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ORIGINAL ARTICLE

Long-term results of implants and implant-supported prostheses under systematic supportive implant therapy: A retrospective 25-year study

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Abstract

Background: Long-term data (>10 years) concerning the survival and success rates of implants and implant-supported prostheses are scarce.

Purpose: The present investigation represents one of the first studies on dental implants covering an observational period of 25 years.

Materials and methods: This study presents the results obtained in 26 patients with 75 implants who participated over a 23- to 28-year period in a supportive implant therapy (SIT) program at a private dental practice. We extracted existing data from the patients' files (pocket depths [PDs], bleeding on probing [BoP], radiographic peri-implant bone loss, and survival rates of the implant-supported prostheses).

Results: After 25 years, the SIT-compliant patients' implants had a survival rate of 95% (prostheses: 88%). The mean peri-implant probing depth was 3.69 mm (median: 3.33; SD: 1.06; range: 2-8.33). The mean peri-implant bone level was 1.84 mm (median: 1.82; SD: 1.20; range: −0.97-5.2). Finally, the prevalence (moment of last consultation) and incidence (during the entire observational period) of peri-implantitis were 7% and 30%, respectively.

Conclusions: Under SIT conditions, clinicians may expect survival rates for implant-supported prostheses of >80%. Most implants (60%) did not develop signs of peri-implantitis over a 25-year period.

KEYWORDS

implant survival, long-term survival, peri-implantitis, success rate, therapy of peri-implantitis

1 | INTRODUCTION

In recent decades, the use of dental implants has developed into a standard treatment procedure for dental reconstructive therapy. Today, different studies have covered observational periods <10 years.[1-7] However, data collected over >15 years concerning the survival and success rates of implants and implant-supported prostheses are scarce. Moreover, a significant number of the available long-

term studies with observational periods >10 years were conducted in dental clinic settings and have often included selected patient groups (ie, edentulous patients or single-tooth implants) and/or a used single implant system.

For observational periods ≥20 years, an implant survival rate of 97% has been reported in 29 patients after a single immediate implant treatment.[8] In partially edentulous patients (n = 67), an implant survival rate of 90% was found after 20 years of supporting either single-unit crowns or short-span fixed dental prostheses.[9] For the treatment of edentulous jaws, implant survival rates of 80% to 95.5% have been published.[10-14]

The present study provides one of the first data analyses of dental implants after 25 years of systematic professional aftercare in a private dental practice. Three different implant systems were used with different implant-abutment connection types, and different typical indications for dental implants were covered over a mean observational period of 25 years.

The aim of this study was to evaluate the peri-implant soft tissue status, hard tissue status, prevalence and incidence of peri-implantitis, and survival rates of the implant-supported prostheses after 23 to 28 years of supportive implant therapy (SIT) compliance in a private practice setting.

2 | MATERIAL AND METHODS

This retrospective study was conducted in a private practice specializing in dental implant therapy. A retrospective noninterventional study design was used based on the analysis of primary patient data that were extracted from the patients' records. We evaluated the radiological and clinical data of the implants after 23 to 28 years. This study was reviewed and authorized by the Ethics Commission of LZK Hessen (No. 01/2020).

Our study was conducted in compliance with the appropriate EQUATOR guidelines (STROBE).

2.1 | Study population

All patients who received dental implants and implant-supported prostheses in our center between 1991 and 1996 were identified; we identified 62 individuals. Of them, all patients who were compliant with the SIT program (≥1 appointment/year) in our center for >23 years were selected for data analysis. Before implant treatment, all patients were diagnosed periodontally and underwent systematical periodontal treatment if necessary. These patients were approached and asked to participate in the study after they received written information regarding the aims and course of the investigation. Patients who provided written informed consent and met the following inclusion criteria were enrolled:

- Age ≥18 years.
- Dental implants and implant-supported prostheses received at the study center.
- Observational period >23 years.
- Availability of the complete medical history, including the following potential risk factors: medication, diabetes, cardiovascular disease, smoking habits, and a known history of periodontitis.
- Availability of radiographs after ≥20 years.

The files of the inaccessible patients were studied to possibly reveal the reasons for dropout.

2.2 | Preventive treatments performed during SIT appointments

After receiving implant-supported prostheses, the appropriate daily peri-implant cleaning techniques performed by experienced dental hygienists were demonstrated to all patients. Moreover, all patients were informed about the necessity and goals of a postimplant aftercare program. The next SIT appointment date was usually fixed. We recommended a 3-month recall interval. For this study, SIT compliance was defined at ≥1 SIT appointment/year.

SIT treatments consisted of the following:

- An intraoral inspection of the peri-implant soft tissues (redness, swelling, and suppuration).
- Calculus/plaque removal and subsequent cleaning (in the early years, rubber cups, and cleaning paste were used, but since 2018, we have used low abrasive air-water polishing devices).
- Measurement of peri-implant pocket depths and subsequent BoP values.
- According to our X-ray scheme, radiographs were taken using the long-cone technique after 1, 3, and 5 years of follow-up.
- In some cases, individual peri-implant cleaning techniques were demonstrated repeatedly in combination with remotivational efforts.

2.3 | Data collection

Between September 1, 2019 and December 1, 2019, the patients in our study were evaluated according to the following parameters using patient records: age and sex, medical history, smoking habits (definition smoker: >10 cigarettes/day), anatomical position of the implants (according to the Federation Dentaire Internationale [FDI] scheme), history of periodontitis, loss of implants, and period of observation. To calculate the peri-implant bone level, intraoral radiographs were assessed after using the parallel technique.

2.4 | Data analysis

All radiographs were obtained using the long-cone technique. They were digitized and analyzed using a PC program (Sidexis XG, Sirona Dental Systems GmbH, Bensheim, Germany). To account for anatomic magnification and distortion in the films, the linear dimensions of the images were calibrated. This was achieved by setting the scale in the

image to the known distance between the implant shoulders at the most apical point of the implant. An independent oral surgeon Heike Schapiro-Frisch who had high-level expertise in image analysis and was not involved in other aspects of the study performed the initial radiographic examination under 4-fold digital magnification. All measurements were saved and independently confirmed by another experienced periodontist who was not one of the authors. They assessed the radiographs, and in cases of a difference, they reached and recorded a consensus value.

2.5 | Diagnostic criteria

During the present study, the following criteria for a diagnosis of peri-implantitis were applied according to the "Consensus report of workgroup 4 of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions"[15]:

- Clinical signs of inflammation of the peri-implant soft tissues (redness, swelling, BoP+, and suppuration).
- Increased probing depth compared to previous examinations.
- Radiographically, progredient peri-implant bone loss beyond crestal bone level changes resulting from initial bone remodeling.

Implant survival was defined as an "osseointegrated implant in the oral cavity irrespective of the peri-implant tissue conditions."

TABLE 1 Characteristics of the investigated patients

Characteristics	Total (n = 26)
Age in years (mv ± SD; median) at baseline	50.2 ± 10.8; 52.2
Age in years (mv ± SD; median) at end of study	74.6 ± 10.9; 77.8
Sex (n)	
Female	13 (50%)
Male	13 (50%)
General illnesses	
Diabetes mellitus	1 (3.7%)
Coronary heart disease	9 (33.3%)
Tobacco smoker	1 (3.7%)
Implants (n = 75)	
Jaw	
Maxilla	29 (38.7%)
Mandible	46 (61.3%)

Implant success was defined as "no signs of peri-implantitis during the entire observational period."

2.6 | Statistical analyses

For descriptive analyses, frequencies, medians, means, and standard deviations were computed. Multilevel mixed-effects ordered logistic regression models were used to analyze the influence of implant surface and different types of implant-supported protheses on peri-implantitis. With a linear mixed model, the influence of implant surfaces on peri-implant bone level values was estimated. All calculations were performed with the statistical software STATA 16.1 (StataCorp LT, College Station, Texas).

3 | RESULTS

In the present study, we included 26 patients with 75 implants. From the originally identified 62 patients, 1 had to be removed due to a lack of radiographs, 2 were referred for therapy and therefore did not participate in the SIT program, 5 changed their dental provider, and 24 died or were unable to visit a dental practice due to serious disease (ie, dementia). For the remaining four excluded patients, we were unable to obtain the reason for their dropout. Of the 75 included implants, 25 implants (33.33%) in 11 patients (42.3%) with a mean age of 46.4 (median: 51.5; SD: 11.5) years wore single crowns, 19 implants (25.3%) in 7 patients (26.9%) with a mean age of 49.6 (median: 50; SD: 13.4) years were pillars of short-span fixed bridges, and 31 implants (41.3%) in 8 patients (30.8%) with a mean age of 54.9 (median: 55.9; SD: 5.7) years supported removable prostheses in edentulous jaws (5 patients were completely edentulous).

We recorded 4 implant losses among 75 assessed implants over a mean observational period of 25.35 years (median: 25.26; SD: 1.55; range: 23.06-28.48). One patient was a smoker, no patient suffered from diabetes, and nine patients had cardiovascular disorders. Three different implant systems with different surfaces were used: 51 implants (65%) with turned, smooth surfaces and 28 implants (35%) with roughened (TPS) surfaces. Relevant data are presented in Table 1 (characteristics of the investigated patients) and in Table 2 (distribution of the included implant systems). Treatment results and sample size information are given in Table 3.

Typical cases are presented in Figures 1 to 3.

TABLE 2 Distribution of the included implant systems

Implant system	Implant placement/abutment connection	Implant surface	N patients	N implants
Ankylos	Bone level, Morse taper	Rough	1 (3.85%)	3 (4.0%)
Branemark	Bone level external hex	Smooth	14 (53.85%)	51 (68.0%)
IMZ	Bone level screwed	Rough	3 (11.54%)	10 (13.3%)
ITI Bonefit	Tissue level internal plug	Rough	8 (30.8%)	11 (14.7%)

3.1 | Implant survival

Initially, 75 implants were placed. Of these, at the time of our investigation, 71 were found intraorally, and 4 implants had been lost (5.3%) in 4 patients (15.4%). Thus, the survival rate of the implants was 94.7% at the implant level (84.6% at the patient level) after 23 to 28 years. We observed no implant loss before loading or during the first loading period. The implants were lost after 3.4 to 22.5 years of intraoral service. In all cases, the implants were lost due to uncontrollable peri-implantitis. No implant loss was recorded in the group of implants with a smooth, turned surface.

TABLE 3 Sample size and treatment results

Number of implants placed	75	100%
Implant losses before loading	0	
Implant losses after loading	4	5.3%
Implant losses due to peri-implantitis	4	5.3%
Survival of implant	71	94.7%
Implants investigated after 23-28 years	71	100%
Peri-implant bone level (n = 71) (mm; mean, SD, median)	1.84 ± 1.20; 1.82	
Pocket depth (n = 71) (mm; mean, SD, median)	3.69 ± 1.06; 3.33	
BoP+ (mucositis)	25	35.2%
Peri-implantitis (prevalence; n = 71)	5	7.0%
Peri-implantitis (incidence 25 years; n = 71)	20	28.2%
Overall diagnosis of peri-implantitis (n = 75)	30	40%
Implant success rate (n = 75)	45	60%

3.2 | Peri-implant pocket depths

The mean pocket depth value of all included implants was 3.69 mm (median: 3.33; SD: 1.06; range: 2-8.33).

3.3 | Bleeding on probing/mucositis

In 26 out of 71 implants (36.6%), positive BoP was recorded and led to a diagnosis of peri-implant mucositis.

3.4 | Peri-implant bone level

We could assess 71 implants in 26 patients radiographically. We found a mean peri-implant bone level depth of 1.84 mm (median: 1.82; SD: 1.20; range: −0.97-5.2).

3.5 | Peri-implantitis

3.5.1 | Peri-implantitis rates: Incidence and prevalence

At the last assessment (71 implants), 5 implants in 5 patients were diagnosed with peri-implantitis. Therefore, the prevalence of peri-implantitis was 7.0% at the implant level and 19.2% at the patient level after 25 years.

Further data analyses revealed that 20 other implants in 9 patients had been diagnosed with peri-implantitis during the observational period but displayed no signs of peri-implantitis in the final examination. This resulted in a rate of 35.2% among the assessed implants (n = 71). Moreover, all 5 implant losses also resulted from an uncontrollable progression of peri-implantitis.

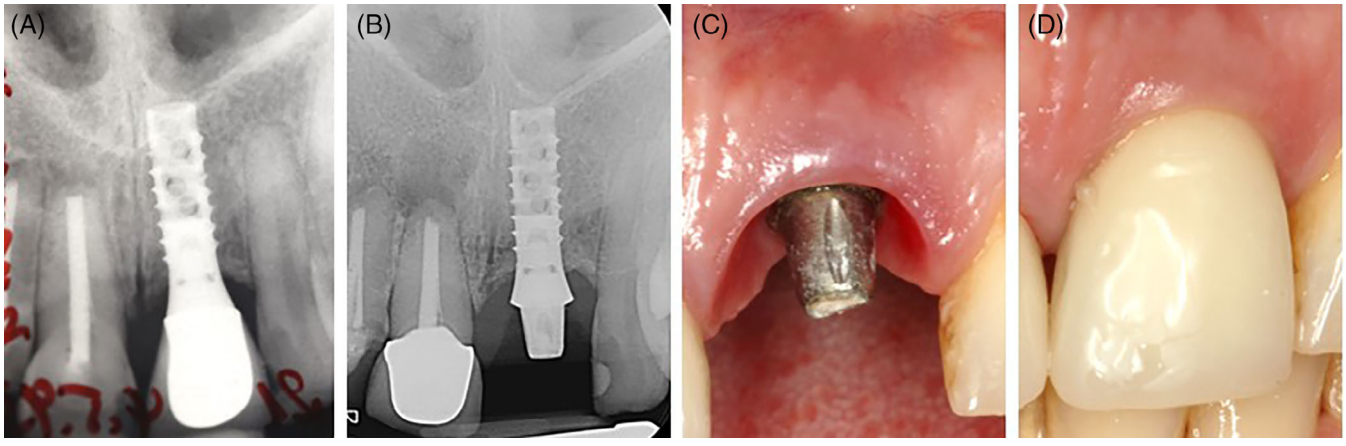

FIGURE 1 A-D, Single tooth replacement of a central maxillary incisor after an anterior tooth trauma (horse riding accident). The procedure was performed in 1991 using a transgingival ITI hollow cylinder implant. A, After 25 years, the crown had to be removed for repair due to chipping. B, The radiograph showed no peri-implant bone loss but slight bone apposition. C, Clinically, complete papillae were found and D, the peri-implant soft tissues displayed no signs of inflammation

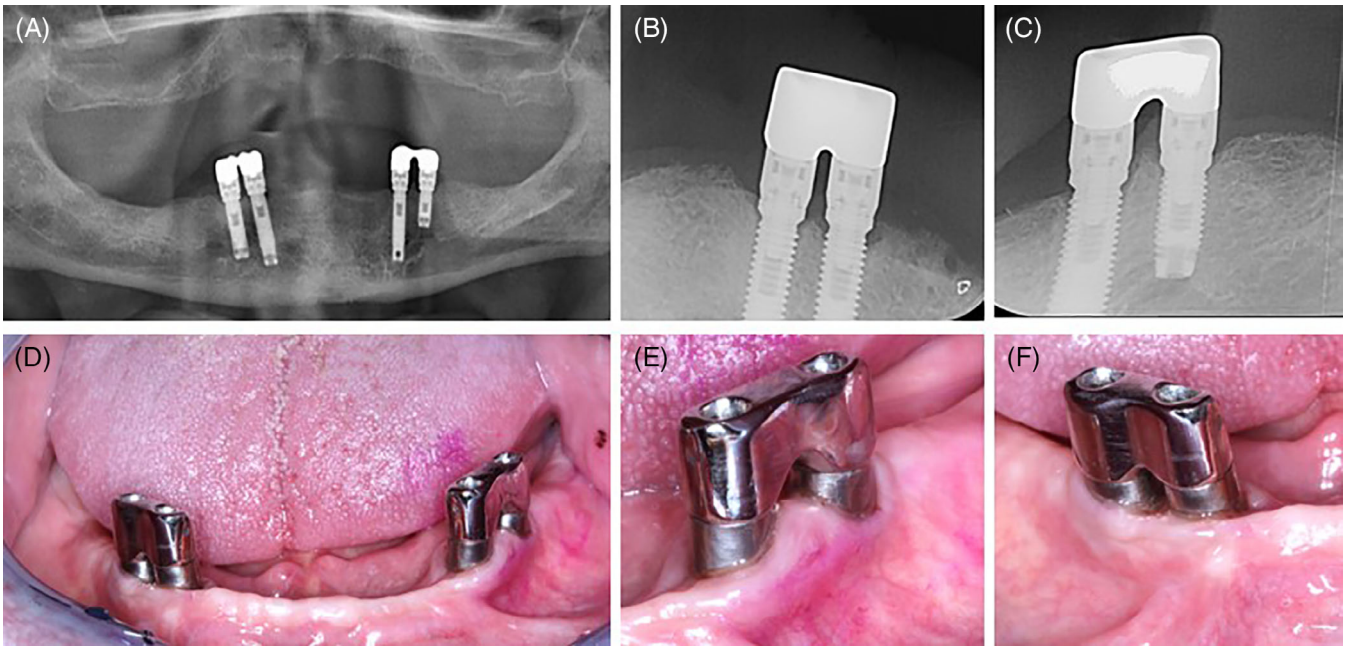

FIGURE 2 A-F, Rehabilitation of an edentulous mandible in 1994 via four Branemark implants supporting a removable prosthesis retained by telescopic crowns (single-piece casting technique/Marburg double crowns). A-C, Over a 25-year period, the radiographs show that no relevant amount of peri-implant bone loss occurred. D-F, Accordingly, the peri-implant tissues showed no signs of inflammation. The use of a double-crown retained construction allowed this 81-year-old patient to easily access the implants for daily hygiene measures. After 19 years of intraoral service, the removable prosthesis was renewed due to abrasion

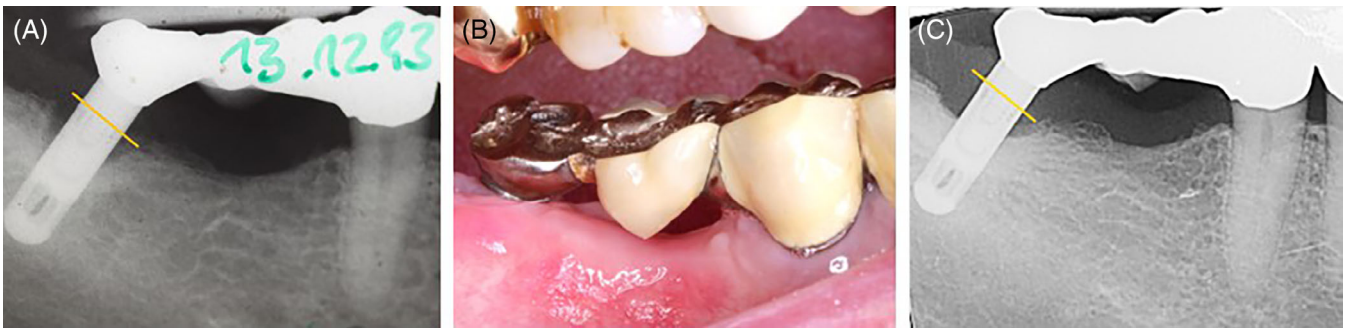

FIGURE 3 A-C, Reconstruction of a unilateral free-end situation in the right mandible area using a fixed bridge crossing from both natural premolars to an IMZ implant. The procedure was performed in 1991 (the implant-abutment connection is marked by a yellow line). A, After 2 years, peri-implant bone loss was observed on a radiograph. After 26 years, B, neither clinical observation nor C, a radiograph showed any pathologic processes

During the entire observational period of 25 years, 30 out of 75 implants developed peri-implantitis, resulting in an overall peri-implantitis rate of 40%.

3.5.2 | Therapy of peri-implantitis

Due to the frequent SIT assessments, the cases of peri-implantitis were diagnosed in a relatively early stage of the disease. In a number of cases, we found that the patient was using insufficient implant hygiene. In these patients, the treatment plan consisted of the following:

- Remotivation for optimal implant hygiene.
- Nonsurgical therapy (repeated biofilm removal plus instillation of CHX gel).
- In 11 cases of insufficient peri-implant soft tissue architecture (very thin peri-implant tissues without keratinized mucosa and/or mobile tissues), we decided in favor of peri-implant soft tissue surgery. We placed a free gingival graft (FGG) at the vestibular aspect of the implants to create a sufficient keratinized mucosa (KM) width and sufficient tissue thickness and to inhibit peri-implant soft tissue mobility (Figure 4A-D). In nine cases (82%), this surgical approach was successful, and we observed permanent remission of peri-implantitis over periods of up to 20 years.

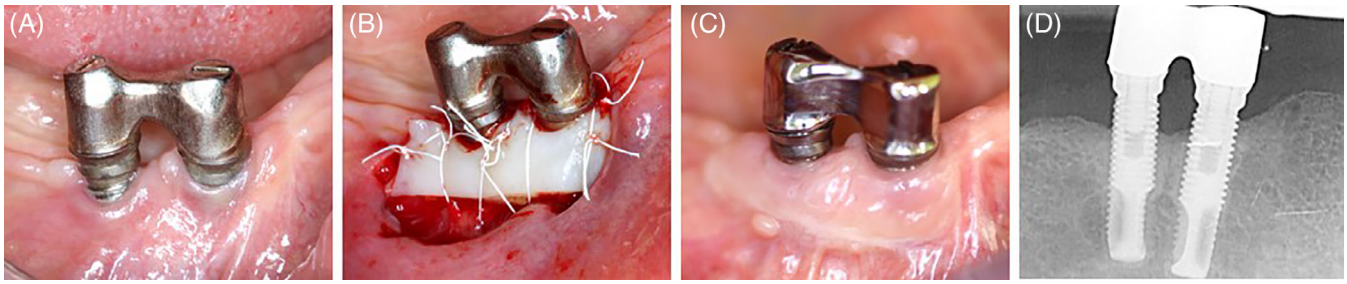

FIGURE 4 A-D, Two out of four telescopic crowns used for rehabilitation of an edentulous mandible supported by four Branemerk implants. After 20 years, two implants showed significant mobility in the peri-implant soft tissue, and no KM was detected. A, Despite the fact that no episode of peri-implantitis was observed during the entire observational period, significant loss of hard and soft tissues was found after 20 years. Due to this progress, we decided to perform peri-implant soft tissue surgery with the aim of reconstructing a sufficient peri-implant soft tissue architecture. B, A free gingival graft (FGG) was placed around both implants to cover the exposed threads. C, Three years later (23 years in total), the implants displayed a sufficient KM width, a significant gain of tissue thickness, and no signs of inflammation. Moreover, the peri-implant soft tissue recessions were covered successfully. D, No further bone loss was detected on radiography

3.5.3 | Additional statistical analyses of factors possibly influencing peri-implantitis

Further analyses were performed to identify factors influencing peri-implantitis. For the implant surface (rough vs smooth) an odds ratio of 6.54 with a very large 95% CI (0.14-316.0) was estimated (P = .34). Furthermore, we investigated a possible impact of different implant surfaces on peri-implant bone level values. We found a 0.6-mm lesser mean bone level around implants with rough surfaces, but this difference was not statistically significant (P = .220). Moreover, the different types of implant-supported protheses (single crowns, bridge pillars, double crowns) showed no significant influence on peri-implantitis rates (P = .105).

3.6 | Survival of implant-supported prostheses

During the 25-year observational period, renewal of the prostheses was necessary at nine implants after a mean intraoral service period of 21.57 years. All remaining prostheses were sufficient. This represents a survival rate for implant-supported prostheses of 82.2% (related to the number of installed prostheses at baseline) and 87.8% (related to the number of investigated prostheses at the study end).

3.7 | Mechanical/technical complications

No implant or abutment fractures were recorded. One abutment screw facture was observed after 19 years in a single mandibular molar implant with an external hex connection. During the observational period, 5 cases of abutment screw loosening (abutment screwed in an implant) and 12 cases of prosthetic screw loosening (crown screwed in an abutment) were found, including 7 in implant-supported double crowns and 5 in fixed restorations. Moreover, eight other complications were treated (ie, chipping, acrylic fracture, relining, replacement of additional retentional elements in double crowns), and two implant-supported double-crown prostheses had to be renewed due to excessive occlusal attrition after 24 and 25 years.

4 | DISCUSSION

4.1 | Main results

As five implants were lost in 26 patients who originally received a total of 75 implants, we calculated an implant survival rate of 94% after 25 years of participation in an SIT program at a private practice. Five of the remaining seventy-one implants were diagnosed with peri-implantitis (7%) at the end of the study. During the observational period, 20 more implants developed episodes of peri-implantitis that were successfully treated via nonsurgical therapy and/or KM augmentation surgery (FGG). Therefore, 45 implants displayed no signs of peri-implantitis during this study, resulting in a success rate of 60% over 25 years. The originally installed implant-supported prostheses were found to be still functional in 65 out of 75 implants (86.7%). When the four lost implants were considered, the survival rate of the prostheses was 82%. New prostheses had to be incorporated into nine implants after a mean functional period of 22 years. The statistical analyses did not reveal a significant correlation between implant surfaces (rough vs turned) and peri-implantitis rates.

4.2 | Interpretation

The results of the present study reveal for the first time that SIT programs can be implemented and conducted successfully in a private practice setting over >25 years. Moreover, patients with permanent SIT compliance predominantly maintained functional implants and healthy peri-implant tissues over 23 to 28 years of use. This applies for different implant systems and different implant supported prostheses (single tooth, implant-supported bridges, tooth-/implant-supported bridges, and double-crown retained removable dentures). Furthermore, in a

preceding study, we found that patient compliance rates were high (~90% during the first 3 years) for a practice-based SIT program.[16]

Lekholm et al[17] investigated 17 partially edentulous patients with 69 Branemark standard implants (turned surface) after 20 years under conditions in a dental clinic setting. The implants displayed a cumulative survival rate (CSR) of 91.3%. Twelve out of twenty-four originally placed implant-supported bridges had to be replaced (50%) after an average of 7 years.

Simonis et al[18] assessed 55 patients with 131 ITI cylinder implants (Straumann) with a roughened surface supporting fixed prostheses after 10 to 16 years. The real survival rate of the implants after 10 years was 89.2%, whereas the calculated survival rate after 16 years was 82.9%. The incidence of peri-implantitis was 16.9%. At the end of the study, PD was measured at 2.73 ± 0.81 mm, and peri-implant bone level was 2.25 ± 3.4 mm.

Ueda et al[19] included 101 edentulous patients wearing two implants in the anterior mandible in a retrospective 10- to 24-year study. They found an implant survival rate of 93.6% after a mean of 16.5 years, and a CSR of 85.9% was calculated after 24 years.

A recent systematic review concerning single-tooth implants with observational periods >10 years comprised nine studies and included a total of 367 patients with 522 implant-supported single crowns. After an average of 11.7 years, the implant survival rate was 95% (single crowns: 89.5%).[20]

The present study found an implant survival rate of 94.7% (implant-supported prostheses: 82%), in accordance with the existing data in the literature, although these data were collected after a significantly longer period of intraoral service.

Our results show that despite a ratio of 51 implants with a smooth surface to 24 implants with a rough surface, all 5 implant losses were in the "rough" group. Additionally, the peri-implantitis rates were unevenly distributed (18% for "smooth" and 41% for "rough" implants), but this difference was not significant. In contrast, previous literature data did not indicate any similar relationship.[21,22]

In our patients, out of 30 implants that fell ill, 5 were lost in the 25-year observation period, 5 others are currently undergoing peri-implantitis therapy, and 20 were successfully treated with nonsurgical therapy and/or via mucogingival surgery to augment the peri-implant KM.

A recently presented study examined a randomly selected sample of Swedish implant patients and found a peri-implantitis rate (criteria: BoP+/suppuration plus>0.5 mm marginal bone loss) of 45% after an average 9-year wearing period.[23] The prevalence of only 7% found in our study is the result of a relatively successful therapy regimen for peri-implantitis. Hence, if one takes into account the value of 40%, we recorded for peri-implantitis over 25 years. This is a comparable order of magnitude.

The current literature provides limited evidence showing that a lack of keratinized mucosa may favor the development of peri-implant diseases.[24] Furthermore, a current review concluded that FGGs that increase KM width and connective tissue grafts (CTGs) used for tissue thickening can provide superior peri-implant soft tissue conditions.[25] All cases of peri-implantitis were diagnosed relatively early. Nine out of eleven implants that had been treated with FGGs remained permanently healthy. Based on our experience, we consider it extremely useful to select a suitable surgical technique during implant insertion and especially during implant exposure to ensure that the implants are surrounded, especially in the vestibular area, by a sufficiently wide zone of KM. If necessary, we have therefore been using FGGs or, increasingly, partially epithelialized connective tissue grafts (PECTGs)[26] preventively for many years (eg, during implant uncovering surgery).

In recent years, there has been an increasing tendency to include patients in SIT programs after the incorporation of implant-supported prostheses with the aim of facilitating the prevention and early detection of peri-implant diseases.[24,27-29] Different recently published studies have indicated that patient compliance with a structured SIT program might significantly decrease the risk of the onset of peri-implantitis by 59%,[30] 77%,[31] and 86%.[32]

4.3 | Limitations

Because the entire treatment concept was performed at a private practice and investigated over a 25-year observational period, some limitations must be taken into account. In this study, we had to use a retrograde study design in which a limited number of patients were included and treated with different implant systems. Hence, two different surface types and different prostheses were assessed. Moreover, all patients were treated by a single dentist. In the first years (1990s), no radiographs were taken after the incorporation of the implant-supported prostheses. Therefore, we could not measure the exact values of peri-implant bone loss. Alternatively, we used the implant shoulder as a reference point. Furthermore, the potential impact of the use of different implant-abutment connection concepts on peri-implant tissue levels was not previously clear. For the statistical analyses concerning a possible relationship between implant surfaces and peri-implantitis or prosthetic reconstruction and peri-implantitis, only a limited number of implants were available. Therefore, these results must not be overestimated.

4.4 | Summary

Under SIT-conditions, implants may support different types of dental prostheses successfully for more than 25 years. Implant survival rates were >90%, and the overall diagnosis rate of peri-implantitis was 40% at the implant level during a 23- to 28-year period. Implant-supported prostheses showed a survival rate of 82%. The necessity of renewal was diagnosed after a mean of 22 years.

4.5 | Generalizability and future research

The present data were assessed in a private practice with a self-developed SIT program. All included patients were compliant with the SIT over long periods of time. This should be considered when

interpreting the present results. Therefore, other researchers should conduct further (prospective) studies with more patients and validate our findings.

CONFLICT OF INTEREST

The authors declare no potential conflict of interest.

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REFERENCES

1. Buser D, Mericske-Stern R, Bernard JP, et al. Long-term evaluation of non-submerged ITI implants. Part 1: 8-year life table analysis of a prospective multi-center study with 2359 implants. *Clin Oral Implants Res*. 1997;8:161-172.
2. Howe MS, Keys W, Richards D. Long-term (10-year) dental implant survival: a systematic review and sensitivity meta-analysis. *J Dent*. 2019;84:9-21.
3. Krebs M, Schmenger K, Neumann K, Weigl P, Moser W, Nentwig GH. Long-term evaluation of ANKYLOS(R) dental implants, part I: 20-year life table analysis of a longitudinal study of more than 12,500 implants. *Clin Implant Dent Relat Res*. 2015;17:e275-e286.
4. Kwon T, Bain PA, Levin L. Systematic review of short- (5-10 years) and long-term (10 years or more) survival and success of full-arch fixed dental hybrid prostheses and supporting implants. *J Dent*. 2014;42:1228-1241.
5. Lazzara R, Siddiqui AA, Binon P, et al. Retrospective multicenter analysis of 3i endosseous dental implants placed over a five-year period. *Clin Oral Implants Res*. 1996;7:73-83.
6. Lekholm U, Gunne J, Henry P, et al. Survival of the Brånemark implant in partially edentulous jaws: a 10-year prospective multicenter study. *Int J Oral Maxillofac Implants*. 1999;14:639-645.
7. Pjetursson BE, Tan K, Lang NP, Bragger U, Egger M, Zwahlen M. A systematic review of the survival and complication rates of fixed partial dentures (FPDs) after an observation period of at least 5 years. *Clin Oral Implants Res*. 2004;15:625-642.
8. Assery M. A 22-year follow up of immediate implant placement without bone augmentation: a case series study. *J Prosthodont*. 2020;29:101-106.
9. Chappuis V, Buser R, Brägger U, Bornstein MM, Salvi GE, Buser D. Long-term outcomes of dental implants with a titanium plasma-sprayed surface: a 20-year prospective case series study in partially edentulous patients. *Clin Implant Dent Relat Res*. 2013;15:780-790.
10. Bakker MH, Vissink A, Meijer HJA, Raghoebar GM, Visser A. Mandibular implant-supported overdentures in (frail) elderly: a prospective study with 20-year follow-up. *Clin Implant Dent Relat Res*. 2019;21:586-592.
11. Jemt T. Implant survival in the edentulous jaw: 30 years of experience. Part II: a retro-prospective multivariate regression analysis related to treated arch and implant surface roughness. *Int J Prosthodont*. 2018;31:531-539.
12. Vercruyssen M, Marcelis K, Coucke W, Naert I, Quirynen M. Long-term, retrospective evaluation (implant and patient-centred outcome) of the two-implants-supported overdenture in the mandible. Part 1: survival rate. *Clin Oral Implants Res*. 2010;21:357-365.
13. Astrand P, Ahlqvist J, Gunne J, Nilson H. Implant treatment of patients with edentulous jaws: a 20-year follow-up. *Clin Implant Dent Relat Res*. 2008;10:207-217.
14. Ekelund JA, Lindquist LW, Carlsson GE, Jemt T. Implant treatment in the edentulous mandible: a prospective study on Brånemark system implants over more than 20 years. *Int J Prosthodont*. 2003;16:602-608.
15. Berglundh T, Armitage G, Araujo MG, et al. Peri-implant diseases and conditions: consensus report of workgroup 4 of the 2017 world workshop on the classification of periodontal and peri-implant diseases and conditions. *J Clin Periodontol*. 2018;45:S286-S291.
16. Frisch E, Ziebolz D, Vach K, Ratka-Kruger P. Supportive post-implant therapy: patient compliance rates and impacting factors: 3-year follow-up. *J Clin Periodontol*. 2014;41:1007-1014.
17. Lekholm U, Grondahl K, Jemt T. Outcome of oral implant treatment in partially edentulous jaws followed 20 years in clinical function. *Clin Implant Dent Relat Res*. 2006;8:178-186.
18. Simonis P, Dufour T, Tenenbaum H. Long-term implant survival and success: a 10-16-year follow-up of non-submerged dental implants. *Clin Oral Implants Res*. 2010;21:772-777.
19. Ueda T, Kremer U, Katsoulis J, Mericske-Stern R. Long-term results of mandibular implants supporting an overdenture: implant survival, failures, and crestal bone level changes. *Int J Oral Maxillofac Implants*. 2011;26:365-372.
20. Hjalmarsson L, Gheisarifar M. Jemt T. a systematic review of survival of single implants as presented in longitudinal studies with a follow-up of at least 10 years. *Eur J Oral Implantol*. 2016;9:S155-S162.
21. Renvert S, Polyzois I, Claffey N. How do implant surface characteristics influence peri-implant disease? *J Clin Periodontol*. 2011;38:214-222.
22. Saulacic N, Schaller B. Prevalence of peri-implantitis in implants with turned and rough surfaces: a systematic review. *J Oral Maxillofac Res*. 2019;10:e1.
23. Derks J, Schaller D, Hakansson J, Wennstrom JL, Tomasi C, Berglundh T. Effectiveness of implant therapy analyzed in a Swedish population: prevalence of peri-implantitis. *J Dent Res*. 2016;95:43-49.
24. Schwarz F, Derks J, Monje A, Wang HL. Peri-implantitis. *J Periodontol*. 2018;89:S267-S290.
25. Thoma DS, Naenni N, Figuero E, et al. Effects of soft tissue augmentation procedures on peri-implant health or disease: a systematic review and meta-analysis. *Clin Oral Implants Res*. 2018;29:32-49.
26. Frisch E, Ratka-Kruger P, Ziebolz D. A new technique for increasing keratinized tissue around dental implants: the partially epithelialized free connective tissue graft. Retrospective analysis of a case series. *J Oral Implantol*. 2015;41:467-472.
27. Heitz-Mayfield LJA, Salvi GE. Peri-implant mucositis. *J Clin Periodontol*. 2018;45:S237-S245.
28. Lang NP. Oral implants: the paradigm shift in restorative dentistry. *J Dent Res*. 2019;98:1287-1293.
29. Monje A, Aranda L, Diaz KT, et al. Impact of maintenance therapy for the prevention of peri-implant diseases: a systematic review and meta-analysis. *J Dent Res*. 2016;95:372-379.
30. Costa FO, Takenaka-Martinez S, Cota LO, Ferreira SD, Silva GL, Costa JE. Peri-implant disease in subjects with and without preventive maintenance: a 5-year follow-up. *J Clin Periodontol*. 2012;39:173-181.
31. Frisch E, Vach K, Ratka-Krueger P. Impact of supportive implant therapy on peri-implant diseases: a retrospective 7-year study. *J Clin Periodontol*. 2019;47:101-109.
32. Monje A, Wang HL, Nart J. Association of preventive maintenance therapy compliance and peri-implant diseases: a cross-sectional study. *J Periodontol*. 2017;88:1030-1041.

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