**.039**
	−1 mm	0.22 ± 1.02	53.04 ± 37.13	0.13 ± 0.69	0.3 ± 1.45	.30
	−2 mm	0.06 ± 0.92	49.9 ± 37.71	0.11 ± 0.37	0.09 ± 1.06	.67
Mesial root	0	0.33 ± 1.27	57.97 ± 34.85	0.43 ± 0.49	0.9 ± 1.21	**.001**
	−1 mm	0.26 ± 0.94	44.54 ± 47.28	0.22 ± 0.35	0.46 ± 1.01	.025
	−2 mm	0.20 ± 0.82	56.36 ± 51.22	0.12 ± 0.35	0.26 ± 0.94	.17
Distal root	0	0.45 ± 0.75	42.16 ± 33.28	0.42 ± 0.88	0.87 ± 1.61	**.009**
	−1 mm	0.32 ± 0.64	40.54 ± 44.35	0.05 ± 0.73	0.31 ± 1.23	.20
	−2 mm	0.13 ± 0.50	41.80 ± 52.31	0.07 ± 0.60	0.13 ± 0.97	.50

Abbreviation: RL, reference line.
Note: Bold values shows $p < 0.05$.

TABLE 4 Vertical bone changes from FU to baseline (mean ± SD) (N = 26)

Localization	Total vertical change Mean ± SD	*p*-value
Buccal	0.18 ± 1.82	.61
Mesial-buccal	0.34 ± 1.87	.35
Mesial-middle	0.35 ± 1.69	.29
Distal-buccal	0.01 ± 1.33	.96
Distal-middle	0.10 ± 1.34	.70

4.2.2 | Vertical bone changes

In all sites, vertical bone dimensions were found to be stable from baseline to FU with no significant differences. Results are presented in Table 4.

4.2.3 | 3D volumes

The statistical analysis of bone volume revealed no statistically significant difference between baseline bone volume and FU ($p = .05$). A bone volume remodeling of 3.28 ± 19.21% ($p = .38$) was observed.

4.2.4 | Maxilla versus mandible data

A comparison of the bone remodeling between the maxillary and mandible was performed and a statistically significant difference in terms of horizontal bone changes above the RL, at the RL and at −2 mm bone level below it were observed from baseline to follow-up around the implants that were placed in the maxilla (Table 5). When looking at the volume analyses, significantly more resorption was also observed in the maxilla (probt = .005). Generally, the horizontal and vertical bone changes between the implants that were placed in the maxilla and the mandible demonstrated homogeneous changes for both jaws (Table 5) in time, except the 0 mm level at the implant section, where we observe a statistically significant reduction around the implants of the maxilla ($p = .038$).

4.2.5 | Type of implant

Fourteen bone level (BL) and thirteen tissue level implants (TL) were placed in the present study. The statistical analysis showed comparable bone changes for both types of implants and for all measurements with no statistical difference observed in the implant midline cross section. Additionally, around TL implants at the 0 mm level of both mesial ($p = .027$) and distal root ($p = .043$) a statistically significant reduction in terms of horizontal bone changes was observed. Regarding BL implants a statistically significant difference was only noticed at the 0 mm level of the mesial root ($p = .014$). Detailed results are presented in Table 6.

4.2.6 | Bone changes in relation to the time of follow-up (FU)-CBCT

The minimum interval between the two radiological exams was 12 months and the maximum 50 months with an average of 27.5 ± 11.8 months (median 26.1 months). The bone remodeling pattern (for all measurements) was not influenced by the FU intervals.

5 | DISCUSSION

This study suggests that the use of customized SSA for immediate implant placement in molar sites combined to ARP procedures may limits post extraction bone remodeling. Horizontal bone changes below 1 mm were observed only in the most cervical area while vertical bone changes were not observed at all (Tables 2-4). The horizontal changes seem to be more pronounced in maxillary implant sites when compared to mandible and TL versus BL implant follow the same bone remodeling pattern. Finally, according to our results, this bone

TABLE 5 Horizontal bone changes above and below the RL in relation to jaw (mean ± SD) (N = 26)

Localization		Maxilla Mean ± SD	Probt	Median	Mandible Mean ± SD	Probt	Median	*p*-value
0 mm	Implant section	1.55 ± 1.32	0.003	1.77	0.16 ± 1.79	0.73	0.52	**.038**
	Mesial root	1.26 ± 0.95	0.001	1.00	0.65 ± 1.34	0.070	0.57	.21
	Distal root	1.42 ± 0.85	0.001	1.52	0.48 ± 1.90	0.32	0.44	.14
−1 mm	Implant section	0.90 ± 0.81	0.004	1.01	0.12 ± 1.66	0.78	0.20	.074
	Mesial root	0.90 ± 0.71	0.002	1.00	0.16 ± 1.1	0.57	0.34	.060
	Distal root	0.73 ± 0.71	0.006	0.64	0.02 ± 1.44	0.96	0.13	.15
−2 mm	Implant section	0.54 ± 0.7	0.029	0.51	0.22 ± 1.17	0.45	0.06	.065
	Mesial root	0.64 ± 0.57	0.004	0.68	0.01 ± 1.06	0.98	0.21	.080
	Distal root	0.41 ± 0.78	0.11	0.38	0.07 ± 1.06	0.81	0.00	.22
Implant Section	RL	0.83 ± 1.08	0.030	0.51	−0.01 ± 1.32	0.98	0.00	.095
	−2 mm	0.52 ± 0.77	0.048	0.40	−0.01 ± 0.66	0.95	−0.06	.066
	−5 mm	0.28 ± 0.52	0.10	0.25	0.09 ± 0.42	0.40	0.00	.30
	−7 mm	0.13 ± 0.47	0.37	0.13	−0.11 ± 0.26	0.11	0.00	.096
Bone volume %		9.75 ± 9.15	0.005	12.41	1.16 ± 23.07	0.84	4.52	.15

Abbreviation: RL, reference line.
Note: Bold values shows $p < 0.05$. Paired student *t* test: Probt value and unpaired student *t* test: *p*-value.

TABLE 6 Horizontal bone changes above the RL in relation to the type of implant (Mean ± SD) (N = 26)

Localization		Tissue level (TL) Mean ± SD	Probt	Median	Bone level (BL) Mean ± SD	Probt	Median	*p*-value
0 mm	Implant section	0.84 ± 1.39	0.051	0.50	0.63 ± 2.06	0.28	0.93	.76
	Mesial root	0.80 ± 1.14	0.027	0.50	0.99 ± 1.31	0.014	0.81	.69
	Distal root	0.94 ± 1.5	0.043	1.00	0.80 ± 1.76	0.11	0.88	.83
−1 mm	Implant section	0.55 ± 0.99	0.069	0.52	0.06 ± 1.79	0.90	0.38	.40
	Mesial root	0.46 ± 0.87	0.083	0.50	0.47 ± 1.17	0.16	0.63	.97
	Distal root	0.15 ± 1.12	0.63	0.62	0.46 ± 1.35	0.23	0.95	.53
−2 mm	Implant section	0.15 ± 0.70	0.45	0.13	0.03 ± 1.33	0.94	0.20	.76
	Mesial root	0.33 ± 0.61	0.073	0.25	0.18 ± 1.18	0.57	0.37	.69
	Distal root	0.01 ± 0.65	0.95	0.00	0.26 ± 1.21	0.44	0.41	.48

Abbreviation: RL, reference line.
Note: Paired student *t* test: Probt value and unpaired student *t* test: *p*-value.

remodeling seems to occur within the first year after the procedure as no extensive resorption was observed on the longer follow-up. To the best of our knowledge, the present retrospective is the first study assessing radiographic outcomes of immediate implant placement in the molar's region using the SSA technique.

5.1 | Horizontal bone changes

The present data demonstrated stable peri-implant bone width below and above the RL, except in the most coronal measurement (0 mm level above the RL) for which a significant bone remodeling of 0.73 ± 1.74 mm was found. These results are not fully consistent with the existing literature exploring the peri-implant crestal dimension after extraction and immediate implants in the posterior region, as several authors found higher horizontal bone change after this type of procedure.[27-29]

The limited horizontal bone changes observed in the present study compared to the existing literature, might be related to the use of a customized healing abutment (SSA) as it has never been explored before. While supporting the peri-implant soft tissues, the SSA also serves the principles of guided bone regeneration.[30] In other words, it provides a mechanical closure of the socket, ensures an undisturbed and uninterrupted environment, in which blood clot and the bone grafting materials are stabilized and prevented from their exposure to the oral cavity. Consequently, SSA abutment creates, maintains and transforms the intralveolar socket to a favorable space in which ARP techniques could be secured and reduce hard tissue alterations.

Additionally, Tallarico et al. compared ARP procedures in the posterior area with or without implant placement (Type 1 versus Type 3) and they found higher horizontal bone loss in the cervical region (1.78 mm) when the implant was immediately placed while the delayed approach allowed a remodeling of only 0.45 mm.[27] However, in their study extra-large diameters implants were used (7 mm in diameter), which could explain the excess remodeling process as wide implants reduce the jump distance, which is important in order to create a room for the ARP procedure[16,17] and to optimize the regeneration process of the socket during ARP techniques as suggested by some authors.[10,18] Moreover, they used a resorbable space filling biomaterials containing 22.4% of organic matrix, which may influence the result of the ARP procedure.[31,32]

In a retrospective radiographic study assessing bone changes in Type 1 implant placement in molars and premolars a horizontal bone loss of 1.25 ± 2.21 mm was found at the most cervical level.[29] Besides, the lack of use of customized sealing abutment, clashes with our results as these are interpreted by the surgical procedure, which includes non-flapless cases as well as premolars indication. Indeed, it was demonstrated that detachment of the periosteum following a tooth extraction leads to an additional osteoclastic resorption and causes bone loss.[33-38] In the current study oral surgeons performed minimally invasive extractions in all cases, which were exclusively molars, so as to optimize integrity of hard tissues, during post extraction healing processes. Indeed, anatomical differences between molars and premolars may also play a role in the degree of the resorption process.[16,17]

From a more recent study,[28] a significant horizontal bone change (1.33 ± 0.37 mm) was found at the RL (at the smooth/rough surface junction of the implant) while our results show very stable bone features from baseline to 1 year. Beyond the potential benefit of an SSA these inconsistencies may be influenced by the vertical positioning of the implant and therefore the position of the RL.

5.2 | Vertical bone changes

The present study showed stable vertical bone measurements in all investigated sites (Figure 2b,c and Table 4). The results are in agreement with the clinical data of Cheng et al.[29] showing a stable vertical dimension of the alveolar crest for immediate implant in posterior region when combined with DBBM and even a slight bone gain of 0.18 mm. SSA took advantage of the use of a slowly resorbable xenogenic grafting material slightly above the alveolar bone (socket overfilling) as described by some authors[20] and that may have played a significant role in the preservation of the vertical dimensions. However, from the present radiological data, the nature of radiopaque tissue remains unknown and histology would be necessary to characterize the regenerated tissue. Nevertheless, based on preclinical data, it was concluded that the biomaterials placed in the jump distance were properly osseointegrated.[18] Additionally, with regards to vertical bone stability, we could once again explain the reduced bone remodeling by a minimally invasive tooth extraction approach combined with the implementation of a rigid alveolar closure.

5.3 | Bone volume

Although horizontal bone remodeling is very limited, the bone loss localized in the most cervical area was also emphasized with 3D volume analysis. Beyond the numerical bone reduction of 3.28 ± 19.21% the volume analysis provides an overview of the bone loss pattern occurring mainly in the most cervical and proximal regions of the implant site while buccal gain can be observed in certain cases (Figure 2d).

5.4 | Maxilla versus mandible data

In the most cervical region, horizontal bone changes were found to be pronounced in maxillary implant sites when compared to mandible ones. This finding may be related to the higher bone mineral density at the posterior mandible as emphasized by several authors.[39,40]

5.5 | Type of implant

The present study suggests TL and BL implants in combination with ARP techniques and SSA can follow the same bone remodeling pattern. Owing to the use of SSA abutment primary closure was achieved and the ARP techniques were secured to reduce hard tissue alterations around TL implants. Furthermore, to compensate the existence of a microgap (as opposed as TL implant), BL implants offer a platform switching, which allows a better crestal stability according to systematic reviews and meta-analysis.[41] Moreover, it has been shown that the shape and space occupied by the transmucosal components directly influences bone stability around the implant shoulder. It was observed that the narrower the transmucosal abutment is around the implant shoulder the less remodeling occurs in this critical area. This explains why emergence profile was designed by the operators in an umbrella shape in order to follow these concepts.[42,43] This may have also played a role in the preservation of the horizontal dimension of the peri-implant alveolar crest.

Regarding the horizontal bone loss that is observed around TL implants in mesial and distal root and around BL implants in the mesial root, the data may be related to the minor thickness of buccal bone plate in that area, which could have enhanced a more pronounced bone remodeling, contrarily to the cross section midline of the implant mainly located in the septum area, which behaves as a thick protecting "bone shield." Additionally, more traumatic manipulations during the tooth extractions take place at these sites, because of the complicated root morphology, which may have influenced the total bone remodeling of the region.[36] Therefore, it could be suggested to perform implant placement into the alveolar septum not only because it matches with most appropriate prosthetic solution but also as to decrease bone remodeling around the implant.

5.6 | Bone changes in relation to the time of FU-CBCT

An additional interesting aspect of the current study is the analyses of hard tissue alterations after such a procedure in relation to the time of FU-CBCT. The data showed that bone changes were not influenced for any variables by the time of FU CBCT and this suggest that the remodeling occurs within the first year after the procedure and thereafter the horizontal and vertical bone dimension remain stable. These findings are in accordance with previous studies[15,44-46] showing that hard tissue changes after extraction and immediate implant occur mainly in the first 3 months following the procedure.

5.7 | Limitations

Although the present study revealed some promising data, further studies including a control group would be needed to confirm the present results. In addition, the results should be interpreted carefully due to the retrospective design of the study and, thus, the heterogeneity of the protocols such as vertical implant positioning, implant type, CBCT resolution to name but a few. Additionally, no correction was made for multiple testing in this study despite the large number of statistical tests applied and the small sample size. Therefore, *p*-values should be interpreted with some caution and not in a strictly dichotomic "significant or not significant way." Further limitations stand in the type of data (radiographic). The presence of metal artifact from the crown or the implant body and the voxel resolution (0.150 mm) of the CBCT may have influenced the results as well.[47] Moreover, the presence of radio-opaque, peri-implant tissue cannot surely be interpreted as a native regenerated bone given that biomaterials used are also radio-opaque. No histological analyses were performed to confirm the exact nature of the preserved tissue dimensions. Finally, the effect of CAD/CAM versus flow composite for the fabrication of customized SSA would be of relevant to investigate in further studies with larger samples.

6 | CONCLUSION

The present study aimed to assess the alveolar bone changes up to 5 years after Type 1 implant placement in the molar region using socket seal abutment (SSA) combined to ARP procedure. Considering the retrospective radiographic data, the following conclusion can be raised:

- Horizontal bone remodeling was not significant in any of the measured area except in the most cervical level, where a mean bone remodeling of 0.73 mm was found.
- Proximal and buccal vertical bone changes remained stable.
- More pronounced bone remodeling was observed around implants placed in the maxilla.
- TL and BL level implants seemed to follow the same bone remodeling pattern.
- Alveolar bone changes occurred mostly during the first year following the surgical procedure.

Within the limit of the present study, we can conclude that the use of customized SSA for immediate implant placement in molar sites combined to ARP procedures may have a positive influence on post extraction bone stability. However, further studies including a control group would be needed to confirm the present results.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest related to this study.

AUTHORS CONTRIBUTIONS

Marianzela Alexopoulou involved in data analysis, data collection, drafting article, approval of the submitted article. France Lambert, Antoine Popelut, and Gary Finelle involved in concept and design of the study, critical revision of the article, approval of the submitted article. Bryan Knafo involved in data analysis, critical revision of the article, approval of the submitted article. Bart Vandenberghe involved in research design and interpretation of the data, critical revision of the article, approval of the submitted article.

DATA AVAILABILITY STATEMENT

Research data not shared

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