Retrospective clinical evaluation of 2- to 6-unit implant-supported fixed partial dentures: Mean follow-up of 9 years

Bruno R. Chrcanovic DDS, MSc, PhD  |  Jenö Kisch DDS, OD Dr h.c.  |  Christel Larsson DDS, PhD

Abstract

**Background:** Implant-supported fixed partial dentures (ISFPDs) are one of the most common options to rehabilitate partially edentulous patients.

**Purpose:** To assess the clinical outcomes of ISFPDs.

**Methods:** This retrospective study included all patients treated with ISFPDs with 2 to 6 prosthetic units at one specialist clinic. Implant/prosthesis failure and technical complications were the outcomes analyzed.

**Results:** Six hundred and forty-two patients with 876 ISFPDs (2241 implants) were included, followed up for 108.0 ± 76.2 months. Eighty-eight prostheses and 112 implants (26 before, 86 after prosthesis installation) failed. The estimated CSR of ISFPDs at 30 years was 72.7%. Smokers presented lower implant survival than non-smokers. Two hundred and ninety-nine ISFPDs (33.2%) presented technical complications. Bruxism was a factor to exert a higher risk of screw and implant fracture, and ceramic chipping. ISFPDs with cantilever presented higher risk of failure, and screw loosening/fracture. Prostheses supported by implants with internal abutment connection or with two pontics had higher risk of presenting ceramic chipping. Extension of the prosthesis did not seem to exert influence on prosthesis failure/complications.

**Conclusions:** ISFPDs presented good long-term prognosis. Implant failure was the main reason for ISFPD failure. The results suggest that bruxism and the presence of cantilever may contribute to the increased rate of mechanical complications and prosthesis failure.

**KEYWORDS**
dental implant, fixed partial denture, implant-supported, survival, technical complications

1  |  INTRODUCTION

The prosthetic rehabilitation of a partially edentulous patient can be established by using a wide range of treatment options. Implant-supported fixed partial denture (ISFPD) is one of these options, having the advantage of preserving intact teeth or reconstructions adjacent to the edentulous space, enabling avoidance of removable prostheses, or rendering the treatment both more elegant and versatile as well as...
more predictable. A review on of the survival and complication rates of implant-supported fixed dental prostheses concluded that these kinds of prostheses are a safe and predictable treatment method with high survival rates, but also observed that technical complications were frequent.

Traditionally, these prostheses were manufactured with a cast-gold alloy framework covered by acrylic resin teeth. Later, milled titanium frameworks were suggested as an alternative to conventional castings in implant dentistry, as these prostheses could provide a better fit to the implants than conventional castings. When it comes to the acrylic occlusal surfaces, these show complications such as wear and tooth fracture clinically. Porcelain was then proposed as an alternative material for artificial teeth, usually presenting greater wear resistance and more favorable esthetic results than acrylic resin, although presenting chipping as a common clinical complication. Ceramic-veneered zirconia frameworks have been introduced more recently, showing high biocompatibility, low bacterial surface adhesion, high flexural strength, toughness, and esthetic properties. However, as with porcelain, chipping of the veneering material was the most frequently reported complication. In order to minimize these complications, monolithic framework materials were developed and introduced, but the long-term outcome of these restorations remains unknown, due to the lack of sufficient clinical studies.

When it comes to dental implants, these were in the early years mainly manufactured with a turned (machined) surface or with an extremely highly roughened surface. The adoption of a moderately rough surface improved the survival rates. The implant abutment connection was another part of the implants that had modifications over time. The external hexagon abutment connection was originally used on the Brånemark implant, but presented some drawbacks. It has been suggested that the connection might allow micromovements under high occlusal loads, resulting in abutment screw loosening or even fatigue fracture. Implants with internal connection were then developed, with a more stable connection permitting a more even stress distribution throughout the body of the implant.

Despite the high survival rate in many studies, implant-supported prostheses are not without problems, and their longevity is limited not only by biologic complications but also by prosthetic maintenance requirements, the restoration material, and the implants used. Therefore, it should be of interest to investigate the outcome of this prosthetic option in routine practice. In this context, the present retrospective study aimed to assess the clinical outcomes of fixed partial dentures supported by dental implants.

## 2 MATERIALS AND METHODS

### 2.1 Materials

This retrospective study included patients treated with dental implants during the period 1980-2018 at one specialist clinic (Clinic for Prosthodontics, Centre of Dental Specialist Care, Malmö, Sweden). This study was based on data collection from patients’ dental records, and the patients were not recalled for further examination. The implants were placed by specialist dentists in oral surgery, and dentists performing the prosthetic treatment were specialists in prosthodontics. The study was approved by the regional Ethical Committee, Lund, Sweden (Dnr 2014/598; Dnr 2015/72).

### 2.2 Definitions

An implant was considered a failure if presenting signs and symptoms that led to implant removal, that is, a lost implant (due to initial failure to osseointegrate, late loss of osseointegration or fracture of the implant). A prosthetic unit was defined as the replacement of one prosthetic tooth in the prosthesis. For example, an ISFPD replacing teeth in the positions 35-36-37 has three prosthetic units.

For this study, the authors followed the definition of bruxism proposed by Lobbezoo et al.: "Bruxism is a repetitive jaw-muscle activity characterized by clenching or grinding of the teeth and/or by bracing or thrusting of the mandible. Bruxism has two distinct circadian manifestations: it can occur during sleep (indicated as sleep bruxism) or during wakefulness (indicated as awake bruxism)." The sign and symptoms of bruxism were listed according to the International Classification of Sleep Disorders, following the same guidelines used in a recent study (the patients suspected to be bruxers, as diagnosed in the records, were recalled in this previous study in order to be clinically reassessed. Part of these patients—the ones with the type of prosthesis being evaluated here—is included in the present observational study). A diagnostic grading system of "possible," "probable," and "definite" sleep or awake bruxism was used, as suggested for clinical and research purposes.

According to an international consensus, "possible" sleep or awake bruxism should be based on self-report, by means of questionnaires and/or the anamnestic part of a clinical examination. "Probable" sleep or awake bruxism should be based on self-report plus the inspection part of a clinical examination. "Definite" sleep bruxism should be based on self-report, a clinical examination, and a polysomnographic recording, preferably along with audio/video recordings. As electrophysiology and/or polysomnography were not used, the patients of the present study would only fall into the category "probable." Thus, a patient was considered as presenting bruxism based on self-report of clenching/grinding during sleep or during wakefulness, plus the inspection part of a clinical examination. Patients smoking a minimum of one cigarette per day were classified as smokers. Patients who stopped smoking before implant placement, and remained nonsmoking until the patient's last follow-up were classified as former smokers. Any condition or situation that led to the removal and/or replacement of the fixed partial denture was considered as a prosthetic failure.

Technical complications could have happened to the prosthesis or to the implant were the following:

- Complications regarding the prosthesis: loss/fracture of superstructure acrylic teeth or ceramic veneer; fracture of the
prosthesis framework (i.e., prosthesis with complete transversal buccal-lingual fracture); Implant access hole sealing lost/fractured; mobility of the prosthesis, prosthesis completely loose due to complete unscrew of all prosthetic screws (prosthesis uncoupled);
- Complications regarding the implant: failure; fracture of the implant itself; loosening, loss or fracture of connecting/abutment screws; loosening, excessive wear, deformation or fracture of prosthetic abutment.

After completion of the prosthetic treatment, the patients were periodically followed up by a dental hygienist at the clinic for a professional dental hygiene program, with attendance frequency to the professional hygiene recall program based on individual needs.

### 2.3 Inclusion and exclusion criteria

Only ISFPDs with 2 to 6 prosthetic units and supported by modern threaded cylindrical- or conical-design implants were included. The patients needed to have at least 6 months of follow-up after installation of the prosthesis.

### 2.4 Data collection

The data were directly entered into a SPSS file (SPSS software, version 25, SPSS Inc., Chicago, Illinois) as the dental records of the patients were being read, and it consisted of several implant-, site-, and patient-related factors.

### 2.5 Statistical analyses

The mean, SD, and percentage were calculated for several variables. The test performed were the following: Kolmogorov-Smirnov (to evaluate the normal distribution), Levene's test (to evaluate homoscedasticity), Student's t-test or Mann-Whitney (for two independent groups, continuous variables), Pearson's chi-squared or Fisher's exact test (for categorical variables).

Comparisons of prosthesis survival between some factors were done using the log-rank test. Univariate and multivariate Cox regression was used to evaluate the associations between clinical covariates and prosthesis failure, as well as between clinical covariates and three of the most prevalent technical complications, namely screw

### TABLE 1

Comparison of the prevalence of bruxers, smokers, and follow-up time between the different factors. The statistical unit is the prosthesis, not the patient

| Group | Prosthetic units | Number of prostheses (%) | Number of failed prostheses (n) | Bruxer (%) | Smoker (%) | Follow-up (months) mean ± SD (min-max) |
|-------|------------------|---------------------------|---------------------------------|------------|------------|--------------------------------------|
| 2     | Prosthetic units | 278 (31.7)                | 16                              | 33/230 (14.3) | 63/229 (27.5) | 83.9 ± 57.8 (6.6-315.0) |
| 3     | Prosthetic units | 337 (38.5)                | 27                              | 28/262 (10.7) | 77/256 (30.1) | 119.0 ± 82.6 (6.3-356.6) |
| 4     | Prosthetic units | 163 (18.6)                | 31                              | 9/121 (7.4)  | 40/114 (35.1) | 118.4 ± 78.4 (7.5-362.5) |
| 5     | Prosthetic units | 66 (7.5)                  | 8                               | 7/53 (13.2)  | 14/51 (27.5) | 127.2 ± 86.1 (9.0-370.4) |
| 6     | Prosthetic units | 32 (3.7)                  | 6                               | 2/23 (8.7)   | 4/21 (19.0)  | 105.4 ± 67.1 (14.3-253.7) |

| Material | Gold/acrylic | 145 (16.6) | 29 | 10/95 (10.5) | 20/91 (22.0) | 163.0 ± 90.2 (6.3-370.4) |
|          | CoCr/acrylic | 9 (1.0)    | 0  | 0/9 (0)      | 1/9 (11.1)   | 82.3 ± 55.8 (14.2-160.7) |
|          | Gold/porcelain | 342 (39.0) | 35 | 30/246 (12.2) | 83/238 (34.9) | 124.2 ± 79.1 (6.6-315.0) |
|          | CoCr/porcelain | 332 (37.9) | 20 | 33/293 (11.3) | 81/289 (28.0) | 75.9 ± 45.6 (7.5-253.2) |
|          | Titan/porcelain | 36 (4.1) | 4  | 6/35 (17.1)  | 9/32 (28.1)  | 49.0 ± 27.6 (8.1-109.7) |
|          | Zirconia/porcelain | 12 (1.4) | 0  | 0/11 (0)     | 4/12 (33.3)  | 61.0 ± 22.1 (35.0-100.5) |

| Jaw | Maxilla | 493 (56.3) | 54 | 40/384 (89.6) | 127/373 (34.0) | 103.1 ± 72.3 (6.3-370.4) |
|     | Mandible | 383 (43.7) | 34 | 39/305 (12.8) | 71/298 (23.8) | 114.3 ± 80.6 (6.8-357.4) |

| Sex | Male | 404 (46.1) | 39 | 41/314 (13.1) | 92/307 (30.0) | 103.0 ± 75.3 (6.6-357.4) |
|     | Female | 472 (53.9) | 49 | 38/375 (10.1) | 106/364 (29.1) | 112.2 ± 76.8 (6.3-370.4) |

| Bruxism a | No | 610 (88.5) | 56 | - | 162/580 (27.9) | 115.5 ± 79.9 (6.3-370.4) |
|           | Yes | 79 (11.5) | 15 | - | 23/70 (32.9)  | 104.8 ± 70.7 (8.6-280.6) |

aCases with available information are considered.

b Former smokers were also considered as “smokers.”
loosening, screw fracture, and ceramic chipping/fracture. Hazard ratio (HR) and 95% confidence intervals (95% CI) were estimated from Cox proportional hazard models. In order to verify multicollinearity, a correlation matrix of all of the predictor variables with a significant odds ratio (P value cut-off point of 0.1) identified in the univariate models was scanned, to see whether there were some high correlations among the predictors. Collinearity statistics obtaining variance inflation factor (VIF) and tolerance statistic were also performed to detect more subtle forms of multicollinearity.

For final multivariable Cox regression models, all variables that were moderately associated (P < .10) with prosthesis failure were included. For this prognosis-level analysis, clustering of multiple prostheses within each patient was accounted for in the Cox models using the methods outlined by Lee et al.16 and Lin.17 Data were statistically analyzed using the SPSS version 25 software (SPSS Inc., Chicago, Illinois). Cox models were performed using the Stata software version 15 (StataCorp LLC, College Station, Texas). The command mestreg was used for the Cox models evaluating some technical complications, in order to take into account repeated events. The degree of statistical significance was considered P < .05.

This observational study followed the STROBE guidelines.

3 | RESULTS

A number of 738 patients were initially planned to receive 1035 ISFPDs in the clinic. A total of 159 prostheses installed in 127 patients were excluded from the study. Thirty-one of these patients had other prostheses that were included in the study. Thus, 96 out of these 127 patients were excluded. These were the reasons for exclusion:

- 72 ISFPDs were connected to at least one tooth;
- 48 prostheses were placed in patients with a very short follow-up (<6 months);
- 10 patients received implants and were planned to receive 12 ISFPDs prostheses, but received the restorations in other clinics;
- 11 patients were planned to receive 13 ISFPDs prostheses, but received other type of prosthetic restoration instead (of which for 10 cases the choice was for single-crowns);
- 5 patients that received 7 prostheses had one or more implants lost within 6 months after prosthesis installation;
- 5 patients planned to receive 6 prostheses, but had one or more implants lost before prosthesis could have been installed;
- 1 patient died a few months after the installation of the prosthesis.

Thus, a number of 642 patients (289 men, 353 women) rehabilitated with 876 ISFPDs (404 in men, 472 in women) were included. Four hundred and fifty-eight patients had one ISFPD, while 144 patients had 2, 30 patients had 3, and 10 patients had 4 ISFPDs.

The patients had a mean ± SD of 57.8 ± 17.0 years of age (min-max, 14.5-90.9, median 61.7) at the time of prosthesis installation. The patients were followed-up for a mean ± SD of 108.0 ± 76.2 months (min-max, 6.34-370.4, median 89.6) from the installation of the prostheses. Information about smoking habits was available for patients with 671 prostheses, of which 161 prostheses were installed in smokers, 37 in former smokers, and 473 in nonsmokers. Smokers smoked a mean ± SD of 12.0 ± 8.2 (min-max, 1-40, median 10) cigarettes/day. Information about bruxism (patients presenting bruxism or not) was available for patients with 689 prostheses. Of these, 79 prostheses were installed in bruxers and 610 in nonbruxers. The use of night guard was registered for bruxers patients with 48 prostheses.

Table 1 shows a comparison between the different groups of the prevalence of bruxers, smokers, failure rate (for implants and prostheses), time to prosthesis failure, and follow-up time. Most of the prosthesis were manufactured of gold and porcelain (39.0%; n = 342), followed by cobalt-chromium (CoCr) and porcelain (37.9%; n = 332), and gold and acrylic (16.6%; n = 145). There were not so

![Figure 1](image-url)
many titan-porcelain prostheses (4.1%; \(n = 36\)) nor zirconia-porcelain (1.4%; \(n = 12\)) or CoCr-acrylic (1.0%; \(n = 9\)). Most of the prosthesis had 3 (38.5%; \(n = 337\)) or 2 prosthetic units (31.7%; \(n = 278\)). A number of 207 ISFPDs had (noncantilevered) pontics (175 prostheses had 1 pontic, 29 had 2 pontics, and 3 had 3 pontics) and 254 ISFPDs had cantilever (227 prostheses had 1 cantilever and 27 had 2 cantilevers).

There was available information about the opposing jaw status for 89.8% of the cases (\(n = 787\)). Most of opposing jaws were consisted of natural dentition with/without fixed partial prosthesis or of implant-supported full-arch prosthesis (92.8%; \(n = 730\)), followed by partially dentate arches with/without removable partial denture (5.3%; \(n = 42\)), and by rehabilitation by removable complete denture or overdenture (1.9%; \(n = 145\)).

A number of 39 implants were lost before the installation of the prosthesis and were not replaced. The cases comprising these 39 nonreplaced lost implants were excluded from the study for two reasons: either the patients lost all implants planned to support the ISFPD or only one implant remained, eventually supporting a single crown.

From the total of 2241 implants installed (already excluding the cases of these 39 implants mentioned above), 26 were lost before the installation of the prosthesis, a mean ± SD of 5.8 ± 2.3 months (min-max, 1.7-11.6) after implant installation, of which 20 implants were

### Table 2

Life-table survival analysis showing the cumulative survival rate of implant-supported fixed partial dentures

| Interval start time (years) | Number entering interval | Number withdrawing during interval | Number exposed to risk | Prosthesis failures | Survival rate within each interval—ISR (%) | Cumulative proportion surviving at end of interval—CSR (%) | SE (%) |
|-----------------------------|--------------------------|-----------------------------------|------------------------|---------------------|--------------------------------------------|-----------------------------------------------------------|--------|
| 0                           | 876                      | 15                                | 868.5                  | 6                   | 99.3                                       | 99.3                                                      | 0.3    |
| 1                           | 855                      | 53                                | 828.5                  | 12                  | 98.6                                       | 97.9                                                      | 0.5    |
| 2                           | 790                      | 52                                | 764                    | 4                   | 99.5                                       | 97.4                                                      | 0.6    |
| 3                           | 734                      | 69                                | 699.5                  | 5                   | 99.3                                       | 96.7                                                      | 0.6    |
| 4                           | 660                      | 57                                | 631.5                  | 9                   | 98.6                                       | 95.3                                                      | 0.8    |
| 5                           | 594                      | 70                                | 559                    | 7                   | 98.7                                       | 94.1                                                      | 0.9    |
| 6                           | 517                      | 44                                | 495                    | 3                   | 99.4                                       | 93.5                                                      | 0.9    |
| 7                           | 470                      | 54                                | 443                    | 6                   | 98.6                                       | 92.3                                                      | 1.1    |
| 8                           | 410                      | 37                                | 391.5                  | 7                   | 98.2                                       | 90.6                                                      | 1.2    |
| 9                           | 366                      | 39                                | 346.5                  | 5                   | 98.6                                       | 89.3                                                      | 1.3    |
| 10                          | 322                      | 44                                | 300                    | 2                   | 99.3                                       | 88.7                                                      | 1.4    |
| 11                          | 276                      | 31                                | 260.5                  | 4                   | 98.5                                       | 87.3                                                      | 1.5    |
| 12                          | 241                      | 34                                | 224                    | 1                   | 99.6                                       | 87.0                                                      | 1.6    |
| 13                          | 206                      | 25                                | 193.5                  | 2                   | 99.0                                       | 86.1                                                      | 1.7    |
| 14                          | 179                      | 30                                | 164                    | 6                   | 96.3                                       | 82.9                                                      | 2.0    |
| 15                          | 143                      | 13                                | 136.5                  | 4                   | 97.1                                       | 80.5                                                      | 2.3    |
| 16                          | 126                      | 16                                | 118                    | 1                   | 99.2                                       | 79.8                                                      | 2.4    |
| 17                          | 109                      | 12                                | 103                    | 1                   | 99.0                                       | 79.0                                                      | 2.5    |
| 18                          | 96                       | 23                                | 84.5                   | 1                   | 98.8                                       | 78.1                                                      | 2.6    |
| 19                          | 72                       | 7                                 | 68.5                   | 0                   | 100                                        | 78.1                                                      | 2.6    |
| 20                          | 65                       | 13                                | 58.5                   | 0                   | 100                                        | 78.1                                                      | 2.6    |
| 21                          | 52                       | 6                                 | 49                     | 0                   | 100                                        | 78.1                                                      | 2.6    |
| 22                          | 46                       | 8                                 | 42                     | 0                   | 100                                        | 78.1                                                      | 2.6    |
| 23                          | 38                       | 9                                 | 33.5                   | 1                   | 97.0                                       | 75.8                                                      | 3.4    |
| 24                          | 28                       | 7                                 | 24.5                   | 1                   | 95.9                                       | 72.7                                                      | 4.5    |
| 25                          | 20                       | 8                                 | 16                     | 0                   | 100                                        | 72.7                                                      | 4.5    |
| 26                          | 12                       | 3                                 | 10.5                   | 0                   | 100                                        | 72.7                                                      | 4.5    |
| 27                          | 9                        | 2                                 | 8                      | 0                   | 100                                        | 72.7                                                      | 4.5    |
| 28                          | 7                        | 3                                 | 5.5                    | 0                   | 100                                        | 72.7                                                      | 4.5    |
| 29                          | 4                        | 2                                 | 3                      | 0                   | 100                                        | 72.7                                                      | 4.5    |
| 30                          | 2                        | 2                                 | 1                      | 0                   | 100                                        | 72.7                                                      | 4.5    |

Abbreviations: CSR, cumulative survival rate; ISR, interval survival rate.
not replaced. These 26 lost implants were excluded from the study since none of them ever played the role as the support to any prosthesis. However, all the patients who lost these implants eventually received one or more ISFPDs, in situations which either the number of prosthetic units of the prosthesis was kept constant (due to replacement of 6 of these 26 lost implants: 1 implant in 4 patients, 2 implants in 1 patient) or the prosthesis was re-planned with a smaller number of prosthetic units (the patients that lost the non-replaced 20 implants). Thus, a total of 2215 implants were used to support prostheses.

Most prostheses were supported by 2 (53.2%, n = 466) or 3 implants (38.1%; n = 335). The rest of the prostheses were supported by 4 (7.1%; n = 61), 1 (1.0%; n = 9) or 5 implants (0.6%; n = 5). Nobel implants (Nobel Biocare AB, Göteborg, Sweden) totaled 1889 implants, of which 1063 turned (machined) Brånemark implants, 799 Nobel MK III TiUnite, 24 Nobel Active TiUnite, and 3 Nobel Replace TiUnite implants. The other implants included

**FIGURE 2** Kaplan-Meier estimated cumulative survival (ECS) curve for implant-supported fixed partial dentures

| TABLE 3 Prevalence of complications, according to prosthesis material, jaw, sex, and bruxism. The statistical unit is the implant-supported fixed partial denture, not the patient neither the implant |
|-----------------------------------------------|
| **Group**                  | **Fractured acrylic teeth (%)** | **Fractured ceramic (%)** | **Prosthesis mobile (%)** | **Prosthesis fracture d (%)** | **Prosthesis completely loose (%)** |
|-----------------------------|---------------------------------|---------------------------|---------------------------|-------------------------------|-----------------------------------|
| Prosthetic units            |                                 |                           |                           |                               |                                   |
| 2                           | 0/8 (0) (0/0)                   | 16/270 (5.9) (23/26)      | 22/278 (7.9) (44)         | 0/278 (0) (0)                 | 2/278 (0.7) (2)                   |
| 3                           | 9/70 (12.9) (15/20)            | 28/267 (10.5) (42/48)     | 54337 (16.0) (95)         | 0/337 (0) (0)                 | 6/337 (1.8) (6)                   |
| 4                           | 6/41 (14.6) (11/16)            | 9/122 (7.4) (10/15)       | 23/163 (14.1) (38)        | 1/163 (0.6) (1)               | 1/163 (0.6) (1)                   |
| 5                           | 6/21 (28.6) (10/12)            | 5/45 (11.1) (14/19)       | 11/66 (16.7) (21)         | 0/66 (0) (0)                  | 0/66 (0) (0)                      |
| 6                           | 4/14 (28.6) (9/12)             | 2/18 (11.1) (8/9)         | 8/32 (25.0) (16)          | 1/32 (3.1) (1)                | 2/32 (6.2) (3)                    |
| Material                    |                                 |                           |                           |                               |                                   |
| Gold/acrylic                | 24/145 (16.6) (44/57)          | -                         | 29/145 (20.0) (51)        | 0/145 (0) (0)                 | 3/145 (2.1) (3)                   |
| CoCr/acrylic                | 1/9 (11.1) (1/3)               | -                         | 0/9 (0) (0)               | 0/9 (0) (0)                   | 0/9 (0) (0)                       |
| Gold/porcelain              | 28/342 (8.2) (47/61)           | 57/342 (16.7) (104)       | 2/342 (0.6) (2)           | 4/342 (1.2) (5)               |                                   |
| CoCr/porcelain              | 27/332 (8.1) (41/46)           | 27/332 (8.1) (52)         | 0/332 (0) (0)             | 3/332 (0.9) (3)               |                                   |
| Titan/porcelain             | 3/6 (8.3) (7/8)                | 5/6 (13.9) (7)            | 0/6 (0) (0)               | 0/6 (0) (0)                   |                                   |
| Zirconia/porcelain          | 2/12 (16.7) (2/3)              | 0/12 (0) (0)              | 0/12 (0) (0)              | 1/12 (8.3) (1)                |                                   |
| Jaw                         |                                 |                           |                           |                               |                                   |
| Maxilla                     | 12/76 (15.8) (25/34)           | 33/417 (7.9) (57/69)      | 73/493 (14.8) (136)       | 1/493 (0.2) (1)               | 8/493 (1.6) (9)                   |
| Mandible                    | 13/78 (16.7) (20/26)           | 27/305 (8.9) (40/49)      | 45/383 (11.7) (78)        | 1/383 (0.3) (1)               | 3/383 (0.8) (3)                   |
| Sex                         |                                 |                           |                           |                               |                                   |
| Male                        | 13/69 (18.8) (22/32)           | 24/335 (7.2) (37/47)      | 53/404 (13.1) (110)       | 1/404 (0.2) (1)               | 8/404 (2.0) (9)                   |
| Female                      | 12/85 (14.1) (23/28)           | 36/387 (9.3) (60/71)      | 65/472 (13.8) (104)       | 1/472 (0.2) (1)               | 3/472 (0.6) (3)                   |
| Bruxism*                    |                                 |                           |                           |                               |                                   |
| No                          | 15/94 (16.0) (25/34)           | 38/516 (7.4) (58/66)      | 76/610 (12.5) (132)       | 1/610 (0.2) (1)               | 9/610 (1.5) (9)                   |
| Yes                         | 3/10 (30.0) (9/13)             | 13/69 (18.8) (28/39)      | 17/79 (21.5) (32)         | 1/79 (1.3) (1)                | 1/79 (1.3) (1)                    |

*At least one occurrence—the same prosthesis may have had more than one event throughout the follow-up.

n/n–total number of events/total number of prosthetic teeth fractured.

n–total number of events.

Prosthesis with complete transversal buccal-lingual fracture, which includes fracture of the prosthesis framework.

*Cases with available information are considered.

Prosthesis uncoupled, due to complete unscrew of all prosthetic screws.
A total of 86 implants failed (out of 2215; 3.9%) after installation of the prostheses in 57 patients (35 patients lost 1 implant each, 16 patients lost 2 implants, 5 lost 3 implants, and 1 patient lost 4 implants), after a mean ± SD of 98.9 ± 67.4 months (min-max, 9.6-310, median 93.0) after implant installation. Ten of these failures were due to implant fracture (out of 86 failures after prosthesis installation; 11.6%). There was no statistically significant difference in the prevalence of failed implants between bruxers and nonbruxers (11/193 vs 62/1542; 5.7% vs 4.0%; P = .279, log-rank test) (Table 1), but bruxers presented statistically significant higher prevalence of fractured implants than in nonbruxers (7/193 vs 3/1542; 3.6% vs 0.2%; P < .001, log-rank test). Smokers and former smokers had a statistically significant higher prevalence of failed implants than non-smokers (32/495 vs 37/1147; 6.5% vs 3.9%; P = .002, log-rank test). A number of 52 lost implants had turned surface (out of 1063; 4.9%) and 34 moderately rough surface (out of 1150; 3.0%; P = .131, log-rank test).

Eighty-eight prostheses failed (10.0%), with no significant differences in failure rate between those installed in maxillae and in mandibles (P = .147, log-rank test), but with statistically significant higher failure rate in bruxers in comparison to nonbruxers (P = .004, log-rank test) (Table 1). Moreover, there was no statistically significant difference in the occurrence of failure between prostheses supported by implants with external and internal abutment connection (78/731 and 10/145, respectively; P = .997, log-rank test). The failures happened after a mean ± SD of 89.5 ± 66.3 months (min-max, 6.3-297, median 77.4) after prosthesis installation. In most of the cases the reason for prosthesis failure was failure of one or more supporting implants, due to loss of osseointegration or implant fracture (48.9% of the failures; n = 43). The second most common reason was change of prosthetic type, or increase of the prosthesis extension to more than 6 prosthetic units, due to the placement of new implants (37.5%; n = 33), followed by prosthetic fracture (4.5%; n = 4), frequent fracture of screws (3.4%; n = 3), and replacement by a newer prosthesis due to esthetic reasons, increase of the vertical dimension of occlusion, change of prosthesis extension, frequent decementation, and removal of osseous graft compromising the supporting implants (1.1% each; 1 case each) (Figure 1). The mean age of the patients (at the time of prosthesis installation) with prostheses that failed (mean ± SD 57.1 ± 13.3 years, min-max 16.2-77.0) was similar to the mean age patients with no failure (mean ± SD 57.9 ± 17.4 years, min-max 14.5-90.9; P = 0.097, Mann-Whitney test).

Most of the failed prostheses were replaced by another ISFPD (55.7%; n = 49). For the other cases of failure, the ISFPDs were replaced by a full-arch prosthesis after the installation of additional implants (14.8%; n = 13), by a single crown (10.2%; n = 9), by a partial removable denture (8.0%; n = 7), by an overdenture (2.3%; n = 2), by a denture or a combined tooth-implant-supported fixed dental prosthesis (1.1%, n = 1 each). No prosthetic replacement was done in 6 cases (6.8%). Life-table survival analysis at the prosthesis level is shown in Table 2. The estimated cumulative survival rate (CSR) after 30 years was 72.7% (Figure 2).

A number of 291 ISFPDs (33.2%) presented technical complications, of which 44 (5.0%) presented only occurrences of loss or fracture of implant access hole sealings. Tables 3 and 4 show the prevalence of complications, according to number of prosthetic units, prosthesis material, jaw, sex and bruxism. According to the Cox regression models, screw loosening presented a statistically significant higher risk to happen in ISFPDs with one or two cantilevers in comparison to prostheses with no cantilever, and when the prostheses were supported by turned/machined implants in comparison to prostheses supported by moderately rough implants (Tables S1 and S2, see supplementary appendix). The risk for the occurrence of screw fracture (Tables S3 and S4) was higher in bruxers in comparison to nonbruxers, and in ISFPDs with one cantilever in comparison to prostheses with two cantilevers or none. The risk for the occurrence of ceramic chipping/fracture (Tables S5 and S6) was higher in bruxers than in nonbruxers, in ISFPDs with two pontics in comparison to one pontic or none, and in prostheses supported by implants with internal abutment connection in comparison to prostheses supported by implants with external abutment connection. Patients had a mean ± SD of 2.1 ± 1.8 (min-max, 1-14, median 1) dental visits for management of technical complications. Bruxers had a higher mean number of visits (2.6 ± 2.5; min-max, 1-14) than nonbruxers (2.0 ± 1.7; min-max, 1-12; P = .111, Mann-Whitney test) for the management of complications.

Table 5 shows a comparison between failed and nonfailed ISFPDs according to different factors, and the results of the univariate Cox proportional hazard models. Bruxism, ISFPDs opposed to natural dentition/fixed prosthesis (status of the opposing jaw), and the presence of cantilever were the factors that continued to present a statistically significant HR in the multivariate Cox regression model (Table 6).

4 DISCUSSION

The use of implant therapy in special populations requires consideration of potential benefits to be gained from the therapy. To better appreciate this potential, the present study aimed to assess the clinical outcome of ISFPDs. We present an analysis of 876 ISFPDs, of which 88 failed, with a mean follow-up of 9 years. Some clinicians might be tempted to calculate the general "failure rate" of the study. However, this would not be appropriate, as this outcome was observed over time and not all participants were observed for the same time therefore censoring has occurred. Therefore, all statistics should include time to event methods, namely, the methods of survival analysis.

The results of the life table analysis should be interpreted with caution. The estimated cumulative survival rate (CSR) was relatively high (72.7%) considering the period of 30 years. However, there was...
no change in the CSR from years 19 to 22, nor from the year 25, as there were no recorded failures. Numbers entering the interval are low and the censored numbers are proportionally high, reducing the confidence of the outcomes.\(^{18}\) The most recent observations are the least reliable because of the decreasing number of patients at risk for the event of interest.\(^{19}\)

Many patients had lost implants before the installation of the prostheses, resulting in either replacement of the lost implants not affecting the initial plan of rehabilitation with ISFPDs, change of the prosthetic rehabilitation plan to single crowns, or in no further treatment. This calls attention to the fact that early failure may affect a considerable rate of implants,\(^{20}\) regardless of the follow-up time,\(^{21}\) and may change considerably the rehabilitation plan. Not only early failures affected the treatment at an early stage of the rehabilitation, but also after the prostheses were installed. The failure of many supporting implants was by far the main reason for prosthesis failure.

Bruxism was a factor that exerted a significant influence not only on the failure of the prostheses, but also on the prevalence of technical complications. Bruxism has been shown to significantly affect the implant failure\(^{14,22,23}\) and implant fracture rates negatively,\(^{24}\) as well as an increase prevalence of technical complications in implant-supported restorations in comparison to patients not presenting bruxism.\(^{14}\) The condition is suggested to generate overload of prosthetic rehabilitations on implants, which could possibly cause implant fracture or peri-implant marginal bone loss (MBL), ultimately resulting in implant failure.\(^{22,25}\) Other studies suggested that bruxism may be a risk factor for fractures of ceramics\(^{26}\) and, in general, for the need for technical interventions on implant-supported restorations.\(^{27-29}\)

Loss of implants was also observed to have a higher prevalence in smokers/former smokers than in nonsmokers. Smoking is a factor that has the potential to negatively affect healing and the outcome of implant treatment.\(^{30}\) Smoking was, however, not a significant factor to directly affect the failure of prostheses, according to the Cox regression model.

Prostheses opposed to either natural dentition or fixed prosthesis presented a higher failure rate than prostheses opposed to removable complete dentures or overdentures, or to partially dentate jaws with or without removable partial denture. It is believed that intraoral force

| TABLE 4 Prevalence of complications, according to prosthesis material, jaw, sex, and bruxism. The statistical unit is the implant, not the patient neither the implant-supported fixed partial denture |
|---|---|---|---|---|---|---|---|
| Group | Number of prosthesis (%) | Number of implants (%) | Screw loose\(^a\) (n)\(^b\) | Screw fracture\(^a\) (n)\(^b\) | Screw lost\(^a\) (n)\(^b\) | Implant hole sealing lost/fractured\(^a\) (n)\(^b\) | Deformation/fracture of prosthetic abutment\(^a\) (n)\(^b\) |
| Prosthetic units | | | | | | | |
| 2 | 278 (31.7) | 549 (24.8) | 53 (19) | 18 (6) | 0 (0) | 21 (14) | 3 (2) |
| 3 | 337 (38.5) | 848 (38.3) | 181 (57) | 27 (15) | 4 (4) | 56 (35) | 3 (2) |
| 4 | 163 (18.6) | 471 (21.3) | 66 (22) | 38 (10) | 0 (0) | 32 (21) | 2 (2) |
| 5 | 66 (7.5) | 226 (10.2) | 56 (10) | 9 (3) | 1 (1) | 8 (8) | 2 (1) |
| 6 | 32 (3.7) | 121 (5.4) | 42 (7) | 17 (3) | 0 (0) | 12 (5) | 0 (0) |
| Material | | | | | | | |
| Gold/acrylic | 145 (16.6) | 410 (18.5) | 107 (29) | 21 (8) | 3 (3) | 41 (27) | 5 (4) |
| CoCr/acrylic | 9 (1.0) | 26 (1.2) | 0 (0) | 0 (0) | 0 (0) | 0 (0) | 0 (0) |
| Gold/porcelain | 342 (39.0) | 903 (40.8) | 208 (55) | 53 (16) | 1 (1) | 59 (35) | 3 (2) |
| CoCr/porcelain | 332 (37.9) | 767 (34.6) | 76 (28) | 25 (10) | 1 (1) | 27 (20) | 0 (0) |
| Titan/porcelain | 36 (4.1) | 83 (3.7) | 7 (3) | 8 (2) | 0 (0) | 2 (1) | 0 (0) |
| Zirconia/porcelain | 12 (1.4) | 26 (1.2) | 0 (0) | 2 (1) | 0 (0) | 0 (0) | 2 (1) |
| Jaw | | | | | | | |
| Maxilla | 493 (56.3) | 1245 (56.2) | 247 (68) | 76 (24) | 2 (2) | 62 (43) | 4 (3) |
| Mandible | 383 (43.7) | 970 (43.8) | 151 (47) | 33 (13) | 3 (3) | 67 (40) | 6 (4) |
| Sex | | | | | | | |
| Male | 404 (46.1) | 1034 (46.7) | 196 (53) | 59 (22) | 3 (3) | 45 (29) | 7 (5) |
| Female | 472 (53.9) | 1181 (53.3) | 202 (62) | 50 (15) | 2 (2) | 84 (54) | 3 (2) |
| Bruxism\(^c\) | | | | | | | |
| No | 610 (88.5) | 1544 (88.9) | 258 (75) | 66 (22) | 5 (5) | 80 (52) | 7 (4) |
| Yes | 79 (11.5) | 193 (11.1) | 45 (14) | 22 (7) | 0 (0) | 20 (10) | 2 (2) |

\(^a\)Total number of occurrences—the same implant may have had more than one event throughout the follow-up.

\(^b\)n—total number of prostheses affected.

\(^c\)Cases with available information are considered.
### TABLE 5  Comparison between failed and nonfailed implant-supported fixed partial dentures according to different factors, and hazard ratio estimated from univariate Cox proportional hazard models

| Factor                | Failed prosthesis (%) | Nonfailed prosthesis (%) | Hazard ratio (95% CI) | P value |
|-----------------------|-----------------------|---------------------------|-----------------------|---------|
| **Sex**               |                       |                           |                       |         |
| Men                   | 39 (9.7)              | 365 (90.3)                | 1                     |         |
| Women                 | 49 (10.4)             | 423 (89.6)                | 1.016 (0.667, 1.548)  | .941    |
| **Age**               |                       |                           |                       |         |
| Increase by 1 year    | -                     | -                         | 1.004 (0.991, 1.018)  | .516    |
| **Jaw**               |                       |                           |                       |         |
| Maxilla               | 54 (11.0)             | 439 (89.0)                | 1                     |         |
| Mandible              | 34 (8.9)              | 349 (91.1)                | 0.728 (0.474, 1.120)  | .148    |
| **Bruxer**            |                       |                           |                       |         |
| No                    | 56 (9.2)              | 554 (90.8)                | 1                     |         |
| Yes                   | 15 (19.0)             | 64 (81.0)                 | 2.270 (1.281, 4.024)  | .005    |
| **Smoker**            |                       |                           |                       |         |
| No                    | 44 (9.3)              | 429 (90.7)                | 1                     |         |
| Yes                   | 24 (12.1)             | 174 (87.9)                | 1.301 (0.791, 2.139)  | .300    |
| **Implant surface**   |                       |                           |                       |         |
| Turned/machined       | 55 (14.4)             | 328 (85.6)                | 1                     |         |
| Moderately rough      | 33 (6.7)              | 460 (93.3)                | 0.867 (0.551, 1.362)  | .535    |
| **Abutment connection** |                   |                           |                       |         |
| External              | 78 (10.7)             | 653 (89.3)                | 1                     |         |
| Internal              | 10 (6.9)              | 135 (93.1)                | 0.999 (0.514, 1.941)  | .997    |
| **Opposing jaw**      |                       |                           |                       |         |
| Denture/overdenture   | 4 (26.7)              | 11 (73.3)                 | 1                     |         |
| Partially dentate w/wt RPD | 3 (7.1)           | 39 (92.9)                 | 0.271 (0.061, 1.211)  | .087    |
| Natural/FPD/ISFCD     | 76 (10.4)             | 654 (89.6)                | 0.448 (0.164, 1.227)  | .118    |
| **Cantilever**        |                       |                           |                       |         |
| No                    | 50 (8.0)              | 572 (92.0)                | 1                     |         |
| 1                     | 31 (13.7)             | 196 (86.3)                | 1.647 (1.052, 2.578)  | .029    |
| 2                     | 7 (25.9)              | 20 (74.1)                 | 3.023 (1.369, 6.677)  | .006    |
| **Pontics**           |                       |                           |                       |         |
| No                    | 56 (8.4)              | 613 (91.6)                | 1                     |         |
| 1                     | 26 (14.9)             | 149 (85.1)                | 1.574 (0.987, 2.509)  | .057    |
| 2                     | 6 (20.7)              | 23 (79.3)                 | 1.971 (0.848, 4.583)  | .115    |
| **Prosthetic units**  |                       |                           |                       |         |
| 2                     | 16 (5.8)              | 262 (94.3)                | 1                     |         |
| 3                     | 27 (8.0)              | 310 (92.0)                | 0.946 (0.507, 1.765)  | .860    |
| 4                     | 31 (19.0)             | 132 (81.0)                | 2.233 (1.216, 4.102)  | .010    |
| 5                     | 8 (12.1)              | 58 (87.9)                 | 1.312 (0.559, 3.083)  | .533    |
| 6                     | 6 (18.8)              | 26 (81.3)                 | 2.467 (0.964, 6.316)  | .060    |
| **Material**          |                       |                           |                       |         |
| Gold/acrylic          | 29 (20.0)             | 116 (80.0)                | 1                     |         |
| Gold/porcelain        | 35 (10.2)             | 307 (89.8)                | 0.678 (0.413, 1.114)  | .125    |
| CoCr/porcelain        | 20 (6.0)              | 312 (94.0)                | 0.713 (0.391, 1.298)  | .268    |

Abbreviations: 95% CI, 95% confidence interval; FPD, fixed partial denture; ISFCD, implant-supported fixed complete denture; RPD, removable partial denture; w, with; wt, without.

*aThe information about bruxism and smoking habits was not available for every patient. That is why the number of failed and nonfailed prostheses does not add up to the total number of prostheses of the study.

*bSmokers and former smokers included.

*cProstheses with three pontics were considered to have not so many cases to be included here (failures/total number of cases, % of failure): 0/3, 0%.

*dProstheses of other materials were considered to have not so many cases to be included here (failures/total number of cases, % of failure): CoCr/acrylic (0/9, 0%), titan/porcelain (4/36, 11.1%), zirconia/porcelain (0/12, 0%).
fracture. A fixed partial denture with two-tooth pontic span will bend substructures flex under heavy or complex loads leading to porcelain on deflection of framework. Moreover, long anterio-posterior metal the pontics. The occluso-gingival thickness of the pontic has an effect of the present study, this may have be related to the dimensions of that the dimensions of the pontics were not measured by the authors the fact that the pontics were not always adjacent to one another and of the ceramic veneer than prostheses with one or no pontic. Despite magnitudes transmitted to prostheses may be higher when opposed to fixed dentition/prosthesis when compared to removable dentures.

ISFPDs with a cantilever prosthetic arm presented a higher risk of prosthesis failure, as well as a higher risk for screw loosening or screw fracture. This is in agreement with some previous studies\(^{31,32}\) that showed a relatively high number of technical or mechanical complications in ISFPDs with cantilever. The incidence of abutment screw problems may be largely attributed to the increased bending moments and rotational forces experienced with the cantilever design.\(^{33}\)

Moreover, ISFPDs with two pontics had a higher risk of chipping of the ceramic veneer than prostheses with one or no pontic. Despite the fact that the pontics were not always adjacent to one another and that the dimensions of the pontics were not measured by the authors of the present study, this may have be related to the dimensions of the pontics. The occluso-gingival thickness of the pontic has an effect on deflection of framework. Moreover, long anterio-posterior metal substructures flex under heavy or complex loads leading to porcelain fracture. A fixed partial denture with two-tooth pontic span will bend eight times as much as a single-tooth pontic fixed partial denture will, if everything else remains unchanged.\(^{34}\)

Ceramic veneer chipping was also more prevalent in prostheses supported by implants with internal abutment connection in comparison to prostheses supported by moderately rough implants. This could be related to the fact that the older turned/ machined implants had external abutment connections and the more recent moderately rough implants had internal abutment connections,\(^{35}\) but this was not confirmed by the statistical model for the present material.

The results of the present study suggest that prosthetic material seems to have no significant impact on survival rates of ISFPDs, in agreement with some reviews on the subject.\(^{4,10,36}\) However, one of the reviews highlighted the considerable heterogeneity of studies with large variation in number of restorations per material group available for analysis, making comparisons difficult.\(^{10}\)

The limitations of the present study include the fact that this is a retrospective study, which inherently results in flaws, manifested by gaps in information and incomplete records. The lack of information on several factors, including biological factors such as oral hygiene status, bleeding on probing, probing pocket depth, and the periodontal status, which may have some influence on the results,\(^{37,38}\) is also related to the retrospective nature of the present study. Moreover, since this was not a prospective study, treatment was not standardized. As a result, the distribution of different materials for the manufacture of the prostheses was not balanced, as it followed the trend of each time period. It can also be observed that several professionals were involved in the treatment of these patients for the long time of observation of the study, and there must have been some variability of surgical and prosthetic approaches and dental laboratory techniques applied by these different professionals. An example would be the dimensioning of the framework, which was not standardized. Another example would be the influence of different surgeons on the implant failure rate.\(^{39,40}\) Furthermore, the diagnosis of bruxism was based on self-report of clenching/grinding during sleep or during wakefulness, plus the inspection part of several clinical examinations during the treatment. The patients were not examined by electromyography and/or polysomnography.

### 5 | CONCLUSIONS

ISFPDs presented good long-term prognosis. Failure of one or more supporting implants was the main reason for the failure of ISFPDs. The results of the present study add evidence to suggest that bruxism and the presence of prosthetic cantilever arms may contribute to the increased rate of mechanical complications in ISFPDs, as well as prosthesis failure.
ACKNOWLEDGMENTS
Trial registration at the U.S. National Institutes of Health (clinicaltrials.gov): NCT02369562. This work was supported by Folktandvården Skåne AB, Sweden.

CONFLICT OF INTEREST
There are no conflicts of interest to declare.

ORCID
Bruno R. Chrcanovic  https://orcid.org/0000-0002-3460-3374

REFERENCES
1. Belser UC, Mericske-Stern R, Bernard JP, Taylor TD. Prosthetic management of the partially dentate patient with fixed implant restorations. Clin Oral Implants Res. 2000;11(suppl 1):126-145.
2. Pjetursson BE, Thoma D, Jung R, Zwahlen M, Zeminc A. A systematic review of the survival and complication rates of implant-supported fixed dental prostheses (FPDs) after a mean observation period of at least 5 years. Clin Oral Implants Res. 2012;23(suppl 6):22-38.
3. Jemt T, Back T, Petersson A. Precision of CNC-milled titanium frameworks for implant treatment in the edentulous jaw. Int J Prosthodont. 1999;12(3):209-215.
4. Bagéni A, Abou-Ayash S, Rucker G, Algarmy A, Att W. The influence of prosthetic material on implant and prosthetic survival of implant-supported fixed complete dentures: a systematic review and meta-analysis. J Prosthodont Res. 2019;63(3):251-265.
5. Larsson C, Vult von Steyern P. Five-year follow-up of implant-supported Y-TZP and ZTA fixed dental prostheses. A randomized, prospective clinical trial comparing two different material systems. Int J Prosthodont. 2010;23(4):555-561.
6. Pozzi A, Tallarico M, Barlatanni A. Monolithic lithium disilicate full-contour crowns bonded on CAD/CAM zirconia complete-arch implant bridges with 3 to 5 years of follow-up. J Oral Implantol. 2015;41(4):450-456.
7. Chrcanovic BR, Albrektsson T, Wennerberg A. Turned versus anodised dental implants: a meta-analysis. J Oral Rehabil. 2016;43(9):716-728.
8. Almeida EO, Freitas AC Jr, Bonfante EA, Marotta L, Silva NR, Coelho PG. Mechanical testing of implant-supported anterior crowns with different implant/abutment connections. Int J Oral Maxillofac Implants. 2013;28(1):103-108.
9. Maeda Y, Satoh T, Sogo M. In vitro differences of stress concentrations for internal and external hex implant-abutment connections: a short communication. J Oral Rehabil. 2006;33(1):75-78.
10. Papia E, Larsson C. Material-related complications in implant-supported fixed dental restorations. A systematic review. Eur J Oral Implantol. 2018;11(suppl 1):S147-S165.
11. Chrcanovic BR, Kisch J, Larsson C. Retrospective clinical evaluation of implant-supported single crowns: mean follow-up of 15 years. Clin Oral Implants Res. 2019;30(7):691-701.
12. Lobbezoo F, Ahlberg J, Glaros AG, et al. Bruxism defined and graded: an international consensus. J Oral Rehabil. 2013;40(1-2):4-4.
13. AASM. International Classification of Sleep Disorders, Revised. Diagnostic and Coding Manual. 3rd ed. Chicago: American Academy of Sleep Medicine; 2014.
14. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A. Bruxism and dental implant treatment complications: a retrospective comparative study of 98 bruxer patients and a matched group. Clin Oral Implants Res. 2017;28(7):e1-e9.
15. Treede RD, Jensen TS, Campbell JN, et al. Neuropathic pain: redefinition and a grading system for clinical and research purposes. Neurology. 2008;70(18):1630-1635.
16. Lee EW, Wei LJ, Amato DA. Cox-type regression analysis for large numbers of small groups of correlated failure time observations. In: Klein JP, Goel PKS, eds. Proceedings of the Survival Analysis: State of the Art. Netherlands: Springer; 1992:237-247.
17. Lin DY. Cox regression analysis of multivariate failure time data: the marginal approach. Stat Med. 1994;13(21):2233-2247.
18. Layton DM. Understanding Kaplan-Meier and survival statistics. Int J Prosthodont. 2013;26(3):218-226.
19. Ferguson JG. Life tables for clinical scientists. J Vasc Interv Radiol. 1992;3(4):607-615.
20. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A. Factors influencing early dental implant failures. J Dent Res. 2016;95(9):995-1002.
21. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A. A retrospective study on clinical and radiological outcomes of oral implants in patients followed up for a minimum of 20 years. Clin Implant Dent Relat Res. 2018;20(2):199-207.
22. Chrcanovic BR, Albrektsson T, Wennerberg A. Bruxism and dental implants: a meta-analysis. Implant Dent. 2015;24(5):505-516.
23. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A. Bruxism and dental implant failures: a multilevel mixed effects parametric survival analysis approach. J Oral Rehabil. 2016;43(11):813-823.
24. Chrcanovic BR, Kisch J, Albrektsson T, Wennerberg A. Factors influencing the fracture of dental implants. Clin Implant Dent Relat Res. 2018;20(1):58-67.
25. Lobbezoo F, Brouwers JE, Cune MS, Naeije M. Dental implants in patients with bruxing habits. J Oral Rehabil. 2006;33(2):152-159.
26. Kinsel RP, Lin D. Retrospective analysis of porcelain failures of metal ceramic crowns and fixed partial dentures supported by 729 implants in 152 patients: patient-specific and implant-specific predictors of ceramic failure. J Prostheth Dent. 2009;101(6):388-394.
27. Brägger U, Aeschlimann S, Burgin W, Hämmerle CH, Lang NP. Biological and technical complications and failures with fixed partial dentures (FPD) on implants and teeth after four to five years of function. Clin Oral Implants Res. 2001;12(1):26-34.
28. De Boever AL, Keersmaekers K, Vanmaele G, Kerschbaum T, Theuniers G, De Boever JA. Prosthetic complications in fixed endosseous implant-borne reconstructions after an observations period of at least 40 months. J Oral Rehabil. 2006;33(11):833-839.
29. Maló P, Nobre M, Lopes A. The rehabilitation of completely edentulous maxillae with different degrees of resorption with four or more immediately loaded implants: a 5-year retrospective study and a new classification. Eur J Oral Implantol. 2011;4(3):227-243.
30. Chrcanovic BR, Albrektsson T, Wennerberg A. Smoking and dental implants: a systematic review and meta-analysis. J Dent. 2015;43(5):478-498.
31. Hälg GA, Schmid J, Hämmerle CH. Bone level changes at implants supporting crowns or fixed partial dentures with or without cantilevers. Clin Oral Implants Res. 2008;19(10):983-990.
32. Palmer RM, Howe LC, Palmer PJ, Wilson R. A prospective clinical trial supporting crowns or fixed partial dentures with or without cantilever. Clin Oral Implants Res. 2012;23(suppl 1):S147-S165.
33. Wiskott HW, Jaquet R, Scherrer SS, Belser UC. Resistance of internal-connection implant connectors under rotational fatigue loading. Int J Oral Maxillofac Implants. 2007;22(2):249-257.
34. Shillingburg HT, Hobo S, Whitsett LD, Brackett SE. Fundamentals of Fixed Prosthodontics. 4th ed. Illinois: Quintessence Publishing Co Inc; 2012.
35. Graci S, Michalakis K, Vigolo P, Vult von Steyern P, Zwahlen M, Sailer I. Internal vs. external connections for abutments/reconstructions: a systematic review. Clin Oral Implants Res. 2012;23(suppl 6):202-216.
36. Abou-Ayash S, Strasing M, Rucker G, Att W. Impact of prosthetic material on mid- and long-term outcome of dental implants supporting single crowns and fixed partial dentures: a systematic review and meta-analysis. Eur J Oral Implantol. 2017;10(suppl 1):47-65.
37. Chrcanovic BR, Albrektsson T, Wennnerberg A. Periodontally compromised vs. periodontally healthy patients and dental implants: a systematic review and meta-analysis. J Dent. 2014;42(12):1509-1527.
38. Chrcanovic BR, Kisch J, Albrektsson T, Wennnerberg A. Analysis of risk factors for cluster behavior of dental implant failures. Clin Implant Dent Relat Res. 2017;19(4):632-642.
39. Chrcanovic BR, Kisch J, Albrektsson T, Wennnerberg A. Impact of different surgeons on dental implant failure. Int J Prosthodont. 2017;30(5):445-454.
40. Sendyk DI, Chrcanovic BR, Albrektsson T, Wennnerberg A, Zindel Deboni MC. Does surgical experience influence implant survival rate? A systematic review and meta-analysis. Int J Prosthodont. 2017;30(30):341-347.

SUPPORTING INFORMATION
Additional supporting information may be found online in the Supporting Information section at the end of this article.

How to cite this article: Chrcanovic BR, Kisch J, Larsson C. Retrospective clinical evaluation of 2- to 6-unit implant-supported fixed partial dentures: Mean follow-up of 9 years. Clin Implant Dent Relat Res. 2020;1–12. https://doi.org/10.1111/cid.12889