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Brief Report

Long-Term Clinical and Radiographic Analysis of Platform Matching and Platform Switching Implants in the Esthetic Zone: A Retrospective Cohort Study

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Abstract: Background: The aims of this study are to retrospectively compare the clinical, radiographic and esthetic outcomes of platform switching (PS) and platform matching (PM) dental implants in the anterior maxilla after ≥ 10 years of functional loading. Methods: Marginal bone loss (MBL) levels were recorded; furthermore, peri-implant clinical parameters (PPD, BOP, PI) were collected and the Pink and White Esthetic scores (PES/WES) were used to evaluate the esthetic outcomes. Wilcoxon signed rank tests were performed to compare collected parameters among the two groups, with a p-value < 0.05. Results: A final sample of 58 patients was enrolled in this study (PM implants = 29; PS implants = 29). PS implants showed lower MBL levels (1.02 ± 0.81 mm vs. 1.67 ± 0.99 mm, $p = 0.028$) and PPD values (3.69 ± 1.1 vs. 5.16 ± 1.09 mm, $p < 0.001$) compared to PM implants. Mean PES values were higher in the PS group compared to the PM group (8.46 ± 0.69 vs. 7.89 ± 0.78, $p < 0.005$), while there were no differences for WES values (7.82 ± 1.09 vs. 7.71 ± 0.85, $p > 0.05$) and peri-implant diseases' prevalence ($p > 0.05$). Conclusions: After 10 years, PS implants showed statistically significant lower MBL and PPD values and higher PES values compared to PM implants.

Keywords: dental implants; esthetics; implant-supported crown; platform matching implants; platform switching implants

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1. Introduction

Implant treatment has shown high long-term survival rates [1–6] and is considered an acceptable choice to replace missing elements.

Nevertheless, implant-related mechanical or biological complications have been extensively reported and, in order to assess peri-implant status and to verify implant success rates over time [7,8], radiographic detection of marginal bone loss (MBL) is considered a primary diagnostic device [9].

Several factors may influence MBL levels, such as surgical trauma, occlusal overload, implant positioning, plaque accumulation and biologic width reformation [10]; furthermore, the implant-abutment interface (IAI) design could also play a key role.

A bone loss of 1.5 mm to 2 mm below the IAI in the first year of loading has been reported [11,12] for dental implants restored using a platform matching (PM) abutment with a supracrestal positioning and/or transmucosal healing [8,13].

Lazzara and Porter, therefore, have proposed and introduced the platform switching (PS) concept [11], which allows iso- and subcrestal implant positioning and aims to reduce the amount of marginal bone loss [11,14]. After explaining the negative effect of the implant-abutment microgap, which is strongly correlated with bacterial leakage and the formation of a chronic infiltrate [15,16], several authors demonstrated that by placing narrower

prosthetic abutments on larger-diameter implant platforms, the IAI is displaced inward from the implant shoulder and ahead from the bone level [14,17]. Hence, the inflammatory connective tissue infiltrate is principally enclosed beyond the implant platform, protecting the crestal bone. This procedure, along with the ability of PS implants to distribute loads and concentrate forces, reduces peri-implant bone resorption, increasing, therefore, the long-term results of dental implants [14,18,19].

Furthermore, Luongo et al. [20] performed a histological evaluation of an implant removed 2 months after placement and hypothesized that the inward shift of the inflammatory connective tissue zone at the IAI could lead to lower bone resorption around PS implants [20], reinforcing, therefore, the Lazzara and Porter study [11]. Moreover, Meloni et al. [21] did not find out any statistically difference in MBL levels between PS and non-PS implants. Apart from the use of PS abutments, the design of the implant neck might also influence the esthetic and functional outcome of prosthetic rehabilitations, and there is currently a lack of knowledge on the long-term results on the comparison between PS and PM dental implants, although few studies reported positive outcomes [22].

The adoption of a prosthetic workflow able to avoid continuous dis-reconnection was demonstrated to additionally reduce MBL changes in case of PS restorations, minimizing the connective tissue microdamages [23]. On the contrary, the literature on the influence of the implant neck (bone level vs. tissue level) on MBL is still controversial: several systematic reviews with meta-analysis [24–28] reported contradictory results. According to Cosola et al. [24], there were no statistically significant differences in MBL levels between bone-level (BL) and tissue-level (TL) implants. Similarly, Paul et al. [27] reported no difference in MBL between submerged and transmucosal implants. However, articles included presented a more limited follow-up of only 12 months. Moreover, Taheri et al. [26] concluded that there was not sufficient evidence to evaluate the superiority of BL implants. Despite this, the authors suggested that the considerable heterogeneity of the studies included may have influenced the results of their meta-analysis. On the other hand, van Eekeren et al. [28] concluded that BL implants showed significantly less MBL after 1 year of loading than TL implants. Implant placement in the esthetic zone is extremely challenging for clinicians, and patients' expectations for long-term, stable results might be quite demanding [29]. To date, there is a clear lack of long-term (>10 years) standardized results on the comparison between different implant designs (bone-level implants restored with a platform switching concept vs. tissue-level implants with platform matching prostheses). Therefore, the aims of this study are to retrospectively compare the long-term clinical, radiographic and esthetic results of PS and PM dental implants after a minimum of 10 years of functional loading inserted in the same center with a standardized procedure.

2. Material and Methods

2.1. Study Design

A retrospective cohort study was conducted at the Department of Oral and Maxillo-Facial Sciences, at "Sapienza" University of Rome.

2.2. Study Population

The study sample was enrolled among patients who had been treated with dental implants in the anterior maxilla (from first right premolar to first left premolar) in a private dental clinic in Rome, Italy, from 1 January 2006 to 31 December 2009.

Only patients meeting the following inclusion criteria were recalled for a follow-up visit: presence of at least one dental implant functioning for >10 years with a baseline periapical X-ray taken at the day of prostheses delivery. Patients were excluded from the study in case of guided bone regeneration procedures, presence of uncontrolled systemic diseases or missing medical or radiographic records. The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines were followed to report this study.

2.3. Surgical and Prosthetic Treatment

One hour prior to surgery, 2 gr of amoxicillin and clavulanic acid (Augmentin®, Roche S.p.A., Milan, Italy) were taken by the patients as prophylactic antibiotics. A dental implant was placed following manufacturer's instructions (Institut Straumann AG, Basel, Switzerland) after raising a full-thickness flap in the edentulous area: TL implants with a sand-blasted, large-grit, acid-etched (SLA) surface and a 1.8-mm polished neck or BL implants with the same surface.

In case of BL implants, a submerged healing protocol was adopted, while for TL implants, a transmucosal healing was carried out. Standard postoperative instructions were given to patients: the use, twice a day, of an antiseptic mouthwash with chlorhexidine 0.2% (Curasept, Curaden Healthcare S.p.A, Saronno, Italy) for 10 days, ibuprofen 600 mg (Brufen, Abbott, Verona, Italy) as needed and a soft diet. Suture removal was scheduled after 10 days. In both groups, prosthetic treatment was carried out in accordance with the specific treatment plan three months after implant placement.

In fact, while, for tissue-level implants, osteointegration time was waited to start traditional impression/restoration process, for bone-level implants, one-abutment/one-time approach was used as prosthetic workflow. Basically, at the time of implant insertion, before suturing, impression was taken and, during the osteointegration time, the abutment and the restoration was created. After hard tissue healing, a small flap was raised, and the abutment was settled and crown-cemented.

For both groups, metal ceramic cemented restorations were delivered.

2.4. Study Variables

2.4.1. Primary Outcome Variable

A digital picture analysis software (version 3.7.0 Digimizer, Medical Software Brolkstraat, Belgium) was used to evaluate mean MBL levels on digital periapical X-rays acquired through an imaging plate scanner (VistaScan, Durr Dental, Bietigheim-Bissingen, Germany) and taken by means of the parallel cone technique using a Rinn alignment system (XCP Centratore, Rinn, York, PA, USA). The bone level was digitally assessed for each implant mesially and distally by calculating the distance between the implant shoulder and the first visible bone contact. In case of TL implants, the known length of the polished neck (1.8 mm) was subtracted from the measured values (Figures 1 and 2). Two examiners assessed the X-rays independently of each other, using the real length and diameter of the implants to calibrate the evaluation. In cases of disagreement, a third examiner, an expert in the field, reviewed the X-rays to calculate MBL.

2.4.2. Secondary Outcome Variables

The same calibrated examiner (PP) recorded probing pocket depth (PPD) values in millimeters (mm) and bleeding on probing (BOP) and plaque index (PI) with dichotomic values (present/absent) using a periodontal probe (PCP-Unc 15, Hu-Friedy®, Chicago, IL, USA) with a light force (approximately 0.2 N). Calibration was achieved if an agreement of 90% within 1 mm was obtained by duplicate measurements of PPD on 10 random teeth and implants.

Furthermore, time of functional loading, implant location (central incisor, lateral incisor, canine, first premolar), type of prosthetic rehabilitation (single crown or multiple unit), opposing dentition (natural teeth, fixed prosthodontics on natural teeth, implant-supported fixed prosthodontics), length and diameter were recorded. A patient was defined as a "periodontitis case" in accordance with the definition provided by Tonetti et al. [30] in the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions.

A trained examiner (PP) realized the esthetic evaluation of the peri-implant mucosa and the implant crown, using the Pink and White Esthetic Score (PES/WES) as described by Belser et al. [31].

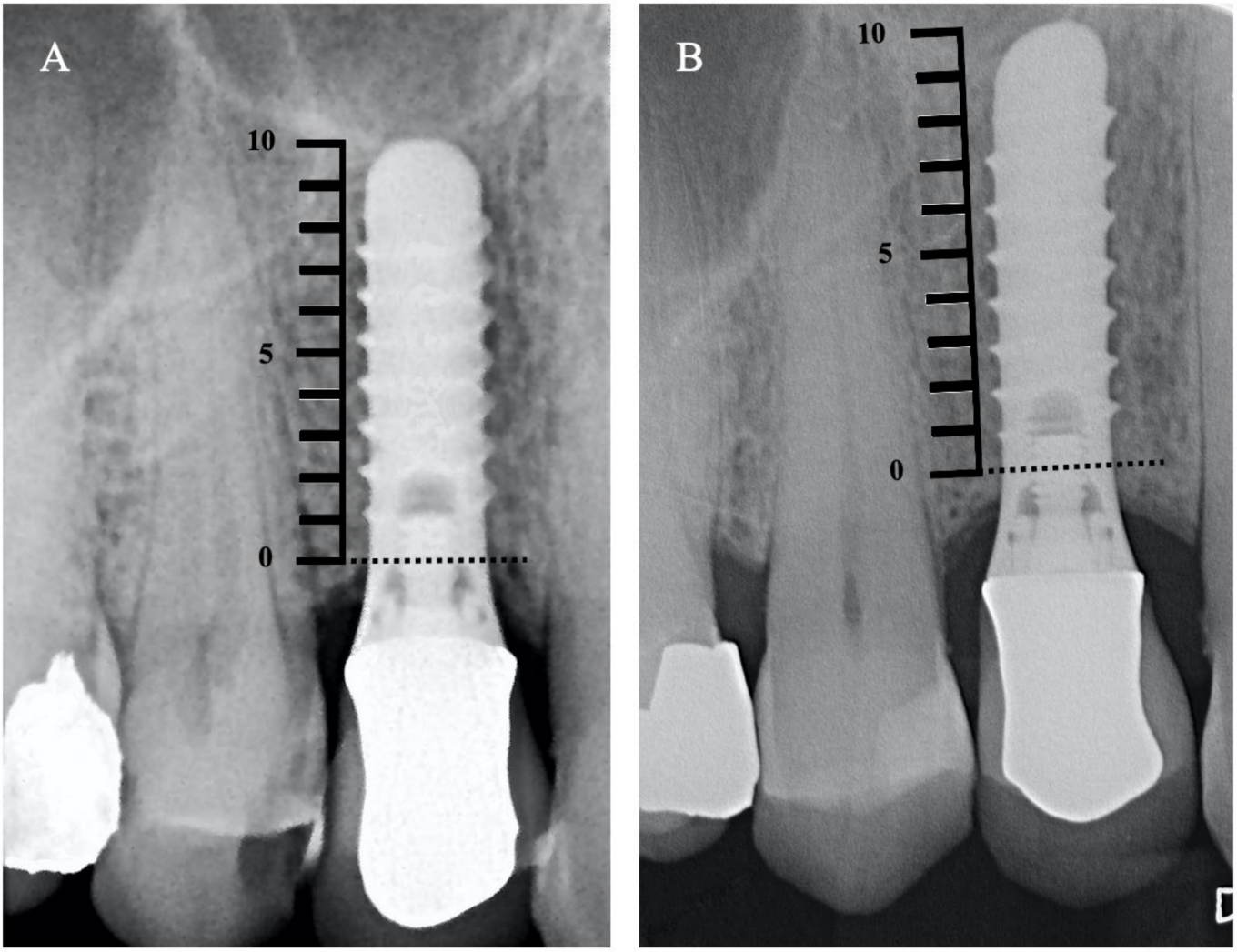


Figure 1. Representative X-rays of an implant of the platform matching group, (**A**). Prosthetic baseline, (**B**). Follow-up.

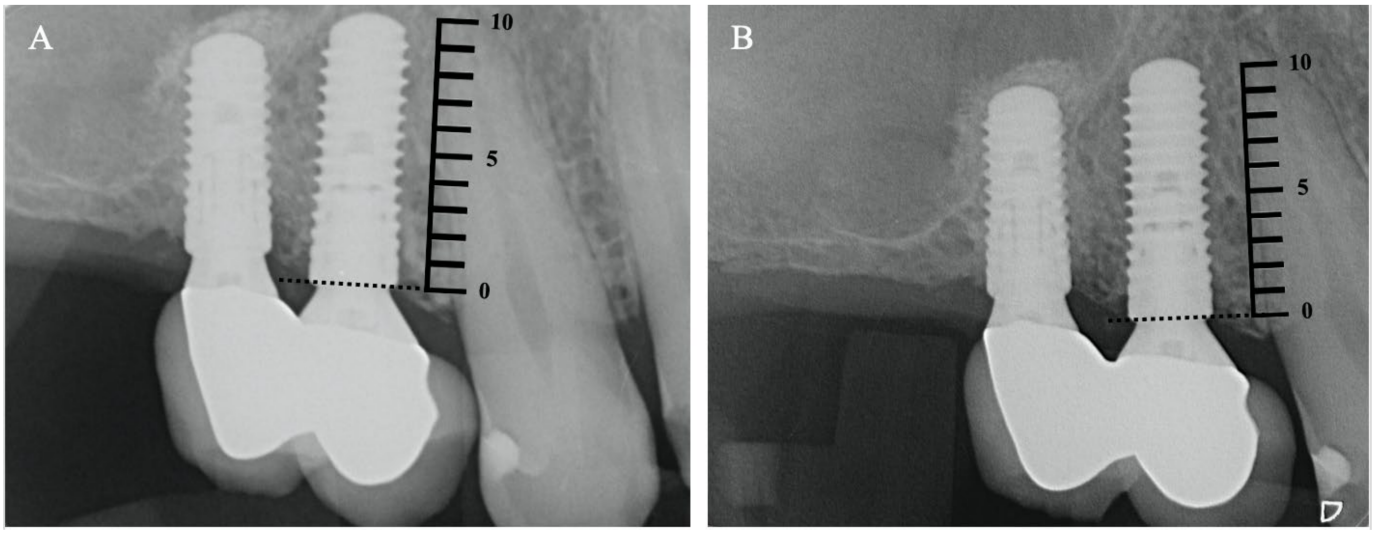


Figure 2. Representative X-rays of an implant of the platform switching group, (**A**). Prosthetic baseline, (**B**). Follow-up.

The examiner evaluated intraoral photographs taken with a digital camera (Nikon D7500, Nikon, Tokyo, Japan) using standard settings (ISO 200, F29, exposure time of 1/160) at the follow-up appointment. Furthermore, impressions were taken, and study casts were realized for each participant to complete the PES/WES assessment. In order to calibrate esthetic evaluation, the examiner evaluated each photograph and study cast in two separate occasions; in case of different scores, the same examiner performed another evaluation.

Case definitions suggested by Berglundh et al. [32] for detecting peri-implant diseases in epidemiological studies were adopted.

Peri-implant health was defined as absence of clinical signs of inflammation, bleeding and/or suppuration on gentle probing, without radiographic bone loss.

Peri-implant mucositis was characterized by presence of bleeding and/or suppuration on gentle probing, without radiographic bone loss.

Peri-implantitis was defined as presence of bleeding and/or suppuration on gentle probing, with radiographic bone levels $\geq$3 mm apical of the most coronal portion of the intraosseous part of the implant.

Absence or presence of peri-implant diseases was recorded at the follow-up visit based on clinical and radiographic records.

2.5. Statistical Analysis

Collected data were inserted in a database created using Excel (Microsoft, Redmond, WA, USA). A specific statistical program (version 22.0, Statistical Package for the Social Sciences, IBM Corporation, Armonk, NY, USA) was used to evaluate data, computing mean and standard deviations (SD) for each variable. The Shapiro-Wilk test was used to check normal distribution of variables, Wilcoxon signed rank tests were performed to compare clinical, esthetic and radiographic parameters among the two groups, considering a p-value < 0.05 as statistically significant.

3. Results

3.1. Screening Process

During the period of time retrospectively observed, 326 dental implants were placed in 188 patients, with a mean of 1.73 implants per patient. Among these patients, 43 did not attend the planned follow-up, while 87 had incomplete medical and radiographic records and were, therefore, excluded from the study.

Therefore, 58 patients were included in this study: 31 females (53.44%) and 27 males (46.56%), with a mean age of 65.91 $\pm$ 9.66 years (age range 37–78).

Patients were divided in two groups based on the type of dental implant installed: twenty-nine received PM implants, while twenty-nine were treated with PS implants. Detailed characteristics of study groups are provided in Table 1.

Among the variables included, only follow-up time (13.37 $\pm$ 2.39 years vs. 11.55 $\pm$ 0.73 years in the PM and PS groups, respectively) and implant diameter (22 vs. 14 regular diameter (ø 4.1 mm) implants in the PM and PS groups, respectively) showed statistically significant differences (p < 0.05) between the two groups.

Table 1. Sample demographics.

Variable	PM	PS	*p* Value
Age	66.37 ± 9.28	65.27 ± 10.03	0.786
Sex			0.795
Male	14	13	
Female	15	16	
Follow-up	13.37 ± 2.39	11.55 ± 0.73	**0.014**
Smoking	6	8	0.542
Periodontitis	13	8	0.175
Implant site			
Central incisor	0	1	0.740
Lateral incisor	6	5	
Canine	4	5	
First Premolar	19	18	
Implant length			0.430
8 mm	0	0	
10 mm	14	11	
12 mm	15	18	
14 mm	0	0	
Implant diameter			**0.032**
3.3	7	15	
4.1	22	14	
Type of prosthesis			0.112
Single crown	15	9	
Multiple unit	14	20	
Opposing dentition			0.280
Natural teeth	19	19	
FPD on natural teeth	6	3	
FPD on dental implants	4	7	

PM = platform matching implants group; PS = platform switching implants group.

3.2. Clinical and Radiographic Analysis

Mean MBL levels at the follow-up visit were 1.02 ± 0.81 mm vs. 1.67 ± 0.99 mm in the PS and PM groups, with a statistically significant difference ($p = 0.028$) among the two groups in favor of PS implants (Figure 1A,B and Figure 2A,B).

Mean PPD values were 3.69 ± 1.1 vs. 5.16 ± 1.09 mm in the PS and PM groups, with a statistically significant difference ($p < 0.001$) in favor of PS implants.

3.3. Esthetic Evaluation

Mean PES values were statistically significantly higher in the PS group compared to the PM group (8.46 ± 0.69 vs. 7.89 ± 0.78, $p < 0.005$), while there were no differences among the two groups for WES values (7.82 ± 1.09 vs. 7.71 ± 0.85, $p > 0.05$) (Figures 3 and 4).

3.4. Biological Complications

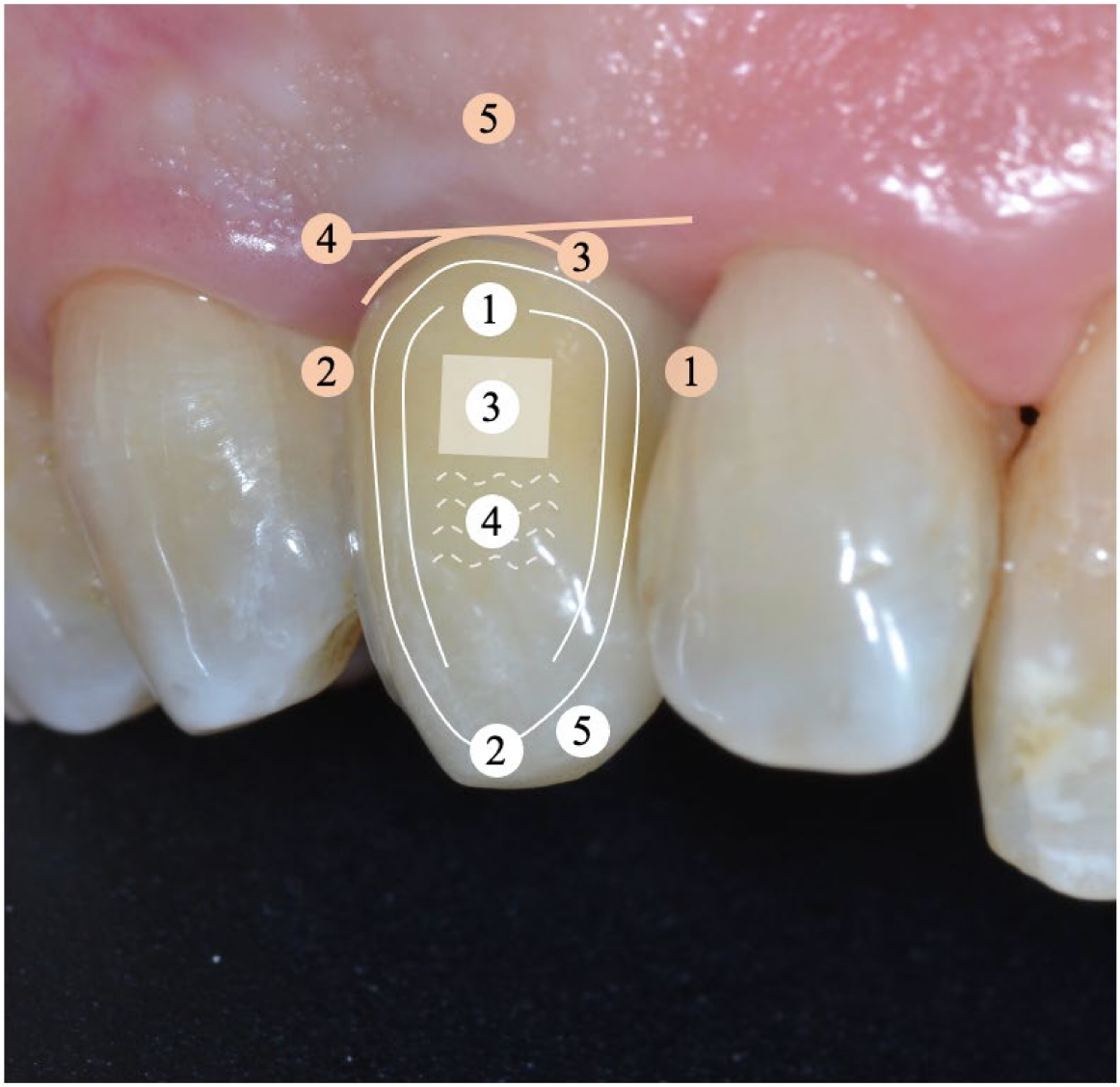
The prevalence of implant biologic complications among the two groups are summarized in Table 2.

Table 2. Prevalence of peri-implant diseases of the study implants.

Peri-Implant Status	PM	PS	*p* Value
Healthy	9	16	0.065
Mucositis	10	9	0.767
Peri-implantitis	9	3	0.053

PM = platform matching implants group; PS = platform switching implants group.

In short, even if a greater prevalence of peri-implant diseases was found out in the PM group, no statistically significant differences were detected.



PES

1 Mesial Papilla

2 Distal Papilla

3 Cuvature of Facial Mucosa

4 Level of Facial Mucosa

5 Root convexity / Soft Tissue Color and Texture

WES

1 Tooth Form

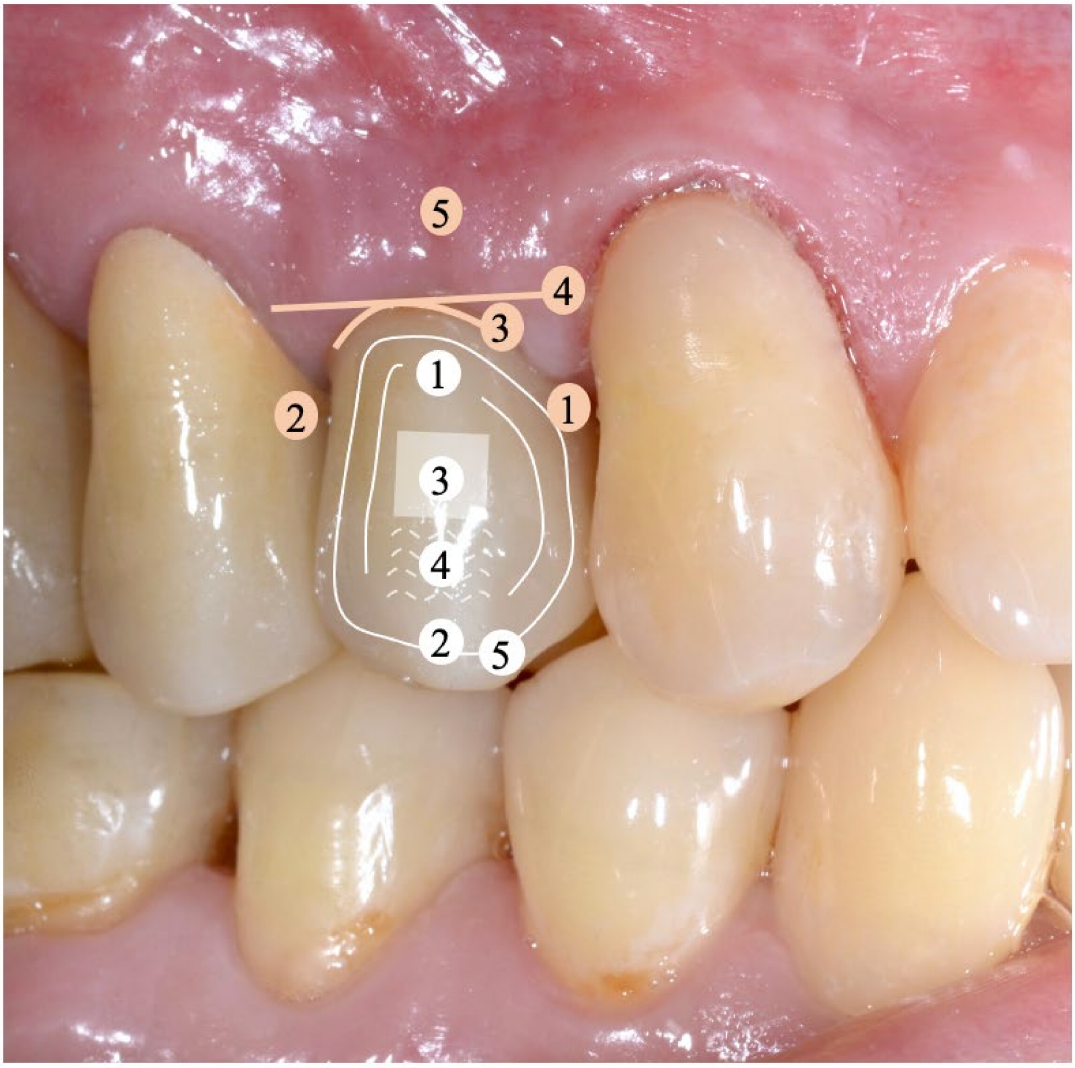
2 Outline / Volume

3 Color (Hue / Value)

4 Surface Texture

5 Translucency

Figure 3. Clinical photograph of an implant of the platform matching group with detailed description of parameters evaluated for the Pink and White Esthetic scores.



PES

1 Mesial Papilla
2 Distal Papilla
3 Cuvature of Facial Mucosa
4 Level of Facial Mucosa
5 Root convexity / Soft Tissue Color and Texture

WES

1 Tooth Form
2 Outline / Volume
3 Color (Hue / Value)
4 Surface Texture
5 Translucency

Figure 4. Clinical photograph of an implant of the platform switching group with detailed description of parameters evaluated for the Pink and White Esthetic scores.

4. Discussion

The aims of this retrospective cohort study were to compare the long term (>10 years) results of PS and PM dental implants in the upper anterior maxilla. Based on our results,

PS implants showed statistically significant ($p < 0.05$) lower MBL and PPD and higher PES values compared to PM implants. As for peri-implant diseases, no statistically significant differences were noted among the two groups, even if a lower prevalence was reported in the PS group. These results are in accordance with previously conducted systematic reviews on the topic: in a meta-analysis, Chrcanovic et al. [33] concluded that PS implants show statistically significant lower MBL levels compared with PM implants. At the same time, a prosthetic workflow able to avoid any microdamage on the connective component may result in an increased stability of marginal bone levels, even in the long run [34].

Furthermore, according to Strietzel et al. [35], significantly less MBL was detected in PS implants compared to PM-implant abutment configuration. Hence, several aspects must be taken into account, starting with patients' pre-existing clinical conditions, operators' experience [35], the micro and macro design of the implant neck [36], the interimplant distance [37] or the IAI positioning [38]. Precisely with regard to the IAI placement with respect to the bone crest, Uraz et al. [25] claimed that no statistically relevant differences were recorded for MBL. Both crestally and subcrestally inserted implants, during a 12-month follow-up period, showed overlapping results. The two groups showed acceptable results [39,40] for the two objective esthetic scores; however, statistically significantly better results were found out for PS implants for the PES score. Even Chappuis et al. [41] reported higher PES values for PS implants without statistically significant differences. In the present study, the same expert operator inserted all dental implants which shared the same implant surface (SLA) and carried out the prosthetic treatment. In all cases, standard commercial abutments were used, with different gingival heights reflecting implant depth and position, and cement-retained single crowns or bridges were delivered to patients.

The main limitations of this study are its retrospective nature and the limited sample enrolled; furthermore, radiographic and clinical analysis were conducted only at the latest follow-up visit, with no interim data on MBL or PPD progression. Several patients could not be enrolled in this study even if they had dental implants installed for more than 10 years due to the absence of a baseline periapical X-ray taken at the day of prostheses delivery, a procedure highly recommended to evaluate reproducible long-term evaluation of MBL [42,43]. However, to the best of the authors' knowledge, this study presented the longest follow-up available in the literature (>10 years) with a standardization of surgical and prosthetic treatments. Both groups showed acceptable MBL levels after a minimum of 10 years of functional loading, ranging from 1.02 to 1.67 mm; however, PS implants exhibited lower peri-implant bone resorption and PPD values. Overall, 17.24% of dental implants at the patient level were affected by peri-implantitis and 32.76% by peri-implant mucositis, a result in accordance with Rakic et al. [44]. As for peri-implant diseases, our data, even if not statistically significant, are in accordance with previous studies [45], showing reduced rates of peri-implantitis for PS implants compared to PM implants. Recently, Sanz-Esporrin et al. [46] evaluated MBL progression using preclinical experimental peri-implantitis model with the same TL and BL implants used in this study. Based on their study, the severity of peri-implantitis was greater in PM implants compared to PS implants. The findings of the present retrospective cohort study suggest that PS implants can obtain an excellent long-term crestal bone stability with a limited bone resorption after 10 years, therefore representing an excellent choice in the esthetic area, resulting in statistically significant higher PES values when compared with PM implants. Their superior results in terms of PPD and MBL values, when compared with PM implants, might be explained by their reduction of the epithelial component of the biological dimension, a finding supported by several clinical studies [47,48].

5. Conclusions

This is the first study to present long-term (>10 years), standardized data comparing PS and PM implants in the esthetic zone. Based on findings obtained, bone-level implants with a PS implant abutment interface, showed statistically significant lower MBL and PPD

values and higher PES values after more than 10 years of functional loading compared to PM implants.

Further follow-up studies with prospective designs, larger samples and interim radiographic and clinical examinations are needed to confirm findings of this study.

Author Contributions: P.P., A.R. and B.D.M. designed and drafted the article and revised it critically for important intellectual content; P.C.P. and L.M. contributed to data analysis and revised the work critically for important intellectual content; A.P. and A.D. made substantial contributions for interpretation of data and revised the manuscript critically for important intellectual content. All authors have read and agreed to the published version of the manuscript.

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Institutional Review Board Statement: The study was performed in accordance with the latest edition of the Helsinki Declaration. The study was approved by the Institution Review Board (IRB) of the Department of Oral and Maxillo-Facial Sciences, at "Sapienza" University of Rome (Ref: 0000111/2020).

Informed Consent Statement: Informed consent was obtained for all participants.

Data Availability Statement: The data presented in this study are available on reasonable request from the corresponding author.

Conflicts of Interest: The authors declare they have no conflict of interest.

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