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Immediate implant placement combining socket seal abutment and peri-implant socket filling: A prospective case series

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Abstract

Objectives: The aim of this prospective case series was to assess the implant outcomes as well as hard and soft tissue dimensional changes of immediate implant placement in posterior sites using a custom-made sealing socket abutment (SSA) combined to peri-implant socket filling (PISF).

Material and methods: Twenty patients were considered for single extraction and immediate implant in upper or lower posterior regions. The remaining peri-implant sockets were filled with Deproteinized Bovine Bone Mineral. Based on intra-oral scans (IOS), custom-made SSAs were placed the same day. Implant survival rate, peri-implant bone changes, peri-implant health and pink esthetic score (PES) were recorded up to 1 year post-implant placement. Moreover, CBCT and IOS were performed to monitor hard and soft tissue dimensional changes.

Results: One implant failed to osseointegrate leading to an implant survival rate of 95% after 1 year. Peri-implant bone changes yielded 0.19 ± 0.31 mm and 84.2% of the implants displayed no or mild bleeding on probing. Horizontal bone remodeling was not significant from baseline to 1 year at any levels. Finally, soft tissue profile was stable in the most cervical area while minor changes occurred during the first 6 months below the gingival margin. The absence of mid-buccal recession (0.07 mm) and good PES were found after 1 year.

Conclusion: Despite its limitations, this study showed that immediate implants in the posterior region using the SSA + PISF protocol resulted in promising implant outcomes with limited hard and soft tissue dimensional changes while decreasing the overall treatment time.

KEYWORDS
biomaterials, bone substitutes, dental implants, humans, prospective studies, survival rates, tooth extractions, tooth socket

1 | INTRODUCTION

In recent years, there has been a change in the management of patients and in the execution of the clinical and laboratory procedures of implant-supported restorations in view of improving patient demand and clinical outcomes. Patients are indeed interested in reducing the length of treatment, the number of surgical and clinical steps while achieving esthetic results. Therefore, this has led to an

increased use of new CAD–CAM technology, novel protocols and immediate implantation techniques.

In order to decrease the overall treatment time, extraction followed by immediate implantation was described. The survival rate of such procedures in the posterior region has proved to be comparable to delayed implants (Atieh et al., 2010; Ketabi et al., 2016; Ragucci et al., 2020). Immediate implant placement in extraction sockets, however, does not prevent from tissue shrinkage (Araújo et al., 2005, 2006; Botticelli et al., 2004, 2006; Covani et al., 2004; Lee et al., 2014; Schropp, Kostopoulos, et al., 2003). Nevertheless, when combined to alveolar ridge preservation procedures (ARP), post-extraction tissue loss can be significantly reduced (Araújo et al., 2011; Chen et al., 2007; Degidi et al., 2013). Indeed, the evidence that post-extraction tissue remodeling is limited by applying different ARP techniques is arising (Avila-Ortiz et al., 2019; MacBeth et al., 2017), and the long-term effectiveness, especially in the anterior region, was recently highlighted (Botilde et al., 2020; Roccuzzo et al., 2014). Unfortunately, in the posterior region, ARP is less documented and one of the remaining difficulties is to achieve primary wound closure without interrupting the soft tissue architecture (Chen et al., 2009).

Recently, specific protocols have been proposed to overcome these problems (Akin, 2016; Conejo et al., 2020; Finelle, 2017; Mihali et al., 2018; Bhatnagar & Raj, 2015; Ruales-Carrera et al., 2019). The "sealing socket abutment" (SSA) technique described by Finelle et al. has the objective of preserving the transgingival profile immediately after extraction by using a custom-made healing abutment (Finelle, 2016; Popelut, et al., 2017). This abutment also allows a primary wound closure and protects the alveolar clot and biomaterial particles underneath. The SSA technique offers all the advantages of implant provisionalization to the posterior region of the mouth and decreases the potential disadvantages of providing a provisional crown with an occlusal surface in this region.

While protocols for accelerating treatments and preserving the esthetic in the anterior zone continue to expand, such protocols in the posterior region are still scare. Moreover, if the SSA technique was nicely described in the literature as case reports and retrospective studies, the predictability and the limits as well as the potential benefit in terms of hard and soft tissue changes remain unexplored prospectively.

The primary objective of the present study was to assess the efficacy of immediate implant using a CAD–CAM custom-made SSA combined to peri-implant socket filling (PISF) in posterior sites to attenuate hard and soft tissue remodeling after extraction. The secondary objective was to evaluate the esthetic outcomes of this protocol.

2 | MATERIALS AND METHODS

2.1 | Regulatory approvals

The study protocol was approved by the Ethical Committee of the University Hospital of the University of Liège, Belgium (file number B707201837061). The study was registered on clinicaltrial.gov (file number: NCT04553146) and was performed according to the STROBE statement (Appendix S1).

2.2 | Study design

The study was designed as a single-center prospective case series with a 1-year follow-up. A total of 20 patients presenting a tooth to be extracted in the molar–premolar area of both jaws were included from January 2018 to July 2019 and followed for 1 year after implantation. Hard tissue dimensions and soft tissue profiles were recorded over the follow-up period as well as implant survival rate, peri-implant health (BOP, PI, PD), peri-implant bone changes and pink esthetic score (PES).

2.3 | Study population

Patients needing tooth replacement in the posterior zone (molars and premolars) were recruited from the Department of Periodontology and Oral and Implant Surgery of the University of Liège, Belgium. All the patients met the following inclusion criteria: good general health (ASA I/II), more than 18 years old, nonsmoker, one hopeless tooth, healthy periodontal condition, the presence of at least 2 mm of keratinized gingiva, intact buccal bone wall, adequate plaque control (FMPS ≤ 25%), adequate bone quantity in the septum if present and at least 5 mm of bone in the apical region and finally written consent provided. The exclusion criteria were: autoimmune disease or immunocompromised patients, uncontrolled diabetes, use of steroids or biphosphonates, local or systemic infection (medical treatment needed prior to entrance to the study), pregnancy or breastfeeding, alcoholism or chronically drug abuse. The local exclusion criteria were: bone availability requiring an angulated abutment, untreated local inflammation, cyst, mucosal disease or oral lesions, local irradiation therapy, oral communication with sinus after the extraction. All the patients read and signed the informed consent form before surgery. Patients who did not meet the inclusion criteria were considered as screen failures. Patients who dropped out from the study were not replaced and the reason of dropout was determined as precisely as possible.

2.4 | Clinical procedure

After a local anesthesia, one of the two experienced surgeons (LF or LG) proceeded to the least traumatic extraction of the concerned tooth. The consecutive drills for implant placement were carried out while considering the future position of the crown for a screw-retained restoration. Twenty BLX implants (Roxolid®, SLAactive®, Institut Straumann AG) were placed flapless with a sufficient apical or septum anchorage and the insertion torque was recorded. The gap around the implant was filled with deproteinized bovine bone mineral (DBBM) (cerabone®, botiss biomaterials GmbH). Just after the

implant placement, an intra-oral scan (IOS) (Trios 3®, 3-Shape) with a scanbody connected onto the implant platform was performed and sent to the dental laboratory to digitally design (Dental Wings®) a customized healing abutment. The SSA was then milled (CARES®, Institut Straumann AG) from a block of PEEK (JUVORA^{TM}PEEK, JUVORA™ Ltd. National Distributor: Institut Straumann AG), cemented to a titanium abutment (Variobase®, Institut Straumann AG) and provided to the patient on the same day. During manufacturing of the SSA, a conventional healing abutment was screwed on the implant and a collagen sponge (Collaplug®) was provisionally placed buccally to protect the exposed biomaterial until the placement of the SSA. A standardized parallel peri-apical radiograph using a custom-made film holder was taken in order to record the baseline bone level. Each patient was instructed to rinse twice daily with an aqueous solution of 0.2% chlorhexidine (Corsodyl®, GSK) and to avoid brushing of the area until the first recall 10–12 days later. Anti-inflammatories (Ibuprofen® 600 mg) and additional analgesics (Paracetamol® 500 mg) were prescribed and taken according to the patient's needs. If the surgeon deemed it necessary, an antibiotic was prescribed (Amoxicillin® 500mg 3x/day during 5 days). Three months after implantation, the abutment was removed, the osseointegration of the implant was checked and the final lithium aluminosilicate ceramic reinforced with lithium disilicate monolithic crown (n!ce® glass–ceramic block, Institut Straumann AG) based on the initial IOS was cemented to a titanium abutment (Variobase®, Institut Straumann AG) and placed. The transmucosal design from the SSA was replicated on the final crown. The clinical procedure is illustrated in Figure 1.

2.5 | Follow-up

Patients were examined before surgery (baseline), 10–12 days after implant placement, after 3 months, 6 months and finally 1 year. The soft tissue profiles were recorded at baseline, after 6 months and 1 year using IOS while the hard tissue dimensions were recorded at baseline and after 1 year using CBCT. Standardized radiographs were performed at baseline, after 3 months and 1 year in order to assess peri-implant bone changes. Implant survival rate and peri-implant health were recorded at each time point and the PES (Fürhauser et al., 2005) at 3 months and 1 year. Patients were asked to contact directly the study coordinator in case of adverse events.

2.6 | Data collection

2.6.1 | Implant outcomes

Implant survival was defined as the percentage of implants initially placed that was still present and not mobile at the follow-up. Failing implants were recorded any time after placement. The lost implants were considered implant failures directly affecting the implant survival rates. They were replaced 3 months after their removal and the new implants were not taken into account for further statistics.

The peri-implant bone levels were assessed on peri-apical radiography using the parallel technique: the linear distance between the implant shoulder of the bone level implants and the first bone to implant contact (DIB, mm) was measured at the mesial and distal aspects (Buser et al., 2009) using the specific software Image J64 (National Institutes of Health). Final DIB values were recorded as the average of the obtained mesial and distal values.

The peri-implant soft tissue health was also assessed at each time point. PI and BOP were scored according to Mombelli (Mombelli et al., 1987). PD was measured by means of a periodontal probe (CP 15 UNC, Hu-Friedy) and rounded off to the nearest millimeter. Although it was initially described to evaluate the esthetic outcomes in the anterior region, the pink esthetic score (PES) was used in this study in the posterior region. The PES compares the peri-implant soft tissue conditions to the respective features present at the contralateral natural tooth site. A score of 0, 1 or 2 was assigned to each parameter (mesial and distal papilla, soft tissue contour, soft tissue level, alveolar process, soft tissue coloring and texture), the highest possible score being 14, as described by Fürhauser (Fürhauser et al., 2005). These parameters were collected at the time of crown placement and at 1-year follow-up.

2.6.2 | Hard tissue dimension analyses

In order to evaluate the alveolar bone dimensions, patients were subjected to CBCT at baseline and at 1-year follow-up with the same device and parameters. The measurements were taken by matching and superimposing baseline and 1-year CBCTs in DICOM format, using 3D reconstruction software (SyngoVia®, Siemens). Firstly, a perpendicular cross section to the implant and alveolar ridge was chosen in the middle of the implant to measure 3 values: bone remodeling, coronal thickness and vertical buccal and palatal/lingual bone height changes (Figure 2). Bucco-palatal remodeling was measured perpendicular to the implant axis at the reference line (implant platform) and at −2, −5 and −7 mm below this line. It was possible to switch on the preoperative CBCT while retaining the measures at exactly the same place. Then, measures were modified and adapted to the preoperative dimensions which revealed global bone thickness changes. Similarly, the buccal remodeling was measured from the buccal aspect of the ridge to the middle of the implant and the palatal/lingual changes from the lingual/palatal aspect of the ridge to the middle of the implant (Figure 2a red). Furthermore, the bucco-palatal/lingual coronal thickness above the implant platform was measured on baseline and 1-year CBCTs at the most coronal aspect of the alveolar bone as well as 1 and 2 mm below (Figure 2a green). Vertical buccal and palatal/lingual bone height changes between baseline and 1-year follow-up CBCTs were also measured (Figure 2b). Additionally, at the panoramic section going through the middle of the implant, the vertical bone changes under both mesial and distal contact points of the implant crown were calculated (Figure 2c).

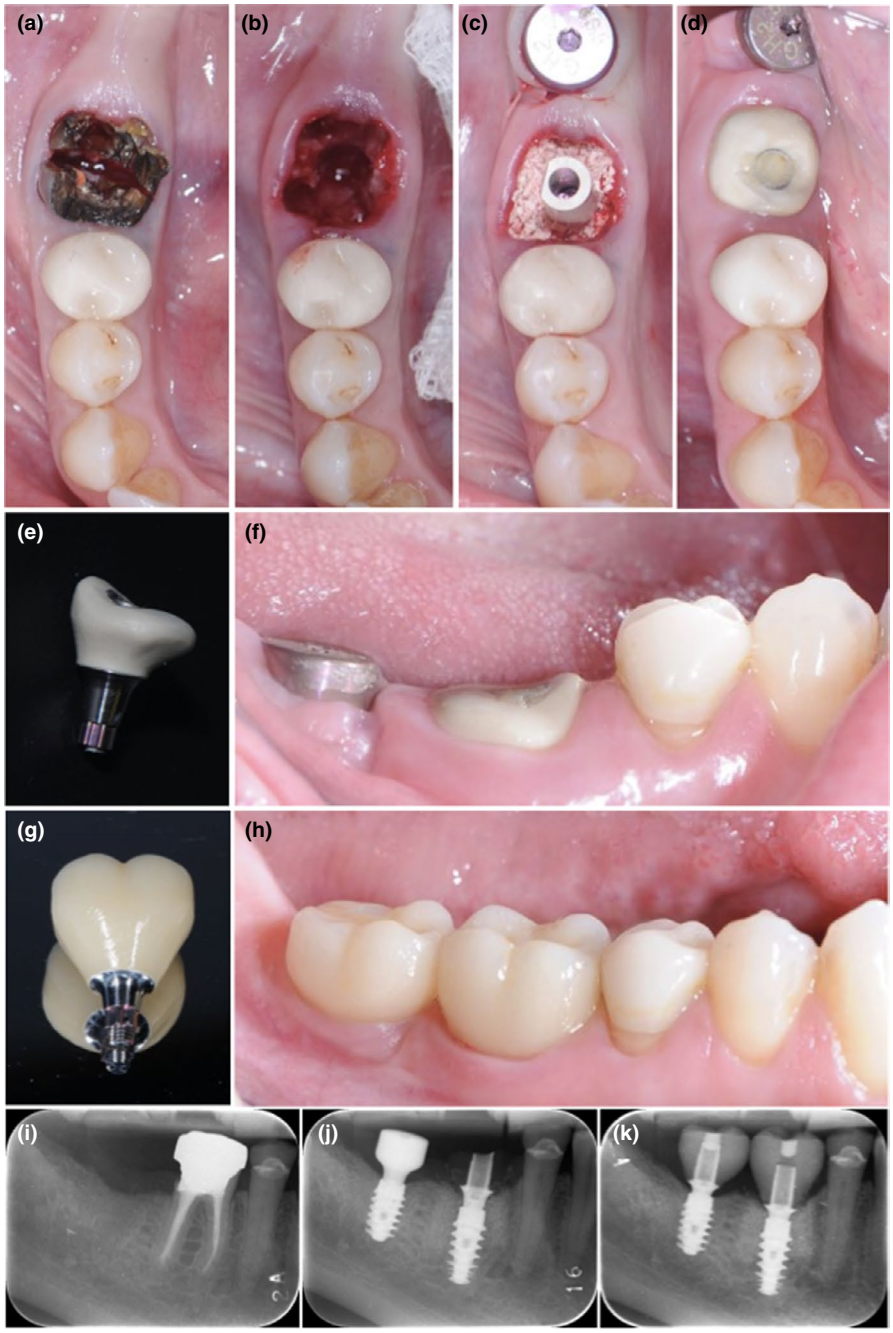

FIGURE 1 Clinical procedure. Hopeless right lower first molar (a), after atraumatic extraction and optimal granulation removal, the protocol drill was performed into the septum (b), implant placement with simultaneous filling of the gap around the implant with biomaterials and delayed implant placement for the right lower second molar (c), SSA after 10 days of healing (d–f), SSA design (e), crown design (g), clinical photography at 1 year (h). Baseline peri-apical radiograph (i), after 3 months (j) and 1 year (k)

Finally, the mean vertical implant positioning was calculated based on the superimposed CBCTs by measuring the distance between the most coronal aspect of the preoperative buccal bone plate and the implant platform.

2.6.3 | Soft tissue profile analyses

IOS (Trios 3®, 3-Shape) were performed just after the surgery, after 6-month and 1-year follow-up. For each patient, the baseline stereolithography (STL) file was superimposed to the 6-month and to the 1-year STL files using an image analysis software (GomInspect®, GOM). For each pair, a 2D bucco-lingual cross section was obtained in the middle of the implant axis. Buccal and lingual/palatal distances between the baseline and the postoperative soft tissue profiles were measured at the gingival margin (GM), and 1, 2, 3 and 4 mm below the GM on each paired STL file (Figure 3a). Finally, the mid-buccal recession was assessed by measuring the vertical distance between GM at the different time points (Figure 3b).

2.7 | Statistical analysis

Results were expressed as mean and standard deviation (SD) for quantitative measurements and as number (%) for categorical findings. The comparison between molar and premolar characteristics was

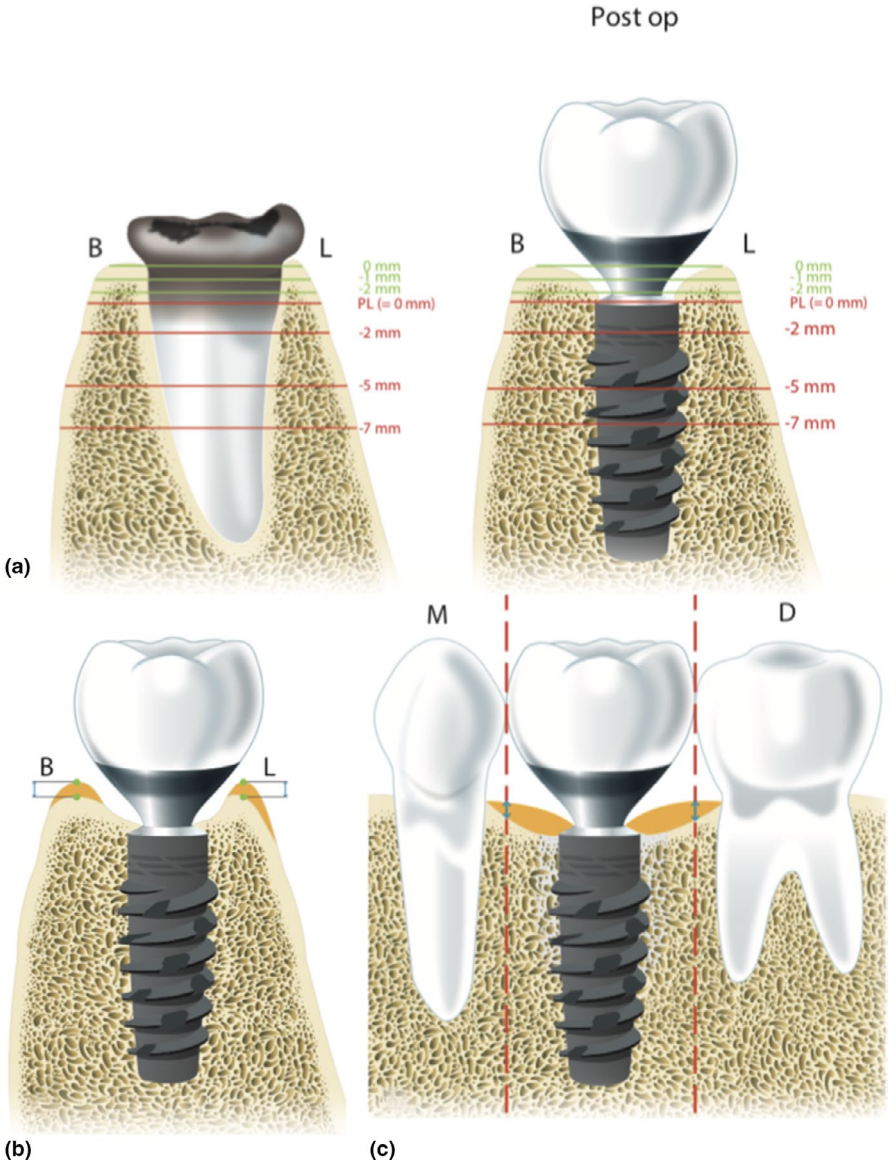

FIGURE 2 CBCT measurements. Horizontal bone changes (a) with bone thickness in pink and coronal thickness in green, vertical buccal and lingual/palatal bone changes in the middle of the implant (b) and vertical bone changes at the proximal surfaces (c)

done by unpaired Student *t*-test or Kruskal–Wallis test. Measurement changes between time points were compared by the paired Student *t* test or Wilcoxon signed-rank test. Longitudinal soft tissue and hard tissue data were analyzed by linear mixed models to assess the effect of time and other fixed factors such as level (0 to −7 mm), side (buccal, lingual/palatal) and localization (distal, middle, mesial) and their interaction. Results were considered significant at the 5% critical level ($p < .05$). All statistical calculations were done with SAS (SAS Institute, Cary, NC, version 9.4).

3 | RESULTS

3.1 | Patient demographics

A total of 11 molars and 9 premolars were replaced in 20 patients. Fourteen patients were women and 6 were men with a mean age of 51.4 years (range of 29–67 years). Patient- and site-related data are displayed in Table 1. One patient failed to take the follow-up radiographic analysis because of pregnancy and was therefore considered as a dropout for the hard tissue dimensional analysis.

3.2 | Implant outcomes

All implants could be placed flapless with a minimal insertion torque of 10 NCm (mean = 26.3). Postoperative infection occurred in three patients, who then received antibiotics after 10–12 days of follow-up. One implant displayed signs of peri-implantitis at 3 months (mesial marginal bone defect, 9 mm probing depth and BOP without suppuration). This peri-implantitis was treated surgically at 6-month follow-up using an electrolytic device (Galvosurge®, Dental AG) for implant surface cleaning combined to a guided bone regeneration (DBBM and resorbable collagen membrane). These postoperative complications (20% of patients) occurred in patients who did not receive antibiotics at the time of surgery and were solved with the above-mentioned

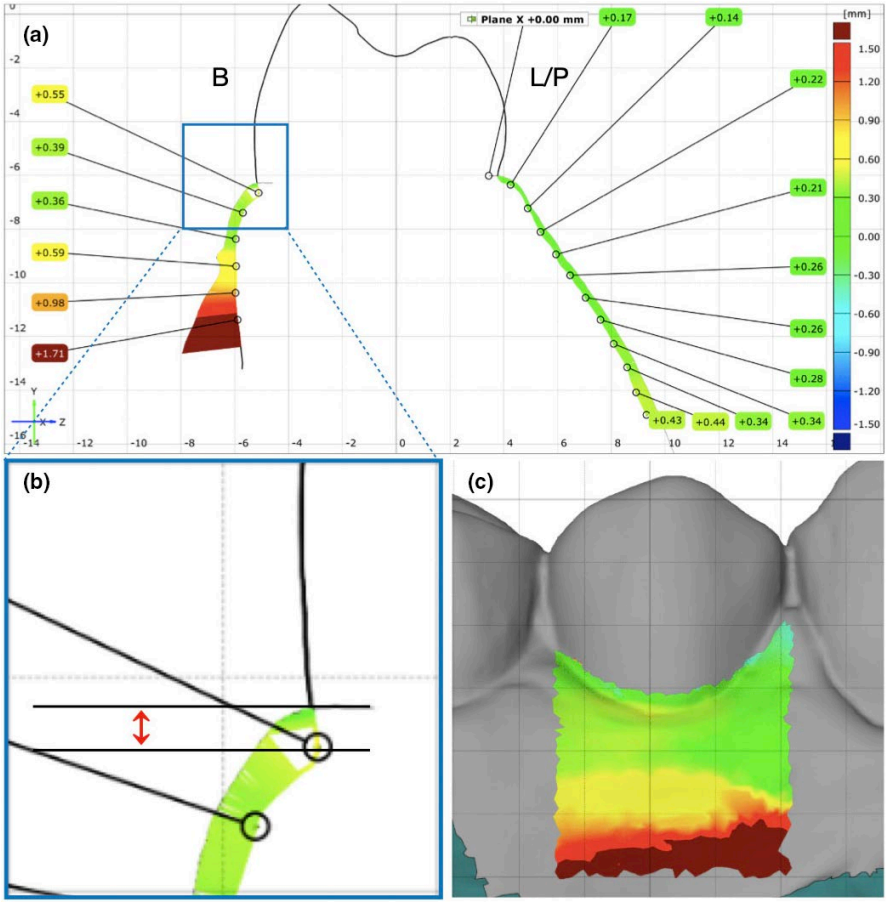

FIGURE 3 Soft tissue measurements. Buccal and lingual/palatal soft tissue changes (a), mid-buccal recession (b), volume cartography at the buccal aspect (c)

TABLE 1 Patient demographics and site characteristics

A, Patient demographics; $n = 20$		
Age (years)	Mean ± SD Min–Max	51.4 ± 11.58 29.0–67.0
Gender	Male	6 (30%)
	Female	14 (70%)
Gingival phenotype	Thick	3 (15%)
	Medium	9 (45%)
	Thin	8 (40%)
B, Site characteristics; $n = 20$		
Sites	Upper premolar	7 (35%)
	Lower premolar	2 (10%)
	Upper molar	1 (5%)
	Lower molar	10 (50%)
Buccal keratinized tissue mm (mean ± SD)	Upper jaw	4.38 ± 1.75
	Lower jaw	3.63±0.98
Plaque index	Sites with plaque	6 (30%)
Bleeding index	Sites with BoP	12 (60%)
Pocket depth (mm)	Mean ± SD Min-Max	3.00 ± 1.03 1.67–5.5

treatments. Furthermore, one implant failed to osseointegrate and was removed at 3 months leading to an implant survival rate of 95% at 1 year. The failing implant was replaced 3 months after removal without any further complication. All implants were successfully restored with the CAD–CAM lithium aluminosilicate ceramic reinforced with lithium disilicate monolithic crown.

TABLE 2 Implant outcomes

Implant-related data; $n = 19$																				p (p-Value)
	Baseline				3 months				6 months				1 year							
Implant survival rate	NA				95%				95%				95%							
DIB Mean ± SD mm	NA				0.50 ± 1.40				NA				0.19 ± 0.31							.37
PI number (%)	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3				
	14 (70)	5 (25)	1 (5)	0 (0)	11 (57.9)	5 (26.3)	3 (15.8)	0 (0)	11 (57.9)	7 (36.8)	1 (5.3)	0 (0)	9 (47.4)	9 (47.4)	1 (5.3)	0 (0)				.27
BoP number (%)	0	1	2	3	0	1	2	3	0	1	2	3	0	1	2	3				
	8 (40)	10 (50)	2 (10)	0 (0)	10 (52.6)	7 (36.8)	2 (10.5)	0 (0)	9 (47.4)	8 (42.1)	2 (10.5)	0 (0)	6 (31.6)	10 (52.6)	3 (15.8)	0 (0)				.32
PD Mean ± SD mm	3.00 ± 1.03				2.79 ± 0.68				2.81 ± 0.741				3.14 ± 0.60							.42
PES Mean ± SD	NA				12.2 ± 2.0				NA				12.1 ± 1.55							.81

Note: NA: nonapplicable. DIB: the linear distance between the implant shoulder of the bone level implants and the first bone to implant contact. PI: plaque index according to Löe (1967). BoP: bleeding on probing according to Mombelli et al. (1987). PD: probing depth. PES: Pink Esthetic Score according to Fürhauser et al. (2005).

The mean DIB was 0.50 ± 1.40 mm after 3 months and 0.19 ± 0.31 mm after 1 year ($p = .37$). At 1 year, 18 out of 19 implants (94.8%) displayed no or mild plaque accumulation and 16 implants (84.2%) displayed no or mild BOP. The mean peri-implant PD was 2.79 ± 0.68 mm at 3 months, 2.81 ± 0.74 mm at 6 months and 3.14 ± 0.60 mm at 1 year, and no statistically significant changes were observed over time ($p = .42$). Finally, the PES score remained stable from 3 months to 1 year ($p = .81$) with a score of 12.2 ± 2.0 at 3 months and 12.1 ± 1.55 at 1 year (out of 14). All implant-related data are summarized in Table 2.

3.3 | Hard tissue analysis

Hard tissue dimension changes were reported on 18 patients because one implant failed and for another patient who became pregnant the CBCT was not performed for safety reason. The overall horizontal bucco-palatal bone remodeling (Figure 2a, red) at the implant platform or below (respectively, −2, −5, −7 mm) did not change from baseline to 1 year, and the same observations were made at the buccal and lingual/palatal sides recorded separately except for the buccal remodeling 2 mm below the implant platform ($p = .0064$). Although not significant, the horizontal changes tended to decrease from the coronal to the apical levels. Above the implant platform (Figure 2a, green), a significant remodeling was observed at the −1 and −2 mm levels ($p = .0071$ and $p = .047$, respectively) while it was stable at the most coronal level ($p = .17$). As for the vertical bone losses, mesial and lingual measurements displayed significant changes (respectively, $p = .0033$ and $p = .0047$) while buccal and distal ones remained unchanged. It is worth mentioning that for all measurements, the mean changes always remained below one millimeter and that higher standard deviations were found in the most cervical measurements (implant platform, 0 mm and vertical measurements). The details of hard tissues data are displayed in Table 3. Furthermore, the mean vertical implant positioning compared to the preoperative buccal bone plate was 1.18 ± 1.52 mm.

3.4 | Soft tissue analysis

From baseline to 6 months, significant soft tissue profile changes were observed both buccally and lingually/palatally and at all levels except for the cervical margins (0 mm). From 6 months to 1 year, no further significant soft tissue profile changes were observed, except for the −4 mm level on the buccal side. No significant mean mid-buccal recessions were observed from baseline to 6 months and to 1 year. The detailed soft tissue profile data are displayed in Table 4.

3.5 | Premolar vs molar data

When premolar and molar data were compared, a large majority of the measurements followed the same trend both for the hard and soft tissue

TABLE 3 Hard tissue analysis

Hard tissue analysis; n = 18				
			Baseline – 1 year	p-value
Bucco-palatal remodeling mm (Mean ± SD) Fig 2.A		Implant platform	-0.93 ± 2.77	0.17
		-2 mm	-0.33 ± 0.81	0.10
		-5 mm	-0.14 ± 0.48	0.24
		-7 mm	-0.12 ± 0.38	0.19
Buccal remodeling mm (Mean ± SD) Fig 2.A		Implant platform	-0.48 ± 2.17	0.09
		-2 mm	-0.36 ± 0.49	0.0064
		-5 mm	-0.18 ± 0.37	0.06
		-7 mm	-0.13 ± 0.33	0.12
Lingual/palatal remodeling mm (Mean ± SD) Fig 2.A		Implant platform	-0.46 ± 1.95	0.26
		-2 mm	0.02 ± 0.47	0.84
		-5 mm	0.04 ± 0.29	0.58
		-7 mm	0.01 ± 0.30	0.94
Coronal thickness mm (Mean ± SD) Fig 2.A		0 mm	-0.66 ± 1.94	0.17
		-1 mm	-0.58 ± 0.80	0.0071
		-2 mm	-0.33 ± 0.66	0.047
Vertical bone loss mm (Mean ± SD)	Fig 2.B	Buccal	-0.41 ± 0.93	0.08
		Lingual/palatal	-0.77 ± 1.01	0.0047
	Fig 2.C	Mesial	-0.76 ± 0.95	0.0033
		Distal	-0.14 ± 1.52	0.69

Note: The colored lines refer to Figure 2. The red contour refer to the red measures on Figure 2. The green contour refer to the green measures on Figure 2 and the blue contour refer to the blue measures on Figure 2. The shaded values represent the statistically significant ones.

TABLE 4 Soft tissue profile analysis

Soft tissue analysis; *n* = 19							
		Baseline – 6 months	*p*-Value	6 months – 1 year	*p*-Value	Baseline – 1 year	*p*-Value
Buccal changes mm (Mean ± SD) Figure 3a	0 mm	−0.20 ± 0.75	.27	−0.11 ± 0.55	.39	−0.31 ± 0.88	.15
	−1 mm	−0.70 ± 0.87	*.0026*	0.04 ± 0.38	.70	−0.66 ± 0.79	*.0017*
	−2 mm	−0.82 ± 0.67	*<.0001*	−0.04 ± 0.21	.39	−0.86 ± 0.63	*<.0001*
	−3 mm	−0.87 ± 0.53	*<.0001*	0.04 ± 0.38	.66	−0.83 ± 0.53	*<.0001*
	−4 mm	−0.97 ± 0.49	*<.0001*	0.14 ± 0.24	.034	−0.84 ± 0.44	*<.0001*
Lingual/palatal changes mm (Mean ± SD) Figure 3a	0 mm	−0.19 ± 0.50	.12	0.04 ± 0.28	.48	−0.14 ± 0.48	.21
	−1 mm	−0.41 ± 0.46	*.0011*	−0.03 ± 0.16	.42	−0.44 ± 0.46	*.0007*
	−2 mm	−0.45 ± 0.40	*<.0001*	−0.02 ± 0.11	.40	−0.48 ± 0.41	*<.0001*
	−3 mm	−0.39 ± 0.36	*.0001*	−0.03 ± 0.12	.30	−0.41 ± 0.41	*.0006*
	−4 mm	−0.34 ± 0.29	*.0003*	−0.02 ± 0.14	.57	−0.37 ± 0.32	*.0004*
Mid-buccal recession mm (Mean ± SD) Figure 3b		−0.10 ± 0.48	.38	0.03 ± 0.25	.56	−0.07 ± 0.55	.61

Note: Italic values are statistically significant.

data and there was no significant difference between premolars and molars. Only for the soft tissue profiles at the 4 mm level below the gingival margin and on the palatal/lingual side, a more pronounced loss was found for the premolars ($p = .017$ at 6 months and $p = .042$ at 1 year).

4 | DISCUSSION

This prospective case series aimed to evaluate implant outcomes as well as hard and soft tissue changes up to 1 year after immediate

implant placement in the posterior area using a CAD–CAM-generated customized healing abutment (SSA technique) combined to PISF using DBBM. The study protocol allowed an implant survival rate of 95%, and although postoperative infectious complications (20%) occurred in patients that did not received postoperative antibiotics, the one-year peri-implant bone remodeling was acceptable and the soft tissue health was rather good. The CBCT data also demonstrated that the technique is efficient to preserve the peri-implant hard tissue dimensions in most of the explored areas. Moreover, the soft tissue profiles in the most cervical levels (gingival margins) were also found to be stable. However, below the cervical levels, significant soft tissue remodeling (below 1 mm) occurred within the first 6 months after the procedure.

4.1 | Implant outcomes

In the present trial, a single implant, for which a low insertion torque (10 Ncm) was recorded, failed to osseointegrate, leading to an implant survival rate of 95%. This is slightly inferior to mean implant survival rates of 97.7%–99% reported by systematic reviews for immediate implant (Type 1C according to Gallucci's classification (Gallucci et al., 2009)) in molar sites after at least one year of follow-up and mean peri-implant bone changes were comparable to a delayed approach (Atieh et al., 2010; Ketabi et al., 2016; Ragucci et al., 2020). Ketabi et al. also reported significantly lower implant survival rate when using extra wide diameter implants. On the other hand, Cosyn et al. reported an implant survival rate of 94.9% and 98.9%, for type 1 and type 4 implant placements, respectively. However, these data include immediate implant in the esthetic zone and consequently immediate loading procedures that may influence the results (Cosyn et al., 2019). The same systematic review also recorded higher implant survival rates for type 1 implant placement when postoperative antibiotics were administrated. In the present study, implant failure occurred in a patient who received a postoperative antibiotic therapy but the 4 infectious complications occurred in patients who did not receive any; therefore, a systematic administration of antibiotics for this type of procedure might be advisable in order to decrease the risk of postoperative infections. Peri-implant bone changes (DIB) and peri-implant soft tissue health (BOP, PI, PD) at 1 year were comparable to the more conventional procedures for bone level implants (DI Girolamo et al., 2016; Taheri et al., 2020); however, long-term follow-ups would be necessary to evaluate the impact of such a procedure on long-term peri-implant health. The improved DIB from 3 months to 1 year can be explained by the patient who had the early peri-implantitis and who was treated surgically with regenerative biomaterials, thus raising the peri-implant bone level at 1 year. As suggested recently by the European Federation of Periodontology (EFP) consensus statements, peri-implant soft tissue health is an important criterion for implant success (Tonetti et al., 2015), and bleeding on probing may be the first indicator of peri-implant disease such as mucositis or peri-implantitis (Jepsen et al., 1996, 2015; Lang et al., 2011; Lindhe et al., 2008). In the present study, after 1 year of loading, 84.2% of the implants displayed none or mild peri-implant soft tissue inflammation. Finally, the mean PES found in the present study was rather high (12.1) while Tallarico et al. (2017) described better PES at 1 year with a delayed implantation after ARP (12.2) when compared to immediate implantation combined to PISF (10.6). The main difference with our study protocol is the use of a customized healing abutment (SSA) after immediate implant placement which may play a significant role in the support and the contour stability of the peri-implant soft tissue.

4.2 | Hard tissue analysis

The horizontal bone changes observed in the present study were not significant at any of the levels below or at the implant platform. The values found at the implant platform were slightly lower than the results described in two previous studies dealing with immediate implant combined to PISF in the posterior region (Chen et al., 2019; Cheng, 2017). Both studies found a mean bone remodeling of, respectively, 1.33 and 1.25 mm, at the implant platform level while we found a mean change of only 0.93 mm. Regarding the horizontal bone changes above the implant platform, no significant loss was found in the most coronal area while significant changes were found at the −1 mm and −2 mm levels. However, these changes remained low, ranging from 0.33 to 0.66 mm while in the study of Tallarico et al. (2016), bone losses of 1.78 and 0.98 mm were found, respectively, at the −1 and −2 mm levels. These differences could be related to the use of a customized healing abutment (SSA) allowing the primary closure of the socket, stabilizing the clot and immobilizing the bone grafting material which was placed above the socket bone walls. This horizontal bone remodeling is most likely related to the resorption of the bundle bone, as described by Matarasso (Matarasso et al., 2009) and the better stability in the most cervical area could be explained by the increasingly thinner bone walls toward coronal aspect of the socket as well as by the placement of a slowly resorbable material above the bone walls of socket. The mean vertical bone height changes were rather low but more remodeling occurred in the lingual/palatal aspect (0.77 mm) compared to the buccal aspect (0.41 mm). Cheng et al observed a similar trend with a vertical bone gain of 0.18 mm at the buccal side and a bone loss of 0.25 mm in the lingual / palatal side. They attributed this difference to the placement of the bone graft biomaterial in excess, above the baseline buccal bone plate (Cheng, 2017) which was also done in our surgical protocol.

4.3 | Soft tissue analysis

In the present study, mid-facial recessions were not observed and the soft tissue profile changes in the most cervical level (0 mm level) were very stable. Although they remained below 1 mm, significant shrinkages were found in the −1, −2, −3 and −4 mm levels 6 months after the procedure and no further profile changes

occurred from 6 months to 1 year. To the best of our knowledge, only one clinical study investigated the soft tissue profile changes after immediate implant in the posterior region (molars sites) and they actually applied a clinical procedure similar to ours (Finelle et al, 2021). They also found a significant soft tissue collapse from the −1 to the −4 mm levels and although the measuring method was not fully similar, the mean values were close to ours varying from 0.87 to 1.33 mm (no data reported for the 0 mm level). When comparing the present data to immediate implant in the esthetic zone, Sanz-Martín et al. (2019) also found a decrease of the soft tissue profile of about 1 mm despite the use of a xenogeneic collagen matrix. Tian et al. (2019) also observed a significant (although limited) loss in soft tissue profile 1 year after immediate implant and provisionalization (using PISF without any gingival graft). However, the measurement methodology was not completely similar to ours and the comparison of results was therefore difficult. The present data also emphasized a great stability of the soft tissue vertical dimension (mean mid-facial recession of 0.07 mm at 1 year). Finelle et al. (2021) found a mid-facial recession with the same protocol of 0.53 mm. The difference can be explained by the longer-term follow-up. However, other authors also found limited mid-facial recession 1 year after immediate implant and provisionalization combined to PISF in the esthetic zone (Chan et al., 2019; Cosyn et al., 2011; Raes et al., 2011; Tian et al., 2019). All above-mentioned studies used a DBBM in the jump distance and an individualized component to seal the socket; therefore, it was difficult to interpret the role of the SSA in our results. Nevertheless, the present data suggest that the vertical and horizontal soft tissue dimensions in the most cervical area are very stable when using the described protocol and this could be the result of the SSA continuously supporting the gingival margin and therefore preventing from collapsing. The relatively limited shrinkage of the underlying soft tissues might be the consequence of the bundle bone resorption. Additional clinical studies including a control group will be necessary to assess the potential benefit of the SSA on a traditional healing abutment to preserve the peri-implant soft tissue dimensions and to guide the soft tissue healing using a custom-made component, as already suggested by some authors (Lambert & Mainjot, 2017). Considering the dynamic loss, the soft tissue profile changes occurred mainly within the first 6 months after the immediate implant and were consistent with the post-extraction shrinkage of alveolar ridge observed with or without ARP (Botilde et al., 2020; Lam, 1960; Rodd et al., 2007; Schropp, Wenzel, et al., 2003; Tan et al., 2012; Tian et al., 2019).

4.4 | Limitations

An important limitation of the present case series study was related to the absence of a control group so that results need to be interpreted cautiously. Randomized controlled trials including control group(s) should be performed to potentially validate the interest of sealing socket abutment for immediate implant in the posterior region. Another limitation was the baseline IOS taken just after the extraction which leave the possibility for the soft tissues to collapse and therefore to overestimate our results. Moreover, the vertical position of the implants was not standardized and may have also influenced the results. Finally, the radiographic results being recorded to the nearest tenth of a millimeter by a single operator, measurement errors may have been made.

5 | CONCLUSION

Despite its limitations, the present study showed that the use of SSA in addition to PISF after immediate implant placement in the posterior region demonstrates promising implant outcomes and hard and soft tissues dimensional stability while decreasing the overall treatment time. Randomized controlled trials should be performed to compare the SSA with conventional abutments' abilities to preserve the peri-implant hard and soft tissue dimensions.

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CONFLICT OF INTEREST

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AUTHOR CONTRIBUTIONS

Romane Lilet: Data curation (equal); Formal analysis (equal); Investigation (equal); Writing-original draft (lead). **Martin Desiron:** Data curation (equal); Investigation (equal). **Gary Finelle:** Conceptualization (equal); Writing-review & editing (equal). **Geoffrey Lecloux:** Investigation (equal). **Laurence Seidel:** Formal analysis (equal). **France Lambert:** Conceptualization (equal); Investigation (equal); Supervision (lead); Validation (lead); Writing-review & editing (equal).

DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

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