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Clinical and Radiographic Changes at Implants Supporting Fixed Partial Dental Prostheses With Cantilever Extensions. A Retrospective Study After at Least 10 Years of Loading

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ABSTRACT

Aim: To report clinical and radiographic changes at implants supporting Fixed Partial Dental Prostheses with Cantilever extensions (FPDPC's) after a loading time exceeding 10 years.

Materials and Methods: Patients with FPDPC's were reevaluated after a loading time of 10–21 years. A clinical and radiographic examination was conducted to assess Marginal bone level change (MBLc), biological, and prosthetic parameters. Pocket depth (PD), Attachment Level (CAL), Bleeding on Probing (BOP), and Presence of Plaque (PL) were also recorded.

Results: Nineteen patients with 21 FPDPC's supported by 47 implants were re-evaluated after a mean loading time of 13.3 ± 2.9 years (range: 10–21 years). Implant survival rate was 100% and implant success rate was 91.5%, accounting for 4 implants (8.5%) that presented with peri-implantitis. Twelve implants (25.5%) exhibited peri-implant mucositis. Three of the FPDPC's had to be replaced due to fracture of the cantilever teeth and one other FPDPC had abutment screw fracture which was corrected, leading to prosthetic survival and success rates of 86% and 81%, respectively. Mean MBLc from implant placement to time of re-evaluation was 0.99 ± 1.11 mm (95% CI: 0.67, 1.31, p-value < 0.001). Mean PD at re-evaluation was 3.9 ± 1.6 mm, mean CAL was 1.2 ± 1.6 mm. Percentages of BOP and PL were 14.89% ± 23.11% and 26.6% ± 30.625 respectively.

Conclusion: Fixed partial dental prostheses with cantilever extensions are a reliable option if extensive bone grafting or sinus lifts are to be avoided, with 10-year results showing 100% implant survival, 90% implant success, and 86% and 81% prosthetic survival and success rates, respectively.

1 | Introduction

The successful use of osseointegrated dental implants in replacing missing teeth has been adequately documented, with multiple studies reporting long-term survival exceeding 10 years of function (Lekholm et al. 2006; Roccuzzo et al. 2014; Chappuis et al. 2013; Seyssens et al. 2020; Frisch et al. 2020; Bäumer et al. 2020). However, there is still insufficient evidence in cases where the availability of adequate bone precludes ideal implant placement. Examples of cases like these include the posterior maxilla when pneumatization of the maxillary sinus does not allow for placement of implants or areas of thin bone that would require extensive guided bone regeneration (GBR) techniques and increase patient morbidity. In such cases, the use of fixed partial dental prostheses with cantilever extension (FPDPC's) has been suggested in lieu of sinus lift techniques or GBR procedures (Aglietta et al. 2012; Schmid et al. 2020).

Questions from in vitro studies were raised whether implants supporting cantilever prostheses were prone to increased marginal bone level change over time or even fracture of the implants as a result of excessive occlusal forces, especially on the implants closest to the cantilever extension (Akça and Iplikçioğlu 2002; Yokoyama et al. 2004). Over the last 20 years, only a few clinical studies have reported on such outcomes (Wennström et al. 2004; Hälg et al. 2008; Romeo et al. 2009; Aglietta et al. 2012; Schmid et al. 2020). They found minor changes in marginal bone loss on implants supporting FPDPC's, well within the acceptable limits of 2 mm (Albrektsson et al. 1986; Renvert et al. 2018), after a mean observation time of 5 to 13 years, concluding that the use of FPDPC's is a reliable treatment option. Additionally, no differences in bone loss between implants proximal and distal to the cantilever extensions were detected. A common conclusion was that narrow-diameter implants (NDI's) were not suitable for such treatment, as Hälg et al. (2008) reported two fractures and Schmid et al. (2020) reported one fracture of NDI's supporting FPDPC's. It must be noted that these studies did not exceed ten years of follow-up, with the exception of only one study (Schmid et al. 2020) which presented data after 13.3 years of follow-up. The studies of Wennström et al. (2004) and Hälg et al. (2008) had a mean observation time of only 5 years, whereas Romeo et al. (2009) had 8 years and Aglietta et al. (2012) presented 6 years of follow-up data.

Another critical aspect in the use of FPDPC's is the incidence of prosthetic complications owing to the presence of cantilever extensions. Complications that have been reported in the aforementioned studies have ranged from small porcelain fractures to screw loosening of the abutments or loss of retention of the prosthesis, and few incidences of loss of the prosthesis.

A recent systematic review (Storelli et al. 2018) reported 5–10-year survival rates of 98.4% for the implants and 99.2% for the restorations. Mechanical technical and biologic complications amounted to 28% and 26% on the implant and patient level, respectively. The conclusion was that this treatment approach is predictable. A similar conclusion was reached at the 5th Consensus Conference of the European Association of Osseointegration (EAO), albeit with a warning that this recommendation is based on a limited number of studies with short to medium follow-up (Hämmerle et al. 2018).

A recent study by Schmid et al. (2020) was the first to present long-term results with a mean observation time of 13 years on 30 FPDPCs supported by 60 implants. The authors reported stable bone levels and minor changes in pocket depths during the observation period. One NDI was lost to fracture and all other implants survived. All prostheses were cement-retained and a high rate of loss of retention (at least once in 9 patients) was reported. Their conclusion was that the use of the FPDPCs is a viable treatment option if surgical procedures with increased morbidity are to be avoided, but more long-term observations are needed to verify the longevity of those positive findings.

The critical gap in current research lies in the lack of comprehensive long-term data addressing the stability of bone levels and the incidence of complications over extended periods (beyond 10 years), specifically for implants supporting cantilever extensions. The existing studies predominantly focus on short-to medium-term outcomes, leaving a significant need for understanding the true longevity and success of FPDPC's in clinical practice.

This retrospective study aimed to provide some insight into this treatment modality by presenting new data on the long-term success rates, marginal bone loss, and the incidence of complications related to FPDPCs supported by at least two or three dental implants following a minimal observation period of 10 years, thus contributing valuable information to the body of knowledge surrounding implant-supported restorations and ultimately aiding clinicians in making informed decisions about treatment options for patients with limited bone availability.

2 | Materials and Methods

The study protocol was submitted to and approved by the Bio-Ethics Committee of the School of Dentistry at the Aristotle University of Thessaloniki, Greece (appl. Protocol number 17/13.07.2022). The study was conducted according to the revised principles of the Helsinki Declaration, and a signed informed consent was obtained from all patients before participating in the study.

2.1 | Patient Selection

The patient sample of this study was part of a retrospective evaluation of patients who received treatment with dental implants in a private periodontal practice run by a single specialist Periodontist (A.B.) between 2000 and 2013, with at least 10 years of functional loading of their prosthetic work. A comprehensive chart review revealed 208 potential patients, and an effort was made to invite all of them for a re-evaluation appointment. A total of 107 patients attended the re-evaluation appointment, and those who had received FPDPC's were included in this study sample. Of the 101 patients who did not attend the re-evaluation exam, 11 had passed away, 12 could not be examined due to advanced age, 26 had moved to a different location, 30 had changed contact information and could not be contacted, 5 experienced early implant failure, and 17 declined to participate in the study. In an effort to reduce selection bias, the records of the 17 patients who declined to participate in the study were reviewed. None of those patients had FPDPC's placed. Five FDPC's were placed in five other patients that could not be examined in the re-evaluation appointment: two had passed away and three patients had moved to a different location.

The inclusion criteria were as follows:

- Age 18 years and over
- Systemic health or controlled medical conditions
- Periodontal health, either no periodontal disease or previously treated periodontal disease under a supportive periodontal maintenance (SPT) program
- Smokers were included but encouraged to enter a smoking cessation program.
- Patients with bruxism or parafunctional habits were included.
- Placement of at least one FPDPC supported by two or three implants

The exclusion criteria were as follows:

- Uncontrolled medical conditions
- Active uncontrolled periodontal disease
- Inability to present for the re-evaluation appointment
- Immediate implant placement
- Cantilever units that were part of full-arch restorations
- Cantilever units that were connected to a single implant
- Non-existent opposing dentition

A total of 19 patients fulfilled the inclusion and exclusion criteria and thus were selected for inclusion in this study.

2.2 | Methodology

Placement of two adjacent implants for a 3-unit FPDPC with either a mesial or distal cantilever, or three adjacent implants for a 4-unit or 5-unit FPDPC with a proximal and/or distal cantilever(s). Either internal hex (no platform switching) or external hex implants (Zimvie, formerly known known as Zimmer Biomet 3i implants, Warsaw, Indiana, United States), cylindrical or tapered, of diameter 3.25 mm or 4 mm and length of 10 mm, 11.5 mm or 13 mm were placed. Implant surface was either Osseotite, Full Osseotite, or Nanotite. Implants were placed with the implant shoulder at a crestal or slightly supracrestal (0.5–1 mm) position. The choice of internal or external hex implants was based on the prosthetic preference of the referring restorative dentist. Surface topography depended on the implant surfaces that were available at the time of placement. Prosthetic rehabilitation was undertaken by the referring dentist/prosthodontist. Six of the prostheses were made by one of the co-authors (H.P.) who is a prosthodontist, and the remaining fifteen prostheses were fabricated by eight restorative dentists, two being prosthodontists. Metal-ceramic crowns were fabricated with no specific instructions as to the length of the cantilever or the retention mechanism, screw-retained or cemented prosthesis, which was left to the discretion of the referring restorative dentist. If bruxism was diagnosed at any stage of treatment or follow-up, a protective occlusal appliance was provided to protect the prosthesis. Each patient was advised to follow a regular Supportive Periodontal Treatment (SPT) maintenance program with yearly visits for both periodontal and prosthetic control.

2.3 | Clinical and Radiographic Examination

After signing an informed consent form to participate in the study, each participant received a comprehensive examination:

- Intraoral photographs of the implants
- Radiographic examination using the parallel cone technique taken either with an analog or with a digital protocol
- Clinical measurements of Probing depth (PD) (Renvert et al. 2018), Clinical Attachment Level (CAL, distance from top of implant platform to bottom of the sulcus), Bleeding on Probing (BOP) (presence/absence) and Presence of Plaque (PL) (presence/absence). Pocket probing depth and Attachment Level were assessed at six sites around each implant (mesio-buccal, buccal, disto-buccal, mesio-lingual, lingual, disto-lingual) using a graduated Michigan periodontal probe (Hu-Friedy Mfg Co LLC, USA), scaled in millimeters.
- Recording of prosthetic complications, either major or minor, using information provided by the dentist performing the SPT appointments (either periodontist or referring restorative dentist) or emergency appointments in cases of severe prosthetic complications.

2.4 | Radiographic Evaluation

The vertical distance from the top of the implant platform to the most coronal point of bone-to-implant contact was defined as Marginal Bone Level (MBL) and was measured on the mesial and distal of each implant, on radiographs taken at implant placement and radiographs taken at the re-evaluation appointment. All radiographs were taken by applying the long cone parallel technique and by using a film holder (Updegrave 1951). Analog radiographs were digitized using a digital camera. Photographs of the analog radiographs mounted on a light box were taken and evaluated together with the digital radiographs using the ImageJ Software (National Institutes of Health, Bethesda, MD, USA). A line was drawn at the top of the implant shoulder from mesial to distal, at the border where the prosthetic restoration started. Calibration of the digital images to correct for angulation variation was achieved by measuring the length of the implant from implant shoulder to the tip of the implants, as provided by the surgical manual of the company, since all implants were from the same manufacturer (ZimVie, previously known as Biomet 3i). Based on manufacturer specifications, the actual size of a 10 mm implant is 9.6 mm, the size of a 11.5 mm implant is 11.1 mm, and for a 13 mm implant, the actual size is 12.6 mm. After calibration of the radiographic lengths, mesial and distal vertical lines were drawn from the implant shoulder to the most coronal point of bone-to-implant contact as seen on the X-ray, to measure mesial and distal MBL (Figure 1). The final MBL value for each time point (time of placement and time of re-evaluation) was calculated as the mean of these two

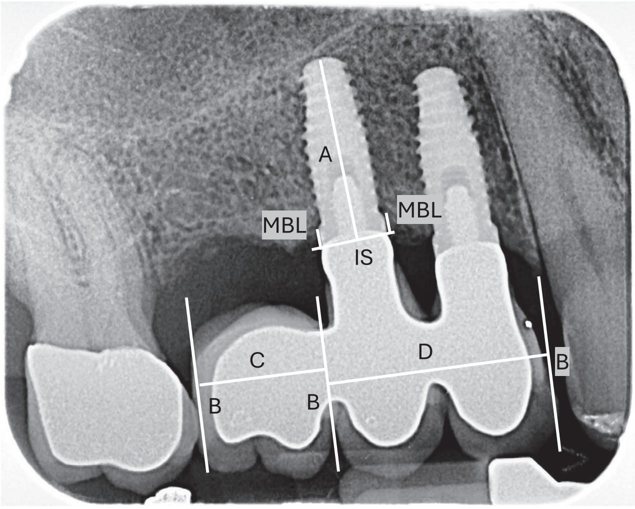

FIGURE 1 | Radiographic reference points used. IS: Horizontal line traced at the implant shoulder where the prosthetic restoration starts, A: Line used to adjust for scale variation measuring the length of the implant and adjusting for size as provided by the manufacturer (10 mm. implant label is actual length 9.6 mm, 11.5 mm label is 11.1 mm and 13 mm label is 12.6 mm), MBL: Mesial and distal marginal bone level measurements, traced vertically from the IS to the point of most coronal bone-to-implant contact. C: Vertical lines were drawn from the most coronal part of the metal connector and perpendicular to the line crossing the occlusal plane of the adjacent teeth to delineate the width of the cantilever tooth (D) and the width of the remaining prosthesis (E).

measurements. The primary outcome variable of the study was the amount of Marginal Bone Level change (MBLc) from time of placement to time of the re-evaluation exam for each implant. This was calculated by subtracting time of placement MBL values from re-evaluation MBL values. All values were expressed in millimeters.

The length of the cantilever and the remaining prosthesis was also measured as described by Romeo et al. (2009). Vertical lines were drawn from the most coronal part of the metal connector and perpendicular to the line crossing the occlusal plane of the adjacent teeth. The same procedure was repeated for the length of the prosthesis (Figure 1).

2.5 | Calibration of Examiner

All measurements were conducted by a single examiner (A.B.) to ensure consistency. Radiographic measurements were performed at least one month after the clinical assessments, without cross-referencing clinical data. The examiner underwent two calibration exercises: one focused on 107 repeat clinical measurements of probing depth (PD) and attachment level (CAL) on 5 patients, and the other on 87 radiographic measurements of 15 patients with similar conditions and treatments to the study cohort.

For clinical calibration, duplicate measurements were taken one hour apart on periodontal and implant patients, yielding an intraclass correlation coefficient (ICC) of 0.888 (95% CI: 0.841–0.922; $p < 0.001$) for PD and 0.961 (95% CI: 0.943–0.973; $p < 0.001$) for CAL. Radiographic calibration, performed on mesial and distal aspects for MBL measurements, achieved an ICC of 0.948 (95% CI: 0.920–0.966; $p < 0.001$).

2.6 | Assessment of Peri-Implant Health

Peri-implant health was evaluated in accordance with the latest guidelines of the World Workshop on the classification of Peri-implant diseases (Berglundh et al. 2018; Araujo and Lindhe 2018; Heitz-Mayfield and Salvi 2018). Peri-implant health was defined as the absence of signs of inflammation (BOP, suppuration) and absence of bone loss beyond what is expected from bone remodeling, up to 2 mm. Peri-implant mucositis was defined as the presence of inflammation in the mucosa surrounding the implant without loss of supporting peri-implant bone beyond what is expected from bone remodeling, with the clinical signs of bleeding on probing, erythema, edema and/or suppuration (Heitz-Mayfield and Salvi 2018). Peri-implantitis was defined as the presence of bleeding on probing and/or suppuration, increased probing depth (≥ 6 mm) and concomitant Marginal Bone Level change (MBLc) of ≥ 2 mm when baseline and re-evaluation radiographs were compared. Implant Survival Rate was defined as an implant still in place at the time of re-evaluation, and Implant Success Rate was defined as an implant with Marginal Bone Level change (MBLc) up to 2 mm, as described by Albrektsson et al. (1986) and Renvert et al. (2018).

2.7 | Prosthetic Complications

Prosthetic complications were assessed either by direct observation of the prostheses or through the dental history as related by the patients during the clinical re-evaluation visit if they had not complied with the suggested periodontal and prosthodontic maintenance program. Complications were divided into three categories (Lang and Zitzman 2012):

Major: implant fracture, loss of supra-structures.

Medium: abutment fracture, veneer or framework fractures, abutment screw fracture.

Minor (corrected by minor adjustments): abutment and screw loosening, loss of cement retention, loss of screw hole sealing, veneer chipping (which could be polished) and occlusal adjustment.

Prosthetic Survival Rate was defined as a FPDPC still in place at the time of re-evaluation, and Prosthetic Success Rate was defined as a FPDPC that did not exhibit major or medium complications.

2.8 | Statistical Analysis

The primary outcome variable was the Marginal Bone Level change (MBLc) from the time of implant placement to the time of re-evaluation. Marginal Bone Level (MBL) was calculated as the average of two radiographic measurements (mesial and distal MBL) for each implant for each time point of the study (implant placement and re-evaluation appointment). Six Pocket Depth (PD) and Attachment Level (CAL) measurements were recorded around each implant, and their averages for each implant were included in the analysis. Bleeding on Probing (BOP) and Plaque Levels (PL) were expressed as mean percentages of the six measurements (YES/NO) for each implant.

2.8.1 | Descriptive Statistics

Descriptive statistics were summarized using the mean and standard deviation (SD). Categorical variables were described using frequency (N) and percentage (%). The assumption of normality was tested using the Shapiro–Wilk test.

2.8.2 | Paired Comparisons

A Paired Samples T-Test was used to compare MBLc between the time of implant placement and the time of re-evaluation within each patient, as well as MBLc between implants adjacent to and distant from cantilever extensions within each patient.

2.8.3 | Group Comparisons

Independent Samples T-Test or Mann–Whitney U Test were used to evaluate associations of changes in MBLc with history of periodontitis, implant body shape (cylindrical vs. tapered), type of hexagonal connection (external vs. internal), retention method (cemented vs. screw-retained), and the ratio of cantilever-tooth width to supporting teeth (≤ 0.50 vs. >0.50). One-Way Analysis of Variance (ANOVA) was used to assess the relationship between MBLc and categorical variables such as smoking status (non-smoker, smoker, former smoker) and frequency of supportive periodontal treatment (none, <1 time/year, ≥ 1 time/year). Chi-Square Tests were performed to examine associations between categorical variables such as implant surface type, prosthesis type, smoking status, recall frequency, periodontal history, and supportive periodontal therapy.

2.8.4 | Non-Parametric Tests

The Mann–Whitney U Test was used when data did not meet normality assumptions for group comparisons. The Kruskal-Wallis Test was applied for multiple group comparisons, such as evaluating the association of MBL changes with smoking status, prosthesis type, or implant surface type.

2.8.5 | Correlation Analysis

Spearman's correlation analysis examined the relationships between MBL and continuous variables such as age, years since implantation, and implant length.

2.8.6 | Multilevel Analysis

Multilevel linear modeling was performed to account for the hierarchical structure of the data, with implants nested within prostheses and patients. Predictors included patient-related variables (age, smoking, periodontal history), implant-specific variables (implant body shape, connection type), and prosthesis-related variables (type, analog ratio). Variance components were estimated at the patient and prosthesis levels to assess the contribution of the hierarchical data structure to overall variability.

2.8.7 | Software

All statistical analyses were performed using the SPSS software (version 28), and statistical significance was set at $p \leq 0.05$.

Reporting on this study was done in compliance with the STROBE guidelines/checklist. The study has been registered in the Clinical Trials Protocol Registration and Results System (https://clinicaltrials.gov), registration number NCT06534398.

3 | Results

Patient data and nature of the cantilever prostheses are presented in Table 1.

3.1 | Patient Characteristics

The patient sample consisted of 19 patients (9 males and 10 females) with a mean age of 55.7 ± 10.6 years at implant placement and 69.1 ± 9.8 years at re-evaluation. Four patients were smokers (more than 10 cigarettes per day).

3.2 | Implant and FPDPC Characteristics

A total of 47 implants were placed, 32 implants in 16 two-implant with one-cantilever FPDPC's and 15 implants in five 3-implant prostheses with one or two cantilevers. All implants were 4 mm in diameter, except one 3.25 mm that was placed in location #12 in a three-implant anterior FPDPC. 21 FPDPC's were placed from 2002 to 2014 for a mean loading period of 13.3 ± 2.9 years with a range from 10 to 21 years of function. One FPDPC was placed in the anterior maxilla, 13 in the posterior maxilla, and seven in the posterior mandible. Fourteen prostheses had a distal cantilever, six had a mesial cantilever, and one had cantilevers on both mesial and distal sides.

Guided bone regeneration was required before placement of two implants in one patient; contour bone augmentation during placement was performed for two implants, and an indirect sinus floor elevation procedure was performed for one implant.

Seven patients exhibited adherence to SPT with a mean rate of ≥ 1 visit per year, 3 patients visited once every 2–3 years, and 9 patients did not adhere to SPT and were seen for the first time after fabrication of their prosthesis.

3.3 | Biologic Complications

No implant was lost during the loading period, thus resulting in a 100% Implant Survival Rate (95% CI: 92.5%–100.0%). At

TABLE 1 | Patient and implant characteristics.

Patient nr.	Age at follow up	Gender	Smoking status	SPT	Follow up (yrs)	Implant location (Cantilever)–FDI syst. retention mechanism	Implant diameter and Hex. (mm)	Implant length and shape (mm)	Grafting procedures
1	62	M	N	3	12	(16), 15, 14 CM and 24, 25, (26) CM	4 I/4 I 4 I/4 I	11.5T/13T and 13T/11.5T	NO
2	69	M	N	2	13	(16), 15, 14 CM	4 I/4 I	11.5C/13C	NO
3	80	M	N	3	11	(16), 15, 14 SR	4 X/4 X	11.5C/13C	NO
4	79	F	N	3	15	(16), 15, 14 CM	4 X/4 X	11.5C/13C	CA
5	79	F	N	2	14	47, 46, (45) SR	4 X/4 X	11.5C/11.5C	NO
6	88	F	N	1	17	24, 25, (26) CM	4 X/4 X	13C/13C	NO
7	69	F	N	1	10	34, 36, (37) SR	4 I/4 I	13C/11C	NO
8	69	F	N	3	10	(16), 15, 14 CM	4 I/4 I	11.5T/13T	GBR
9	64	M	N	3	10	(46), 45, 44 SR	4 I/4 I	13C/11.5C	NO
10	69	M	Y	1	10	(16), 15, 14 SR	4 X/4 X	11.5T/11.5T	NO
11	68	M	N	1	13	46, 45, (44) CM	4 I/4 I	10C/11.5C	CA
12	73	M	N	1	13	(34), 35, 36 SR	4 X/4 X	11.5C/13C	NO
13	53	M	Y	1	13	24, 25, (26) SR	4 X/4 X	11.5T/11.5C	ISFE (#25)
14	73	F	Y	1	14	(16), 14, 15 SR and 24, 25, (26) SR	4 X/4 X 4 X/4 X	11.5T/13T and 13T/11.5C	NO
15	46	F	Y	2	18	12, 11, 21, (22) CM	3.25 X/4 X/4 X	13C/13C/13C	NO
16	68	M	N	1	14	46, 45, 44, (43) CM	4 X/4 X/4 X	13C/13C/11C	NO
17	78	F	N	2	12	(22), 23, 24, 25, (26) CM	4 I/4 I/4 I	13R/13C/11C	NO
18	63	F	N	1	13	17, 16, 15, (14), (13) CM	4 I/4 I/4 I	11.5C/10C/11.5C	NO
19	62	F	Y	1	21	(34), 35, 36, 37 CM	4 X/4 X/4 X	10C/11.5C/10C	NO

Abbreviations: C, Cylindrical implant; CA, Contour augmentation; CM, cemented restoration; F, female; FDI, world dental federation tooth numbering system; GBR, guided bone regeneration before implant placement; Hex, nature of hexagonal connection; I, internal hex; ISFE, internal sinus floor elevation; M, male; SPT category, 1: no SPT, 2: 1 every 1–3 years, 3: at least 1/year; SR, screw retained restoration; T, tapered implant; X, External Hex.

re-evaluation, peri-implant health was diagnosed for 31 implants (66%), peri-implant mucositis for 12 implants (25.5%, 95% CI: 13.9%–40.3%) and peri-implantitis for 4 implants (8.5%, 95% CI: 2.4%–20.4%). On a patient level, 2 patients presented with peri-implantitis (10%) and 5 patients presented with peri-implant mucositis (26%). It must be noted that one of the patients with peri-implantitis had been suffering from severe lichen planus, which had complicated her peri-implant health (Table 2).

TABLE 2 | Prevalence rates for biological and prosthetic complications and percentages of biologic and prosthetic success and survival of implants supporting fixed partial dental prostheses with cantilever extensions (FPDPC's, range of loading 10–21 years), with 95% confidence intervals. (Clopper-Pearson exact method). (*n*, number of occurrences, *N*, total number of implants or prostheses).

Complication	Cases (*n*/*N*)	Prevalence	95% confidence interval
Biological complications			
Peri-implantitis	4/47	8.5%	2.4%–20.4%
Peri-implant mucositis	12/47	25.5%	13.9%–40.3%
Implant survival	47/47	100%	92.5%–100.0%
Implant success	43/47	91.5%	79.6%–97.6%
Prosthetic complications			
Major complications	3/21	14.3%	3.0%–36.3%
Medium complications	1/21	4.8%	0.1%–23.8%
Minor complications	3/21	14.3%	3.0%–36.3%
Prosthetic survival	18/21	85.7%	63.7%–97.0%
Prosthetic success	17/21	81.0%	58.1%–94.6%

Mean PD at re-evaluation was 3.9 ± 1.6 mm, mean CAL was 1.2 ± 1.6 mm. Percentages of Bleeding on Probing and Presence of Plaque were 14.89% ± 23.11% and 26.6% ± 30.62% respectively. Implant Success Rate, defined as an implant without signs of peri-implantitis (Albrektsson et al. 1986; Renvert et al. 2018) was 91.5% (95% CI: 79.6%–97.6%), accounting for 4 implants (8.5%) with peri-implantitis. Two representative cases are shown in Figure 2: a 3-unit FPDPC with a distal molar cantilever tooth supported by two implants on the upper maxilla after 10 years of functional loading (A) and a 4-unit FPDPC with a mesial premolar cantilever supported by 3 implants after 21 years of loading (B).

3.4 | Mechanical/Technical Complications

The following prosthetic complications were noted and categorized as discussed earlier:

Major (requiring replacement of the restoration): Two patients experienced a fracture of their cantilever tooth, which required replacement of the restoration. Patient #19 experienced a fracture of her cantilever teeth in two prostheses in both maxillary posterior areas after 3 years of function. Patient #3 experienced a fracture of their cantilever abutment tooth in the maxillary posterior after 11 years of function. In total, 3 restorations had to be replaced. Both failed cases are shown in Figure 3 (Table 2).

Medium: Patient #9 suffered abutment screw fracture on both abutments of his prosthesis after 7 years of function. The broken abutment screws were retrieved, and the existing prosthesis was refitted with new abutment screws.

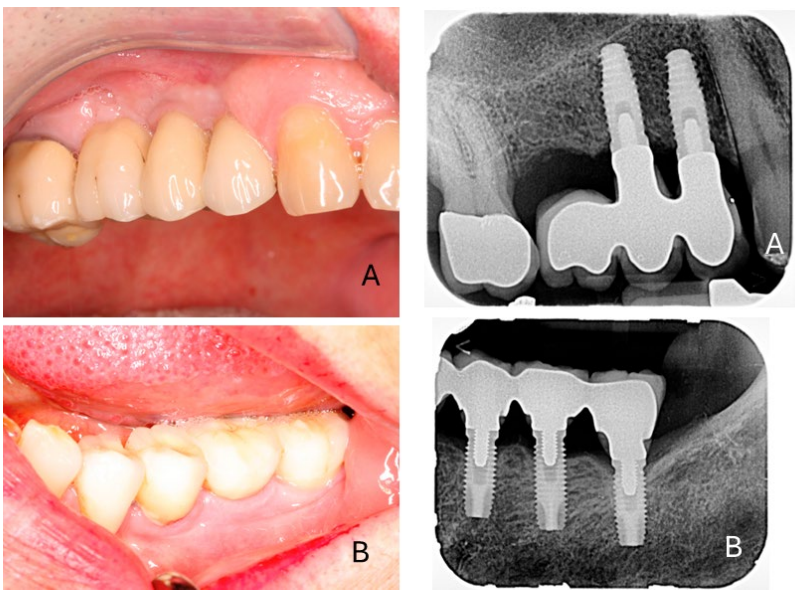

FIGURE 2 | (A) 3-unit FPDPC after 10 years of loading. (B) 4-unit FPDPC after 21 years of loading.

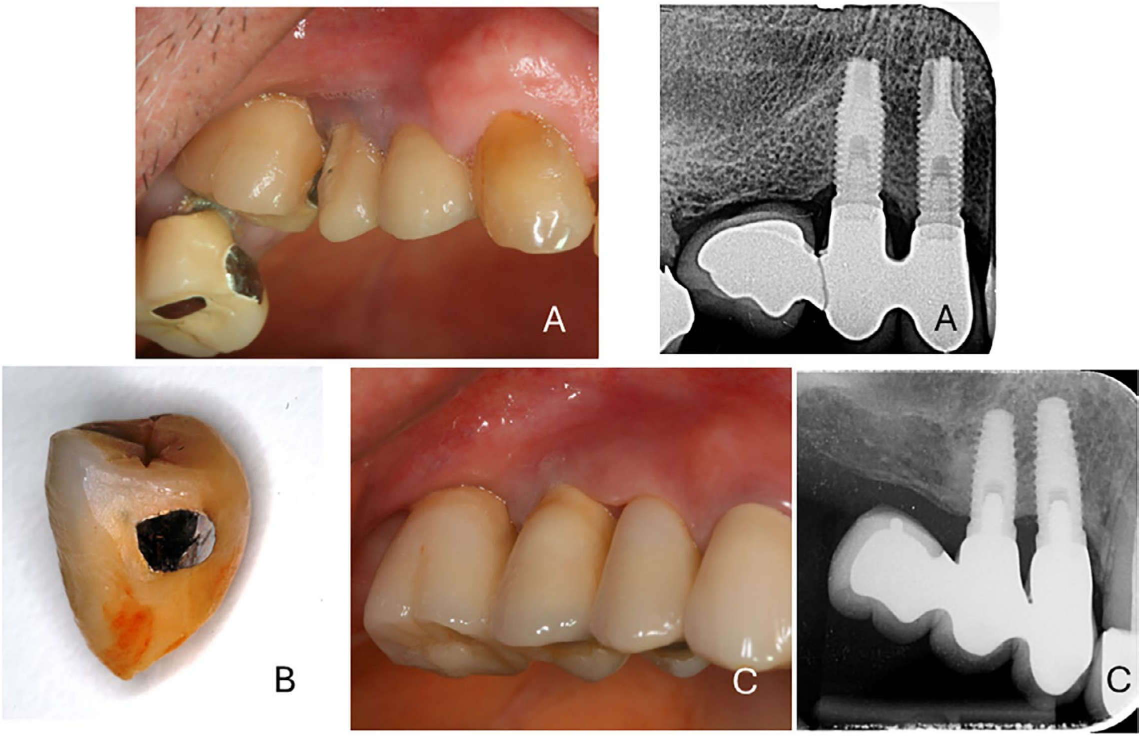

FIGURE 3 | (A) Patient #3, fractured cantilever after 11 years of function. (B) Patient #19, fractured cantilever due to inadequate connector dimensions after 3 years of function. (C) Patient #19, replacement FPDPC after a further 11 years of function.

TABLE 3 | Mechanical and technical complications.

Mechanical/technical complication	Patient-based events ($n = 19$) (%)	FPDPC-based events ($n = 21$) (%)	Implant-based events ($n = 47$) (%)
Implant fracture	0 (0)	0 (0)	0 (0)
Cantilever abutment fracture	2 (10%)	3 (14%)	6 (13%)
Framework fracture	0 (0)	0 (0)	0 (0)
Screw fracture	1 (5%)	1 (5%)	2 (4%)
Screw loosening	1 (5%)	1 (5%)	2 (4%)
Loss of retention	0 (0)	0 (0)	0 (0)
Porcelain chipping	2 (10%)	2 (10%)	3 (7%)

Minor: minor porcelain chipping was seen in two prostheses (patient #3,6), and abutment screw loosening was seen in one other patient (13) after 12 years of function.

It must be noted that all three patients who suffered from major or medium complications were bruxers who had declined to use their prescribed protective mouthguards.

Eight prostheses were screw-retained and 13 were cemented. No incident of loss of retention of the cemented prostheses occurred in this patient sample. All mechanical complications are summarized in Table 3.

Prosthetic Survival Rate, defined as a FPDPC still in place at the time of re-evaluation, was 86% (18/21 restorations still in place, 95% CI: 63.7%–97.0%) and Prosthetic Success Rate, defined as a FPDPC that did not exhibit major or medium complications, was 81% (17/21 restorations, 95% CI: 58.1%–94.6%). Kaplan Meier survival curves of Biologic and Prosthetic Survival and Success rates are presented in Figures 4–6.

3.5 | Changes in Radiographic Bone Levels

The mean Marginal Bone Level (MBL) at the time of placement was measured at 1.01 ± 0.48 mm below the implant platform, due to supracrestal placement of the implants. The mean MBL at the time of re-evaluation was 2.01 ± 0.91 mm, which was statistically significantly greater compared to the time of implant placement. Mean Marginal Bone Level change (MBLc) from baseline to re-evaluation was 0.99 mm (95% CI: 0.67, 1.31 mm, $p < 0.001$). This difference remained statistically

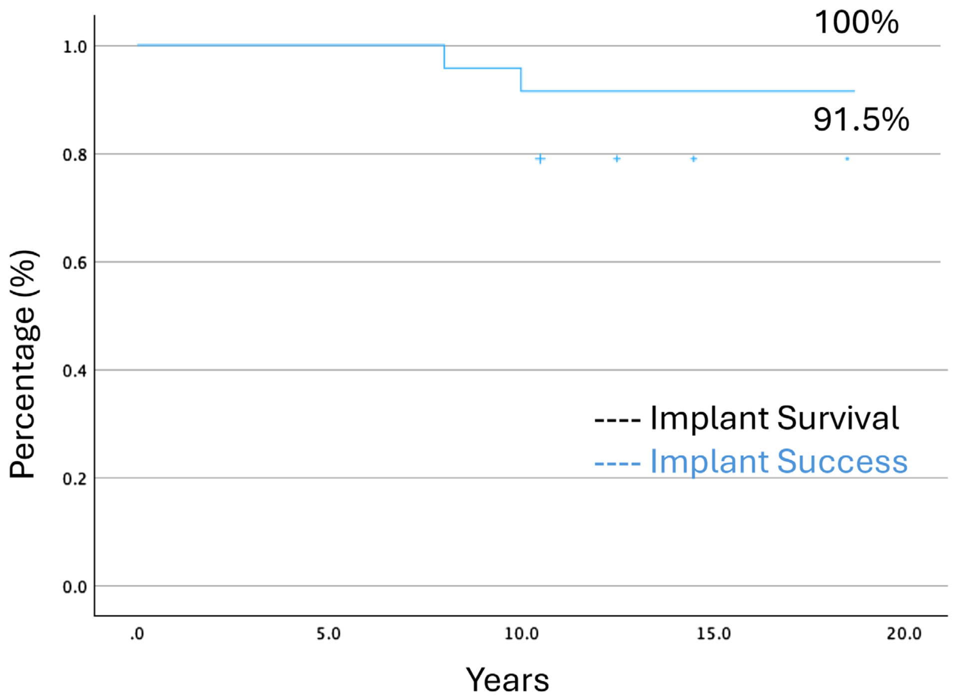

FIGURE 4 | Kaplan–Meier cumulative survival and success rates of implants supporting fixed partial dental prostheses with cantilever extensions (FDPC's).

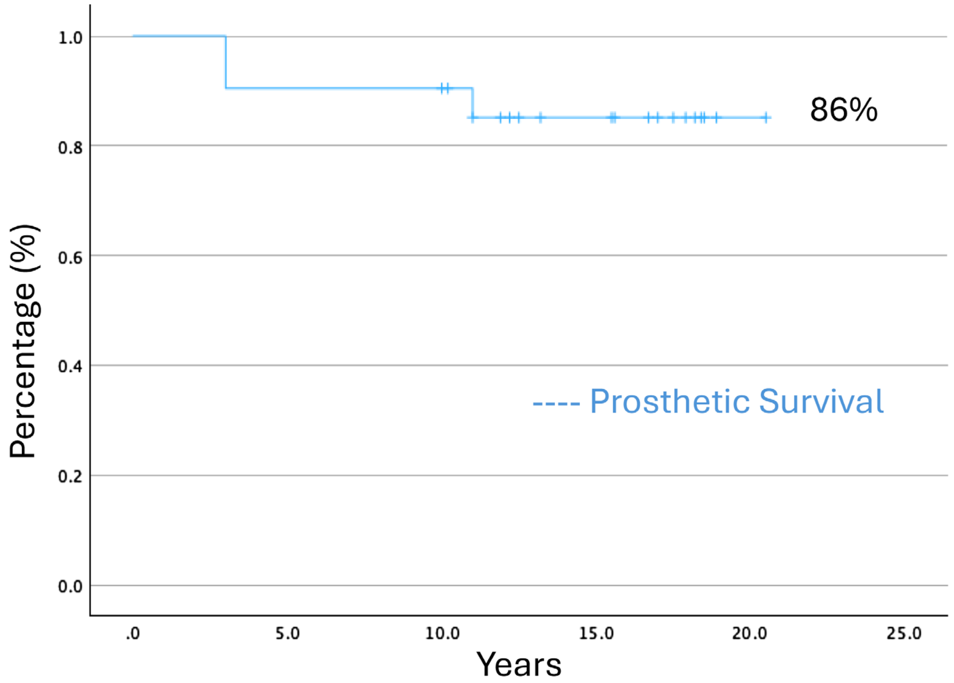

FIGURE 5 | Kaplan–Meier cumulative Prosthetic Survival Rate of fixed partial dental prostheses with cantilever extensions (FDPC's).

significant when the change in MBL between baseline and re-evaluation was evaluated separately for implants adjacent to the cantilever extension (Mean Difference = 0.83 mm (95% CI: 0.37, 1.28), $p < 0.001$) and for implants distant from the cantilever extension (Mean Difference = 1.04 mm (95% CI: 0.58, 1.49), $p < 0.001$). To check whether implants adjacent to and distant from the cantilever extension had experienced different patterns of change in MBL after years of loading, a comparison was made, which did not show a statistically significant difference in MBLc ($p = 0.29$). Implants adjacent to the cantilever extension exhibited a mean MBLc of 0.83 mm (95% C.I.: 0.37, 1.28 mm) compared to implants distant from the cantilever extension with an MBLc of 1.04 mm (95% C.I.: 0.58, 1.49 mm) (Table 4).

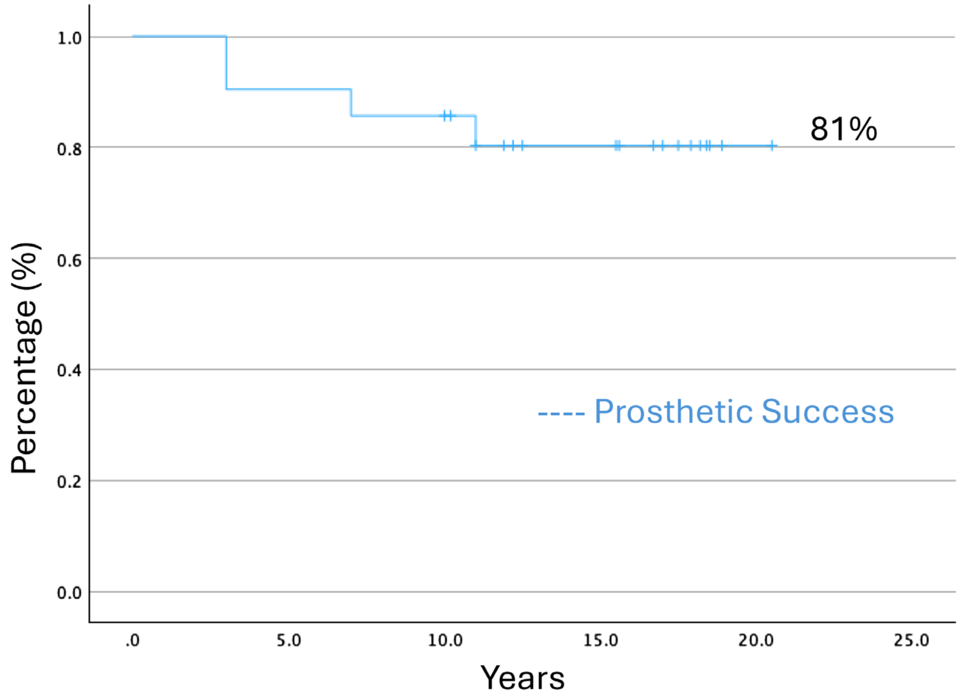

FIGURE 6 | Kaplan–Meier cumulative Prosthetic Success Rate of fixed partial dental prostheses with cantilever extensions (FDPC's).

TABLE 4 | Marginal bone level (MBL) position (in mm) at the time of implant placement and at the time of re-evaluation (mean 13.3 ± 2.9 years after implant placement). Marginal bone level change (MBLc) of implants (in mm) between the two time points. Comparison of implants mesial and distal to the cantilever tooth.

	MBL at implant placement (95% CI)	MBL at time of reevaluation (95% CI)	MBL change (MBLc) (95% CI)	*p*
All implants	1.01 (0.48) [0.87, 1.15]	2.01 (0.91) [1.75, 2.27]	0.99 (1.11) [0.67, 1.31]	< 0.001*
Implants adjacent to cantilever extension	1.09 (0.43) [0.97, 1.21]	1.92 (0.86) [1.68, 2.17]	0.83 (1.6) [0.37, 1.28]	< 0.001*
Implants distal from cantilever extension	0.96 (0.48) [0.82, 1.10]	1.99 (0.86) [1.74, 2.23]	1.04 (1.54) [0.58, 1.49]	< 0.001*
p-value (adjacent vs. distal at each time point)	0.210	0.713	0.295	

Abbreviation: CI, confidence interval.
*Statistically significant at $p \leq 0.05\%$ (Paired samples *t*-test).

3.6 | Association of MBLc With Other Parameters

Smoking status: Four patients were smokers, three were former smokers, and the remaining 12 were non-smokers. Mean MBLc at time re-evaluation was 0.76 ± 0.66 mm, 0.63 ± 0.57 mm, and 1.17 ± 1.28 mm, respectively. Comparison between those groups at the final examination did not reveal any statistical significance ($p = 0.37$) (Table 5).

Adherence to Supportive Periodontal Treatment (SPT): Complete compliance with SPT was exhibited by 6 patients, who presented for their appointment at least once per year. Five patients were erratic compliers, averaging one appointment every 2–3 years, and eight patients had not received any care since implant placement. Mean MBLc from baseline to re-evaluation was 1.33 ± 1.41 mm, 1.01 ± 0.94 mm, and 0.68 ± 0.77 mm, respectively. Comparison between those groups at the final examination did not reveal any statistical significance ($p = 0.21$).

History of periodontitis: Eight patients had a history of periodontitis and received periodontal treatment prior to implant placement. Mean MBLc of periodontal and healthy patients at time of re-evaluation was 1.15 (0.79, 1.778) mm and 0.40 mm (0.08, 1.08) respectively. Comparison between those groups at the final examination revealed statistically significant differences in the amount of MBL change ($p = 0.011$). It must be noted that both patients with peri-implantitis at the final examination had a history of periodontal disease, and neither had complied fully with the SPT protocol.

TABLE 5 | Association of marginal bone level change (MBLc) from time of implant placement to time of reevaluation (mean 13.3 ± 2.9 years of functional loading) with various parameters.

Clinical variable	MBLc from implant placement to re-evaluation (mm) Mean (SD)	*p*
Smoking status		0.369
Non-smoker (*n* = 12)	1.17 (1.28)	
Smoker (*n* = 4)	0.76 (0.66)	
Former smoker (*n* = 3)	0.63 (0.57)	
Adherence to SPT		0.215
None (*n* = 8)	0.68 (0.77)	
1 time/2–3 years (*n* = 5)	1.01 (0.94)	
≥ 1 time/year (*n* = 6)	1.33 (1.41)	
History of periodontitis		0.011*
No (*n* = 11)	0.74 (1.25)	
Yes (*n* = 8)	1.26 (0.78)	
Implant shape		0.538
Cylindrical (*n* = 34)	0.93 (1.20)	
Tapered (*n* = 13)	1.15 (0.74)	
Hexagonal connection		0.357
External (*n* = 37)	0.87 (1.20)	
Internal (*n* = 20)	1.16 (0.90)	
Type of retention		0.264
Cemented (*n* = 39)	1.13 (1.24)	
Screw-retained (*n* = 18)	0.77 (0.75)	
Cantilever tooth length/Abutment length Ratio		0.819
≤ 0.50 (*n* = 6)	0.88 (1.16)	
> 0.50 (*n* = 13)	0.97 (0.63)	

Abbreviation: SD, standard deviation.
*Statistically significant at $p \leq 0.05$ (Mann–Whitney test).

Implant shape: 34 implants were cylindrical and 13 were tapered, with mean MBLc at time of re-evaluation measured at 0.93 ± 1.20 mm and 1.15 ± 0.74 mm, respectively. Comparison between those groups at that time point did not reveal any statistical significance ($p = 0.54$).

Type of implant-abutment connection: 37 implants featured an external and 20 featured an internal hexagonal connection, with mean MBLc at time of re-evaluation measured at 0.87 ± 1.20 mm and 1.16 ± 0.90 mm respectively. Comparison between those groups at that time point did not reveal any statistical significance ($p = 0.35$).

Type of retention: 39 implants supported cement-retained prostheses and 18 supported screw-retained prostheses, with mean MBLc at time of re-evaluation measured at 1.13 ± 1.24 mm and 0.77 ± 0.75 mm, respectively. Comparison between those groups at that time point did not reveal any statistical significance ($p = 0.26$).

Length of cantilever tooth: The length of the cantilever has been a subject of scrutiny, as longer cantilever teeth might exert higher forces on the supporting implants in FPDPC's. To examine this, two groups were formed using a ratio of cantilever length/remaining prosthesis length of 0.5 as the cutoff point, which would be equivalent to constructing a small cantilever (e.g., premolar cantilever on a FPDPC involving implants at #14 and #15) and having a ratio of 0.5 or lower, versus constructing a full molar extension, where the ratio would be more than 0.5. A large cantilever was constructed in 13 prostheses and a small one in 6 prostheses. The length of the cantilever teeth ranged from 5 mm to 12.8 mm. The mean MBLc at the time of re-evaluation was measured at 0.97 ± 0.63 mm and 0.88 ± 1.16 mm for large vs. small cantilever teeth, respectively. Comparison between those groups at that time point did not reveal any statistical significance ($p = 0.82$).

3.7 | Multilevel Analysis

A multilevel analysis of change in Marginal bone level change (MBLc) was performed to evaluate its relationship with various factors, considering the hierarchical structure of the data. This structure included 47 implants nested within 21 prostheses and 19 patients. The analysis incorporated a range of predictors: smoking, periodontal history, age, sex, recall frequency, medication use, and prosthesis type.

3.7.1 | Key Findings

Age showed a near-significant negative association with MBLc ($\beta = -0.050$, 95% CI: −0.101 to 0.001, $p = 0.054$), suggesting that older patients tended to experience less cumulative bone loss. Smoking demonstrated a non-significant negative effect on MBLc ($\beta = -0.371$, $p = 0.235$). History of periodontal disease was positively associated with MBLc ($\beta = 0.511$), though not statistically significant ($p = 0.282$). Other predictors such as gender, recall frequency, medication use, and prosthesis type showed minimal and non-significant effects on MBLc.

3.7.2 | Variance Components

Patient-Level Variance was substantial (0.473), indicating considerable variability in MBLc between patients. Prosthesis-Level Variance was negligible, suggesting that differences at the prosthesis level had little impact on MBLc.

4 | Discussion

The aim of this study was to present evidence about the longevity of implant-supported fixed partial dental prostheses with cantilever extensions (FPDPC's). The results showed that this treatment option can provide long-lasting successful restorations while avoiding surgical procedures with high morbidity such as sinus floor elevation in the posterior maxilla, or extensive guided bone regeneration procedures if bone quality and quantity are lacking to place implants in their proper positions.

No implant was lost after a mean 13.3 years of loading (range 10–21 years) for 100% implant survival, similar to what has been reported in the literature. Previous investigations (Wennström et al. 2004; Romeo et al. 2009; Aglietta et al. 2012) also reported 100% implant survival after 5, 8, and 7 years, respectively. Hälg et al. (2008) and Schmid et al. (2020) reported implant survival of 95.7% after 5 years and 98.3% after 13.3 years, owing to the loss of three Narrow Diameter Implants (NDI). All implants except for one in this study were 4 mm in diameter, a factor that has been shown to be important in previous studies. In the present study, one NDI of 3.25 mm diameter was used in a 3-implant FPDPC in the maxillary anterior, and no problems were encountered. Therefore, and within the limitations of this study, it can safely be supported that 4-mm diameter implants are safe to be used for the fabrication of FPDPC's.

Peri-implant health was diagnosed in 31 (66%) of implants and 12 (71%) of patients; peri-implant mucositis was present in 12 (25.5%) of implants and 5 (27%) of patients, whereas peri-implantitis was diagnosed for 4 (8.5%) of implants and 2 (12%) of patients, for rates of Implant Success of 91.5% on an implant and 88% on a patient level. The study of Schmid et al. (2020) with a very similar follow-up period of 13.3 years reported patient-level percentages of 46.2% for health, 26.9% for mucositis, and 26.9% for peri-implantitis. However, all patients in that study had a previous history of treated periodontal disease, which could explain a higher incidence of biologic complications compared to this study, where only 6 of 19 (32%) patients had a history of periodontal disease. Aglietta et al. (2012) did not discuss biological complications in their 7-year study, and Romeo et al. (2009) reported an implant success rate of 90.5% after 8.2 years, quite similar to this study.

History of periodontitis was found to be positively associated with a statistically significant increase in Marginal Bone Level change (MBLc). The results showed mean MBLc of 0.93 ± 1.2 mm for patients with no history of periodontal disease vs. 1.15 ± 0.75 mm for previously treated periodontal patients. Although the differences in this study may not be clinically significant, this has been a clinical finding reported in other studies (Karoussis et al. 2003; Derks et al. 2016; Roccuzzo et al. 2012). In the study by Wennström et al. (2004) all patients had received periodontal treatment before implant placement and were maintained on a Supportive Periodontal Treatment (SPT) program. Mean MBLc after 5 years was 0.4 ± 0.76 mm. In the study of Schmid et al. (2020), all patients had previously undergone periodontal treatment and were enrolled in a regular SPT program. Their findings showed mean MBLc of 0.4 ± 0.3 mm after an average of 13.3 years of loading. When evaluating those numbers along with the findings of the current study, it can be surmised that previous history of treated periodontitis was not correlated with clinically significant MBLc.

The patient sample in the present study did not exhibit adequate adherence to the SPT suggestions; however, this variable did not reach statistical significance as related to MBLc. Seven of 19 patients were non-compliers to SPT and presented a mean MBLc of 0.68 ± 0.77 mm, compared to five of 19 patients who were erratic compliers (1 appointment every 2–3 years) who presented a mean MBLc of 1.01 ± 0.94 mm. Five of 19 compliant patients (SPT at least once a year) presented a mean MBLc of 1.33 ± 1.41 mm. These differences were not statistically significant. Eleven of 19 patients enrolled in this study were periodontally healthy, and this may be a reason that they did not comply with SPT since they did not experience any problems with their dentition over time. Only 3 of the other 8 patients with a history of periodontal disease complied with SPT. Previous long-term studies reported on well-maintained patients; Schmid et al. (2020) had periodontal patients that were enrolled in a SPT program, Aglietta et al. (2012) also had patients enrolled in a regular maintenance program, and Romeo et al. (2009) monitored their patients yearly. It is interesting to note that other long-term retrospective studies, such as Balshi et al. (2015) have removed from their analyses any patients that stopped attending their maintenance appointments. The landmark study of Costa et al. (2012) clearly showed the importance of preventive maintenance programs in implantology, with increased incidence of peri-implantitis in a group of patients with peri-implant mucositis who did not attend their maintenance appointments. In the present study, all patients were included in the analysis, irrespective of their compliance to the SPT program, and this factor did not seem to have a negative effect on Marginal Bone Level change in this small patient sample.

Prosthetic complications did occur as expected during the follow-up period. Screw loosening was easily corrected in one patient, broken abutment screws were retrieved, and the existing prosthesis was refitted with new abutment screws in one other patient. In patient #14 who suffered a fracture of the cantilever teeth, further examination of the connector sites in her two restorations revealed inadequate connector dimensions (2×2 cm) of the metal framework next to the cantilever area, and this was possibly a reason for this complication, along with the possibility of faulty soldering. The prostheses were replaced with new ones, and no other incidents have occurred in 11 years of subsequent function. Patient #3 was a bruxer who did not wear his protective mouthguard and experienced a fracture of his cantilever tooth after 11 years of function, along with severe porcelain chipping of the abutment teeth. His prosthesis was replaced with renewed directions about using his mouthguard. Therefore, prosthetic survival rates after 13.3 years of function amounted to 90% of patients and 86% of FPDPCs, and Prosthetic Success Rates were 84% on a patient level and 81% on a FPDPC level. In the Wennström et al. (2004) study, after an average of five years of function in 50 FPDPCs, three patients experienced screw loosening, and minor porcelain fractures were observed in three other patients. In the Hälg et al. (2008) study, which included 27 FPDPCs after an average of 5.3 years of function, prosthesis survival was 88.9%; 2 FPDPCs failed due to implant fracture, and one restoration had to be remade. Minor chipping was also observed in 4 FPDPCs. In the Aglietta et al. (2012) study, 21 FPDPCs were observed for an average of 5.6 years. However, prosthetic complications were not reported in the study. Finally, in the Schmid et al. (2020) study, 30 FPDPCs were followed for an average of 13.3 years. They reported one abutment fracture for a success rate of 96.2%, albeit with stricter inclusion criteria compared to the present study that excluded bruxer patients and demanded short cantilever teeth corresponding to one premolar unit only (6–7 mm). Loss of retention of cemented restorations occurred nine times in that patient sample, which was not observed in the present study. Screw loosening occurred once, same as in the present study. It must be noted that some of the prosthetic complications occurred after more than ten years of function, further underscoring the need for long-term reporting of such restorations.

Mean MBL was statistically significantly increased from baseline to re-evaluation; however, the mean MBLc was 0.99 mm, which is well within acceptable limits after a mean time of 13.3 years, according to Albrektsson et al. (1986) and Renvert et al. (2018) where a limit of 2 mm was set. Therefore, the observed MBLc was not clinically significant and in line with what has been reported in the literature. In a 5-year retrospective evaluation of FPDPC's by Wennström et al. (2004) MBLc was 0.4 mm, similar to the findings of Aglietta et al. (2012) of 0.2 mm after 5 years of function. Romeo et al. (2009) reported mean MBLc of 1.1 mm after an 8-year observation period, and Schmid et al. (2020) reported 0.4 mm after 13.3 years of mean loading time. It must be noted that baseline radiographs in the current retrospective evaluation were available from the time of implant placement; therefore, part of the observed MBLc could be attributed to initial bone remodeling subsequent to implant placement and therefore over-reported. Unfortunately, radiographs after delivery of the prosthesis were not available to account for early bone remodeling.

Several other variables were also examined. Smoking status was not found to influence bone loss after 13.3 years of function; however, only 5 of 19 patients were smokers (at least 10 cigarettes/day) in the present study, so the results must be interpreted with caution. In the study of Wennström et al. (2004) smokers were also included, and smoking was potentially identified as harmful, but did not reach statistical significance. In the study of Romeo et al. (2009) smokers (> 15 cigarettes/day) were excluded, whereas in another trial (Schmid et al. 2020) only 4/26 patients were smokers, and it is noteworthy that this factor was not discussed as a potential risk factor in their study. The low numbers of smokers in all these studies surely preclude any useful conclusions as to the deleterious effect of smoking in long-term implant maintenance. This also holds true for the lack of significance observed in the type of retention of the prostheses (cemented vs. screw-retained) and the type of implant-abutment connection of the implants used (internal vs. external hex implants). None of the aforementioned studies focused on these variables, so a comparison cannot be made.

Another aspect worthy of consideration is the length of the cantilever extension. To examine this, two groups were formed using a ratio of cantilever length/remaining prosthesis length of 0.5 as the cutoff point, which would be equivalent to constructing a small cantilever (e.g., premolar cantilever on a FPDPC involving implants at #14 and #15) and having a ratio of 0.5 or lower, versus constructing a full molar extension, where the ratio would be more than 0.5. Data analysis did not show this parameter to be of significance in relation to MBLc; however, all three major prosthetic complications with fracture of the cantilever teeth occurred in two patients with lengthy cantilevers, i.e., molar cantilevers supported by implants placed in the premolar regions. As previously mentioned, the Schmid et al. (2020) study allowed only for reduced width of cantilever teeth, equivalent to a premolar tooth and did not report any fractures, whereas in the present study, many of the cantilever teeth were wider than one premolar unit, especially in cases where the presence of neighboring teeth (e.g., tooth #17 in a FPDPC involving implants #14 #15 and a cantilever #16) would require a cantilever tooth of adequate width to fill the gap. Romeo et al. (2009) also measured the length of the cantilever teeth and did not find any statistical significance on MBLc.

An interesting question that has been raised in previous publications (Michalakis et al. 2003; Gracis et al. 2012; Pjetursson et al. 2018) was whether the implant closest to the cantilever tooth is under heavier strain and if this fact may affect MBLc measurements. None of the previous studies on the subject have found a significant impact of this factor. Wennström et al. (2004), Aglietta et al. (2012) and Schmid et al. (2020) all reported on differences between proximal and distal implants to the cantilever tooth and found very small, statistically not significant differences. The same was found in this study, with mean MBLc at implants adjacent to the cantilever extension being 0.83 mm vs. 1.04 mm for the implants distant from the cantilever extension. The comparison of these differences did not yield any statistical significance.

Furthermore, it may be pointed out that this is the first report using Zimvie implants (previously known as Zimmer Biomet 3i implants, Warsaw, Indiana, United States) supporting FPDPC's. Except for the Wennström et al. (2004) study that used Astra implants (Astra Techs Dental Implant System, Molndal, Sweden), all other previous studies (Hälg et al. 2008; Aglietta et al. 2012; Schmid et al. 2020) used ITI implants (Straumann Dental Implant System, Institut Straumann AG, Basel, Switzerland). There are limitations in trying to make comparisons between implant systems, and clinical findings from one implant system cannot be unequivocally applied to all other systems (Roccuzzo et al. 2014); therefore, being able to report on a different implant system is also an important element of a long-term study providing information on implant therapy outcomes. Furthermore, to the best of the authors' knowledge, this is also the first report that has used tapered implants supporting FPDPC's. Thirteen out of forty-seven implants placed were tapered, and no difference was found in mean MBLc between tapered and cylindrical implants. Likewise, the type of hexagonal connection (internal vs. external) or type of retention (screw-retained vs. cemented) also did not have an impact on mean MBLc measurements or the frequency of prosthetic complications, as has been shown in previous publications (Michalakis et al. 2003; Gracis et al. 2012; Pjetursson et al. 2018).

Limitations of this study are surely defined by its retrospective status and the relatively small number of participants. Only 107 of 208 (51,4%) patients from the initial sample group were able to present for the re-evaluation examination. Five FDPC's were placed in five patients that could not be examined in the re-evaluation appointment: two had passed away and three patients had moved to a different location. Out of the 101 patients that could not be examined, it was assumed that the 17 patients who declined to participate in the study could be a factor of bias. Thus, the records of these17 patients were reviewed and none of these patients had FPDPC's placed, which reduced the selection bias of the study. It must be noted that the 107 patients that were examined averaged an observation time of 15 ± 3 years (range 10–23 years), so a high percentage of losstofollow up was to be expected. In a recent retrospective study of implant-supported restorations with a mean observation time of 20.3 ± 9.7 years, only 40 out of 84 potentially eligible patients were examined (Bischof et al. 2024) and the authors came to similar conclusions regarding loss to follow up after many years of observation.

The number of patients and restorations is also small. However, a comparison with previous studies shows that Wennström et al. (2004) reported on 24 patients with 48 implants after five years, Hälg et al. (2008) reported on 19 patients with 38 implants after five years, Romeo et al. (2009) reported on 18 patients with 56 implants after eight years, Aglietta et al. (2012) reported on 21 patients with 42 implants after seven years, and Schmid et al. (2020) reported on 26 patients with 60 implants after 13 years. The current investigation presented findings from 19 patients with 47 implants after a mean time of 13.3 years, which could be considered comparable to what has been previously published, especially when the time of re-evaluation is considered. Another limitation is the fact that clinical and radiographic measurements were not available after prosthesis delivery. Thus, only baseline radiographs from the time of placement could be used to compare MBLc after 13.3 years of function. Part of the MBLc observed in this study could be attributed to initial bone remodeling in the first few months after implant placement (Berglundh et al. 2018). Since mean MBLc after 13.3 years was only 0.99 mm, it can be surmised that this limitation did not have a deleterious effect on the final conclusions of the present study. Radiographs were not fully standardized regarding angle; however, an attempt was made to account for that factor by using implant length as a known dimension to correct for angulation variation of the radiographs. Additionally, no formal prosthodontic aftercare, such as occlusal analysis, was performed for this group of patients, and this could also be a factor in avoiding prosthetic complications (Romeo et al. 2009).

The fact that this report is based on patients that were treated in a private practice setting could be seen as an advantage, since the results may better reflect everyday clinical situations. As mentioned by Derks et al. (2015), many publications have been using “convenience samples” (Tomasi and Derks 2012), with all patients receiving treatment in specialist or university settings. They reflected on the need for studies to include “randomly and appropriately sized patient groups treated by different categories of clinicians” (Derks et al. 2015). Although in this study all patients received their implant surgeries in one private periodontal practice, further prosthetic treatment was undertaken by 9 restorative dentists, three out of those being prosthodontists. This indicates that a variety of prosthetic approaches were used, depending on the personal preferences of each clinician.

Results of the multilevel statistical analysis highlighted the significant role of patient-level differences in influencing MBLc. Although age appeared to be a key factor, the lack of statistical significance across other predictors may reflect the limited sample size or insufficient variability within these factors. The findings emphasize the need for larger, more diverse datasets and the exploration of additional predictors, such as systemic health conditions or implant-specific factors, to better understand the determinants of cumulative bone loss.

Future research on the successful application of FPDPCs should focus on well-designed Randomized Controlled Clinical studies with adequate sample size and long-term follow-up and evaluation of results for time frames exceeding 10 years of functional loading. Patient-reported outcome measures (PROM's) should also be included in order to shape our clinical decision-making for the future. Finally, variables pertaining to the type and shape of the implants used, as well as the type of retention, would also be helpful to be investigated in future research in order to have a better understanding of the optimal technique and materials when choosing this type of treatment.

Within the limitations of this retrospective clinical study and the relatively small sample size, the following conclusions can be drawn:

1. The use of FPDPC's seems to be a viable option if extensive bone regeneration procedures are to be avoided, with long-lasting results ranging up to 21 years of function. No implants were lost during a mean follow-up period of 13.3 years, for 100% Implant Survival and 91.5% Implant Success.
2. Mean marginal bone level change (MBLc) of 0.99 mm was observed after a mean of 13.3 years of function.
3. Major prosthetic complications were scarce, leading to a Prosthetic Survival Rate of 86% of the prostheses and Success Rate of 81%. Complications that occurred could have been avoided with careful construction of the prostheses (adequate connector dimensions to support the cantilever tooth) and proper prosthetic follow-up of the patients, including the use of protective mouthguards in bruxers.
4. Position of the implants (closer or farther from the cantilever tooth) had no effect on MBLc.
5. Length of the cantilever tooth had no effect on MBLc

Author Contributions

Alexios Bakopoulos: conceptualization, investigation, writing – original draft, formal analysis, methodology. **Haralampos Petridis:** writing – review and editing, formal analysis, supervision, conceptualization. **Konstantinos Michalakis:** conceptualization, supervision, writing – review and editing. **Lazaros Tsalikis:** supervision, writing – review and editing. **Ioannis Vouros:** conceptualization, investigation, writing – review and editing, supervision, project administration, methodology, validation, formal analysis.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

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