

# The Effects of Anti-infective Preventive Measures on the Occurrence of Biologic Implant Complications and Implant Loss: A Systematic Review

Giovanni E. Salvi, DMD, Prof Dr Med Dent<sup>1</sup>/Nicola U. Zitzmann, DMD, PhD, Prof Dr Med Dent<sup>2</sup>

**Purpose:** To systematically appraise whether anti-infective protocols are effective in preventing biologic implant complications and implant loss after a mean observation period  $\geq 10$  years after loading. **Materials and Methods:** An electronic search of Medline via PubMed and Embase via Ovid databases complemented by manual search was conducted up to October 31, 2012. Studies were included provided that they were published in English, German, French, or Italian, and conducted on  $\geq 20$  partially and fully edentulous patients with dental implants and regular ( $\geq 1\times$ /year) supportive periodontal therapy (SPT) over a mean observation period  $\geq 10$  years. Assessment of the identified studies and data extraction were performed independently by two reviewers. Authors were contacted if required. Collected data were reported by descriptive methods.

**Results:** The initial electronic search resulted in the identification of 994 titles from Medline via PubMed and 531 titles from Embase via Ovid databases, respectively. After elimination of duplicate titles and exclusion of 60 full-text articles, 143 articles were analyzed, resulting in 15 studies eligible for qualitative analysis. The implant survival rate ranged from 85.7% to 99.2% after a mean observation period  $\geq 10$  years. One comparative study assessed the effects of regular SPT on the occurrence of biologic complications and implant loss. Overall, regular diagnosis and implementation of anti-infective therapeutic protocols were effective in the management of biological complications and prevention of implant loss. Residual probing depths at the end of active periodontal therapy and development of reinfection during supportive periodontal therapy (SPT) represented a significant risk for the onset of peri-implantitis and implant loss. Comparative studies indicated that implant survival and success rates were lower in periodontally compromised vs noncompromised patients.

**Conclusions:** In order to achieve high long-term survival and success rates of dental implants and their restorations, enrollment in regular SPT including anti-infective preventive measures should be implemented. Therapy of peri-implant mucositis should be considered as a preventive measure for the onset of peri-implantitis. Completion of active periodontal therapy should precede implant placement in periodontally compromised patients. *INT J ORAL MAXILLOFAC IMPLANTS* 2014;29(SUPPL):292–307. doi: 10.11607/jomi.2014suppl.g5.1

**Key words:** bone loss, complication, dental implants, implant loss, implant survival, peri-implantitis, prevention, prophylaxis, supportive periodontal therapy

Outcomes from long-term clinical studies demonstrated that supportive periodontal therapy (SPT) after completion of active therapy is an essential component for the prevention of disease recurrence (eg, caries and periodontitis) and tooth loss.<sup>1–5</sup> Patients

treated for advanced periodontitis and subsequently enrolled in a regular SPT program experienced a mean incidence of tooth loss ranging between 2% and 5% over an observation period of 10 years.<sup>1,4,6–8</sup> On the other hand, lack of enrollment in or adherence to a regular SPT program was associated with disease progression and higher rates of tooth loss.<sup>5,9,10</sup> In the majority of patients complying with SPT, periodontal disease progression and tooth loss occurred rarely.<sup>10</sup> In patients not adhering to SPT, however, a sevenfold increase in tooth loss due to periodontitis was reported compared with patients adhering to SPT over a mean period of 10 years following active periodontal therapy.<sup>10</sup> Despite the evident benefits of SPT following active periodontal therapy, only a minority of patients comply with the recommended recall intervals.<sup>11–13</sup>

<sup>1</sup>Department of Periodontology, School of Dental Medicine, University of Bern, Bern, Switzerland.

<sup>2</sup>Department of Periodontology, Cariology and Endodontology, University of Basel, Switzerland.

**Correspondence to:** Prof Dr Giovanni E. Salvi, University of Bern, School of Dental Medicine, Department of Periodontology, Freiburgstrasse 7, CH-3010 Bern, Switzerland. Fax: + 41 31632 4915. Email: giovanni.salvi@zmk.unibe.ch

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It should be noted that residual pocket probing depths (PPD)  $\geq 6$  mm, full-mouth bleeding on probing (BoP+)  $\geq 30\%$ , and heavy smoking (ie,  $\geq 20$  cigarettes per day) after active periodontal therapy represented risks for periodontitis progression and tooth loss over a mean period of 11 years of SPT.<sup>14</sup>

Over the last decades, placement of dental implants with high long-term survival and success rates became a routine procedure in the oral rehabilitation of fully<sup>15–19</sup> and partially edentulous patients,<sup>20–24</sup> respectively. While survival rates describe implants or prostheses still in place and functioning, implant prosthetic success takes any technical and biologic complications into account. The latter comprise peri-implant diseases including peri-implant mucositis and peri-implantitis.<sup>25</sup>

Based on the fact that biologic complications around dental implants are characterized by similar etiologic factors as those involved in the development of periodontal diseases,<sup>26</sup> it may be postulated that long-term survival and success rates of dental implants can be achieved by applying the same principles used during supportive therapy of natural teeth. A cause-effect relationship between bacterial biofilms and the development of an inflammatory response (ie, peri-implant mucositis) was demonstrated in humans when bacterial biofilms were allowed to accumulate around dental implants.<sup>27–29</sup> If left untreated, peri-implant mucositis may lead to progressive destruction of peri-implant marginal bone (peri-implantitis) and, eventually, implant loss. Partially edentulous patients with high plaque scores before implant placement experienced more implant losses than those with lower plaque levels.<sup>30</sup> Moreover, peri-implant mucositis represented a common finding among patients not adhering to a regular SPT program including implant maintenance.<sup>31–33</sup>

Periodontitis-susceptible patients treated for their periodontal conditions may experience more biologic complications and implant losses compared with non-periodontitis patients.<sup>34</sup> Outcomes from several studies indicated that in partially edentulous patients treated for periodontitis and adhering to a regular SPT program, the remaining dentition acted as a reservoir for bacterial colonization around implants.<sup>35–40</sup>

Once osseointegration is established, evidence indicates that the use of clinical and radiographic parameters may be used for the long-term evaluation of peri-implant tissue conditions.<sup>41</sup> In 1997, a systematic diagnostic and anti-infective therapeutic approach for the prevention and treatment of peri-implant diseases was proposed.<sup>42</sup> This protocol, referred to as Cumulative Interceptive Supportive Therapy (CIST),<sup>42</sup> includes diagnostic and therapeutic procedures aimed at detecting and interfering at an early stage with the disease process. The diagnostic component includes

the assessment of peri-implant bleeding on probing (BoP+), suppuration, peri-implant pocket probing depth (PPD), and radiographic crestal (ie, marginal) bone loss. Furthermore, long-term diagnostic monitoring of tissue conditions around dental implants should be performed at regular intervals. From a therapeutic point of view, infection control by nonsurgical mechanical debridement followed by the adjunctive delivery of antiseptics and in some cases, local or systemic antibiotics, should always precede surgical interventions of peri-implant lesions.<sup>42</sup>

Based on the fact that peri-implant tissue destruction is characterized by a chronic inflammatory process becoming evident after several years of recurrent biofilm exposure,<sup>8,43–45</sup> an observation time exceeding 5 years may be required to detect the onset of biologic implant complications. Outcomes of a multicenter retrospective comparative study indicated that a past history of treated periodontitis may not have a significant impact on implant failures up to 5 years after loading.<sup>46</sup> Moreover, conclusions from systematic reviews on implant therapy in patients with a history of treated periodontitis emphasized the necessity of reporting on long-term data of well-characterized patient samples with an appropriate size.<sup>34,47–49</sup>

Therefore, the aim of the present systematic review was to assess the effects of anti-infective preventive measures on the occurrence of biologic implant complications and implant loss after a mean observation period of at least 10 years.

## MATERIALS AND METHODS

The Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) were adopted throughout the process of the present systematic review.<sup>50</sup>

### Focus Question

The focus question for this review was developed using the PICO (population, intervention, comparison, outcome) criteria<sup>51</sup>: “In patients with osseointegrated dental implants, what are the effects of adherence to a regular SPT program on the occurrence of biological implant complications and implant loss?”

The PICO criteria used were as follows:

- *Population*: Patients with osseointegrated dental implants
- *Intervention or exposure*: Adherence to a regular SPT program
- *Comparison*: Lack of adherence to a regular SPT program
- *Outcomes*: Occurrence of biological implant complications and implant loss

## Search Strategy

A comprehensive and systematic electronic search of Medline via PubMed and Embase via Ovid databases was conducted for articles published in the dental literature in English, German, French, and Italian up to October 31, 2012.

The following key words were used:

- *Population:*  
MeSH terms: dental implantation OR dental implant OR dental implants  
OR  
Text words: oral implant OR oral implants OR dental implant OR dental implants OR implant dentistry OR dental  
AND
- *Intervention:*  
MeSH terms: dental prophylaxis OR maintenance  
OR  
Text words: prevention OR prophylaxis OR maintenance OR maintenance care OR implant maintenance OR supportive therapy OR supportive care OR supportive periodontal care OR supportive periodontal therapy OR recall  
AND
- *Outcome:*  
MeSH terms: peri-implantitis OR mucositis OR alveolar bone loss OR bone resorption  
OR  
Text words: periimplantitis OR peri-implantitis OR peri-implant disease OR peri-implant diseases OR mucositis OR peri-implant mucositis OR bone loss OR crestal bone loss OR marginal bone loss OR implant loss OR bone resorption OR implant failure OR implant survival OR implant success OR complication

A manual search of the reference lists of relevant articles published in the *Journal of Periodontology*, *Journal of Oral Rehabilitation*, *Journal of Clinical Periodontology*, *Clinical Oral Implants Research*, *International Journal of Oral & Maxillofacial Implants*, *Implant Dentistry*, *Clinical Implant Dentistry and Related Research*, *International Journal of Periodontics and Restorative Dentistry*, and *International Journal of Prosthodontics* was performed up to October 31, 2012.

## Study Selection

**Inclusion Criteria.** Studies were included provided that they were published in English, German, French, or Italian and conducted in partially and/or fully edentulous patients with the intervention being the enrollment of  $\geq 20$  patients with dental implants adhering to a regular SPT program ( $\geq 1\times/\text{year}$ ) over a mean follow-

up of  $\geq 10$  years. In addition, publications reporting on fixed and/or removable implant-supported dental prostheses were considered.

Screening was performed independently by two reviewers (GES and NUZ). Eligibility assessment was performed first through titles and abstract analysis and second through full-text analysis. In order to avoid exclusion of potentially relevant articles, abstracts providing unclear results were included in the full-text analysis. If necessary, authors were contacted for clarifications on frequency and content of SPT. From all studies of potential relevance, full text was obtained for independent assessment by the two reviewers against the stated inclusion criteria. Any disagreement was resolved by discussion between the two reviewers. In the event of multiple publications on the same patient sample, relevant data on the primary and secondary outcome measures were extracted from each publication.

**Outcome Measures.** The primary outcome measure included:

- Implant loss after delivery of the prosthetic restoration

The secondary outcome measures included:

- Radiographic crestal (marginal) bone loss
- Bleeding on probing (BoP+), Gingival Index (GI), modified Sulcus Bleeding Index (mSBI), Plaque Index (PII), suppuration
- Pocket probing depth (PPD), mucosal recession (REC), probing attachment level (PAL)

**Exclusion of Studies.** Studies not reporting on the content and frequency of anti-infective preventive measures during SPT were excluded unless personal communications were available and the inclusion criteria were fulfilled. Furthermore, publications not reporting on the number of patients/implants assessed at the 10-year follow-up were excluded.

Animal studies, abstracts, letters to editors, narrative reviews, case reports, and studies with  $< 20$  patients were excluded.

**Data Collection.** From the selected articles fulfilling the inclusion criteria, data addressing the primary and secondary outcome measures were extracted for analysis.

## Quality Assessment

Quality analysis of nonrandomized studies including case-control and prospective and retrospective cohort studies was performed according to the Newcastle-Ottawa scale (NOS). Based on a system assigning a rank of one to nine stars, the NOS was developed to provide a simple tool for quality assessment of nonrandomized studies included in a systematic review.

## Data Synthesis

Preliminary evaluation of the selected publications revealed considerable heterogeneity between the studies with respect to design, population characteristics, and modalities, content, and frequency of SPT. Consequently, a qualitative report of the data was planned by applying descriptive methods, and a quantitative data synthesis for meta-analysis was discarded.

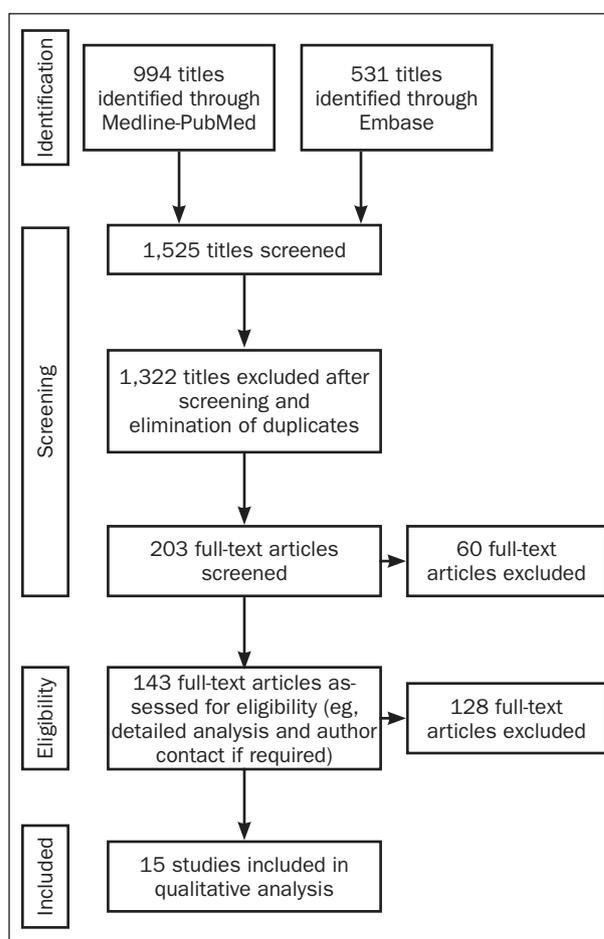
## RESULTS

According to the search strategy, a total of 1,525 titles were screened, followed by a full-text screening of 203 articles (Fig 1). Detailed assessment for eligibility was performed in 143 full texts and supplemented by direct author contact via email if required. A total of 15 studies were included in the systematic review (Table 1). Three studies not fulfilling the inclusion criterion of a mean observation period  $\geq 10$  years but adding substantial findings on patient subgroups with and without SPT<sup>64</sup> and with and without residual periodontal disease<sup>21,65</sup> were considered as supplemental information (Table 3). The quality assessment of the 12 cohort and 3 case-control studies was performed according to the Newcastle-Ottawa scale.

### Characteristics and Outcomes of the Included Studies

The oldest study included in this review reported data from 71 patients, who had been restored with 151 hollow-cylinder ITI implants and observed for a mean period of 14.1 years (range: 11.4 to 19.7 years).<sup>52</sup> Patients had been followed regularly in the Department of Prosthodontics at the University of Bern, Switzerland (41 patients) or in four private practices of ITI members in Switzerland (30 patients). According to personal communication, all patients received regular recalls (1 to 2 times per year) including SPT.<sup>52</sup> Plaque was scored at 38% of all implants; 32% showed BoP+ and there was a correlation between increased PPD, radiographic bone loss, and BoP+. Ten implants (6.6%) were affected by peri-implantitis, eight of which had to be removed.

Four studies reported different aspects from the same study cohort<sup>8,44,53,54</sup> with patients receiving implants after comprehensive periodontal treatment and examinations at 1 and 10 years (range: 8 to 12 years). Patients underwent SPT at regular intervals between 3 and 6 months at the university clinic or in private practice. Karoussis et al<sup>44</sup> focused on 53 patients treated with 112 hollow-screw implants, and distinguished between 8 patients being treated for chronic periodontitis (group A) and 45 patients with no history of periodontal disease (group B). The 10-year peri-



**Fig 1** Flow diagram of the systematic review.

implantitis incidence was higher in patients in group A (28.6%) than among those in group B (5.8%). Among patients in group A, there was a tendency for less favorable survival in smokers (80%) versus nonsmokers (100%).<sup>44</sup> In following studies from the same research group,<sup>8,53,54</sup> a total of 89 patients with 179 implants of the ITI Dental Implant System (former Bonelit System, Institut Straumann) were reevaluated at 10 years. In addition to the 112 hollow screws (HS), 49 hollow cylinder (HC) and 18 angulated hollow cylinder implants (AHC) had been placed. Karoussis et al<sup>8</sup> compared the 179 implants with matching contralateral control teeth. While the Plaque Index (PII) was similar at implants and teeth, PPD, BoP+ and radiographic bone loss was higher at implants than teeth.<sup>8</sup> Peri-implantitis (defined as PPD  $\geq 5$  mm, BoP+, and presence of radiographic bone loss) was found at 15.4% of all implants with the greatest incidence at HC (29%) compared to HS (10%) and AHC (12%).<sup>53</sup> With respect to peri-implantitis incidence among different types of restorations, it was reported that implant-supported single crowns were most frequently affected (29%), compared to implants

**Table 1 Systematic Search Strategy**

**Focus question** In patients with osseointegrated dental implants, what are the effects of adherence to a regular supportive periodontal therapy (SPT) program on the occurrence of biological implant complications and implant loss?

**Search Strategy**

Population	Patients with osseointegrated dental implants
Intervention or exposure	Adherence to a regular SPT program
Comparison	Lack of adherence to a regular SPT program
Outcome	Occurrence of biological implant complications and implant loss
Search combination	<p><i>Population:</i> MeSH terms: dental implantation OR dental implant OR dental implants OR Text words: oral implant OR oral implants OR dental implant OR dental implants OR implant dentistry OR dental AND <i>Intervention:</i> MeSH terms: dental prophylaxis OR maintenance OR Text words: prevention OR prophylaxis OR maintenance OR maintenance care OR implant maintenance OR supportive therapy OR supportive care OR supportive periodontal care OR supportive periodontal therapy OR recall AND <i>Outcome:</i> MeSH terms: peri-implantitis OR mucositis OR alveolar bone loss OR bone resorption OR Text words: periimplantitis OR peri-implantitis OR peri-implant disease OR peri- implant diseases OR mucositis OR peri-implant mucositis OR bone loss OR crestal bone loss OR marginal bone loss OR implant loss OR bone resorption OR implant failure OR implant survival OR implant success OR complication</p>

**Database search**

Language	English, German, French, Italian
Electronic	Medline via PubMed, Embase via Ovid
Journals	<i>Journal of Periodontology, Journal of Oral Rehabilitation, Journal of Clinical Periodontology, Clinical Oral Implants Research, International Journal of Oral &amp; Maxillofacial Implants, Implant Dentistry, Clinical Implant Dentistry and Related Research, International Journal of Periodontics and Restorative Dentistry, and International Journal of Prosthodontics</i>

**Selection criteria**

Inclusion criteria	<p>Clinical studies only Enrollment of <math>\geq 20</math> partially and/or fully edentulous patients with dental implants in a regular SPT program (ie, <math>\geq 1 \times / y</math>) Mean follow-up of <math>\geq 10</math> years Publications reporting on fixed and/or removable implant-supported dental prostheses</p>
Exclusion criteria	<p>Animal studies Abstracts Letters to editors Narrative reviews Case reports Studies with <math>&lt; 20</math> partially and/or fully edentulous patients No author response to inquiry email for data clarification</p>

included in combined implant-tooth-supported fixed dental prostheses (FDPs) (13.6%), and those included in solely implant-supported FDPs (11.6%).<sup>54</sup>

A case-control study investigated periodontally healthy patients (PHP, 28 patients) and periodontally compromised patients (PCP) with moderate (37 patients) or severe disease (36 patients), who had received periodontal therapy before implant placement.

Data were reported in two parts focusing on implant loss and bone loss<sup>55</sup> and on the clinical results.<sup>62</sup> After insertion of HC, HS, or solid-screw (S) implants, all patients were placed on an individual SPT program including motivation, reinstruction, instrumentation, and treatment of re-infected sites. Two patients decided not to attend follow-up examinations and were classified as drop-outs. Among the 101 patients followed

for 10 years, their frequency of participation to the proposed SPT program was classified as “adherence” or “nonadherence” to SPT (24/4 in PHP, 26/11 in moderate PCP, and 29/7 in severe PCP). More pronounced radiographic bone loss of  $\geq 3$  mm was more often observed in moderate (11.2%) and severe PCP (15.1%) than in PHP (4.7%). Less plaque and BoP+ were observed in PHP (PII 16.1%, BoP+ 12.3%) compared to moderate (PII 29%, BoP+ 31%) and severe PCP (PII 23.1%, BoP+ 30.9%).<sup>62</sup> The deepest probing pocket depths during SPT were higher in severe PCP, with 5.5 mm, compared to 5.1 mm in moderate PCP and 4.2 mm in PHP. More sites with PPD  $\geq 6$  mm during SPT were found in moderate PCP (29.5%) and severe PCP (45.6%) compared to PHP (6.6%). Treatment of peri-implantitis was required during SPT in 10.7% of PHP, 27% of moderate PCP, and 47.2% of severe PCP. While no differences were found in PHP with or without complete adherence to SPT, patients in both periodontally compromised subgroups who did not adhere ideally to the proposed SPT revealed a higher incidence of implant loss.<sup>55</sup> This correlation was documented for the clinical parameters with higher PII and BoP+ at the 10-year examination and higher values of the deepest PPD in subjects not adhering to SPT.<sup>62</sup> In addition, more implants had PPD  $\geq 6$  mm during SPT, when patients did not regularly adhere to SPT compared to those adhering to SPT (58.1% versus 15.6% in moderate PCP, 88.9% versus 34.7% in severe PCP).

Matarasso et al<sup>56</sup> compared implants with machined (N-implants; Nobel Biocare) and titanium plasma-sprayed surfaces (TPS, S-implants; Straumann Dental Implant System) in patients with a history of treated periodontitis (PCP) and a group of periodontally healthy patients (PHP). All patients were nonsmokers and adhered to a regular SPT program. The single-unit implant restorations revealed greater bone loss in PCP (N-implants: 2.78 mm, S-implants: 2.32 mm) than in PHP (N-implants: 1.95 mm, S-implants: 1.43 mm).<sup>56</sup> The same study protocol was applied in tobacco smokers with an uninterrupted consumption of  $> 10$  cigarettes/day at the beginning and at the 10-year follow-up.<sup>59</sup> Similarly, greater bone loss was observed in PCP (N-implants: 3.47 mm, S-implants: 3.77 mm) than in PHP (N-implants: 2.65 mm, S-implants: 2.51 mm) with a trend to more bone loss in the smoking cohort.<sup>59</sup>

Data from an edentulous cohort provided with implant-retained mandibular overdentures was reported in two separate publications.<sup>57,58</sup> The SPT recall attendance with at least 1 annual visit was 93.4% and comprised an average of 1.5 visits at the dental hygienist and 2.4 dental visits including treatments for prostheses remake.<sup>57</sup> The cumulative implant survival after 24 years amounted to 85.9%, and 31% of the failures were related to peri-implantitis.<sup>58</sup>

Östman et al<sup>60</sup> reported on 52 single, partial, or complete restorations inserted in 46 patients including 121 implants (TiUnite, Brånemark). SPT was adapted according to individual patient needs, with 20 patients recalled annually presenting with good oral hygiene and healthy soft tissue conditions, 24 patients who received professional cleaning twice a year showing acceptable oral hygiene, and 2 smoking patients with poor oral hygiene who received SPT every 3 months. At the 10-year recall appointment, 10.8% of the implants showed BoP+ or suppuration, 11.3% had more than 2 mm radiographic bone loss, and 4.7% had more than 3 mm bone loss. In these sites with pronounced bone loss (ie,  $> 3$  mm), a correlation with BoP+ or suppuration and impaired oral hygiene was observed.<sup>60</sup>

In partially edentulous patients treated at the University of Bern and recalled at the university clinics and in private practice, high survival (98.8%) and success rates (97%) were reported.<sup>22</sup> Failures from peri-implantitis with acute infection, suppuration, and progressive bone loss were rare (1.8%), while sites with increased PPD of  $\geq 5$  mm were found in 11.5% and bone levels  $\geq 4$  mm measured from the implant shoulder to the bone-to-implant contact were present in 15.6% of the implants at 10 years. With the standard tissue level implants (Straumann Dental Implant system) used in this study, a 2.8-mm polished neck is intended for the transmucosal portion and a bone level at 4 mm corresponds theoretically to only 1.2-mm bone loss. Similar failure rates (2.4%) from peri-implantitis were also reported with TiUnite implants (Nobel Biocare); however, a total of 10% of the implants were diagnosed for peri-implant mucositis and 8% had peri-implantitis requiring surgical treatment.<sup>61</sup> Frisch et al<sup>63</sup> reported on overdenture prostheses retained by telescopic crowns placed on 6 different types of implant systems (Table 2). After a mean observation period of 14 years with an SPT program for peri-implantitis prophylaxis, peri-implant mucositis was found in 21.3% of the implants and 36.4% of the patients. Peri-implantitis was defined as PPD of  $\geq 5$  mm, BOP+, and radiographic bone loss  $> 3.5$  mm. Eight percent of the implants and 9.1% of the patients were diagnosed with peri-implantitis.<sup>63</sup>

Although the study by Costa et al<sup>64</sup> did not fulfill the requirement of a mean observation period  $\geq 10$  years and was therefore not included in the review, some results of this study revealed important aspects related to the effects of SPT (Table 3). A group of 80 partially edentulous patients had been diagnosed for peri-implant mucositis in 2005, when they had implants in place for 6 months up to 5 years.<sup>66</sup> During the following 5 years, patients either adhered to SPT with at least 5 dental visits (GTP group: 39 patients with 156 implants) or remained without SPT (GNTP group: 41 patients with 180 implants).

**Table 2 Publications Included in the Systematic Review**

Study	Study type	Materials and methods	SPT used
Mericske-Stern et al <sup>52</sup>	Retrospective cohort study  Implant therapy at university clinic	71 patients with 151 HC ITI implants (Straumann) SCs, FDPs, or overdentures Mean observation time: 14.1 y (range: 11.4–19.7)  Reevaluation of the 71 patients in 1998–1999 (132 implants still in situ)	SPT not clearly specified in the text, patients had been followed regularly in the Department of Prosthodontics, University of Bern (41 patients) or in 4 private practices of early ITI members in Switzerland (30 patients)
Karoussis et al <sup>44</sup>	Prospective cohort study  Implant therapy at university clinic	53 patients with 112 HS implants (ITI, Straumann) SCs or FDPs Mean observation time: 10 y (range: 8–12)  Group A: 8 patients with 21 implants with history of chronic periodontitis Group B: 45 patients with 91 implants, no history of periodontitis Success criteria: PPD ≤ 5 mm, BoP–, bone loss < 0.2 mm/y	SPT at intervals between 3 and 6 mo (at university clinic or private practice) with an implant maintenance and CIST treatment protocol
Karoussis et al <sup>8</sup>	Prospective cohort study  Implant therapy at university clinic	127 patients included: 9 passed away, 29 moved Mean observation time: 10 y (range: 8–12), 10-y reevaluation in 89 partially edentulous patients with 179 implants (ITI, Straumann) after comprehensive periodontal treatment SCs or FDPs  179 matching control teeth as reference	SPT at intervals between 3 and 6 mo
Karoussis et al <sup>53</sup>	Prospective cohort study  Implant therapy at university clinic	127 patients included: 9 passed away, 29 moved Mean observation time: 10 y (range: 8–12), 10-y reevaluation in 89 partially edentulous patients with 179 implants (ITI, Straumann) after comprehensive periodontal treatment 112 HS implants 49 HC implants 18 AHC implants Success criteria: PPD ≤ 5 mm with BoP– (or BoP+ with PPD < 5 mm), bone loss < 0.2 mm/yr	SPT at intervals between 3 and 6 mo  During recall all biological complications (peri-implantitis) were recorded and treated according to the CIST protocol
Brägger et al <sup>54</sup>	Prospective cohort study  Implant therapy at university clinic	127 patients included: 9 passed away, 29 moved Mean observation time: 10 y (range: 8–12), 10-y exam in 89 partially edentulous patients (comprehensive perio therapy), 179 implants (ITI, Straumann): 112 HS, 49 HC, 18 AHC 48 patients with 69 SC (69 implants) 29 patients with 33 I-I FDP (69 implants) 21 patients with 22 mixed I-T FDP (22 implants and 24 tooth abutments) Success criteria: PPD ≤ 5 mm with BoP–	Supportive periodontal care was provided either at the clinic or by referring dental practices. During recall sessions, all incidences of biological and/or technical complications were noted. In case of a biological complication (defined PPD ≥ 5mm and BoP+ or suppuration), the CIST protocol was applied
Roccuzzo et al <sup>55</sup>	Prospective case-control study  Private specialist practice	112 partially edentulous patients (11 patients lost); 246 TPS implants (ITI, Straumann) with HC, HS, S  10 y follow-up exam with 101 patients: 28 PHPs 37 moderate PCPs 36 severe PCPs	SPT individualized (motivation, reinstruction, instrumentation, and treatment of reinfected sites)  Adhering/not adhering to SPT: 24/4 PHP 26/11 moderate PCP 29/7 severe PCP

Results	Remarks from authors	NOS
<p>Survival: 10 y 91.4%, at mean observation of 14.1 y 84.6%</p> <p>More biologic complications with baskets than with cylinder type F</p> <p>13 implants lost before 10-y observation, 4 implants lost after 10 y in situ</p> <p>7 implant fractures, 2 loss of osseointegration, 10 peri-implantitis (with 2 still in situ)</p> <p>38% of all implants had some plaque, 32% BoP+, correlation between increased PPD and radiographic bone loss and BoP+</p>	<p>Personal communication: all patients had regular (1–2×/y) recalls with SPT</p>	4
<p>Survival rate: group A 90.5%, group B 96.5%</p> <p>Success rate: group A 52.4%, group B 79.1%</p> <p>10-y peri-implantitis incidence: group A: 28.6%, group B: 5.8%</p> <p>Among group A: tendency for poorer survival in smokers (80%) vs nonsmokers (100%)</p>		6
<p>Pll similar at implants (0.36) and teeth (0.40)</p> <p>PPD (2.78 vs 2.02 mm) and BoP+ (42.2% vs 30.2%), radiographic bone loss (0.68–0.72 vs 0.59–0.62mm) higher at implants than at teeth</p> <p>Smoking was associated with greater marginal bone loss</p>	<p>Same patient cohort as in Karoussis et al<sup>53</sup></p>	4
<p>Survival rates at 10 y: 95.4% HS, 85.7% HC, 91.7% AHC</p> <p>Success rates at 10 y: 74% HS, 63% HC, 61% AHC</p> <p>Peri-implantitis (PPD ≥ 5 mm with BoP+ and radiographic bone loss): 15.4% of all implants, and 10% HS, 29% HC, 12% AHC</p>	<p>Same study group as in Karoussis et al<sup>8</sup></p>	4
<p>Success (free of complication): 66.5% SC, 54.5% I-I FDP, 50% I-T FDP</p> <p>Survival: 90% SC, 93.9% I-I FDP, 68.2% I-T FDP</p> <p>Peri-implantitis treatment in: 20% of SCs, 11.6% implants in I-I-FDPs, 13.6% implants in I-T FDPs</p> <p>Suprastructures with implants treated for peri-implantitis had an increased OR of 5.44 to result in a biological failure compared to suprastructures with healthy implants</p>	<p>Same patient cohort as in Karoussis et al<sup>8,53</sup></p>	4
<p>Survival: 96.6% PHP, 92.8% moderate PCP, 90% severe PCP</p> <p>Mean bone loss: 0.75 mm PHP, 1.14 mm moderate PCP, 0.98 mm severe PCP</p> <p>Bone loss ≥ 3mm: 4.7% PHP, 11.2% moderate PCP, 15.1% severe PCP</p> <p>Lack of adherence to SPT correlated with higher incidence of implant loss in patients with PCP:</p> <p>-moderate PCP: 5/11 patients not attending SPT had lost implants, 1/26 patients attending SPT lost implant</p> <p>-severe PCP: 4/7 patients not attending SPT lost implants, 3/29 patients attending SPT lost implants</p>	<p>Same patients as in Rocuzzo et al<sup>62</sup></p>	8

**Table 2 continued Publications Included in the Systematic Review**

Study	Study type	Materials and methods	SPT used
Matarasso et al <sup>56</sup>	Retrospective case-control study Private specialist practice and university clinic	80 patients (contributing 1 implant in single-unit gaps, in 1997), SCs Observation time: 10 y -40 PHPs -40 PCPs (generalized chronic perio, treated, but in some cases isolated residual pockets) 20 patients each in PHP and PCP groups with Brånemark N (machined) or Straumann S (TPS screw) implants Baseline exclusion of smokers, FMPS or FMBS > 25%	SPT regular program with individually tailored maintenance care program
Rentsch-Kollar et al <sup>57</sup>	Prospective cohort study Implant therapy at university clinic 1984–1997	147 edentulous patients with 314 implants (HC and S, Straumann) Observation time 16.5 y (range: 10–24) Mandibular overdentures (gold bar or single abutments) Reevaluation of 101 patients in 2008	Regular maintenance scheduled 2×/y, plaque control by dental hygienist, OH instruction SPT attendance defined as ≥ 1 annual visit
Ueda et al <sup>58</sup>	Prospective cohort study Implant therapy at university clinic 1984–1997	147 edentulous patients with 314 implants (HC and S, Straumann) Observation time 16.5 y (range: 10–24) Mandibular overdentures (gold bar or single abutments) Reevaluation of 101 patients in 2008 (46 drop-outs)	Regular maintenance 1–2×/y, plaque control by dental hygienist, OH instruction
Aglietta et al <sup>59</sup>	Retrospective case-control study Private specialist practice and university clinic	40 tobacco smokers (>10 cig/day during the 10-y period) Observation time: 10 y -20 PCPs -20 PHPs 10 patients each in PCP and PHP groups with Brånemark N (machined) or Straumann S (TPS screw) Single-unit gaps with SCs (in 1997)	All patients enrolled in a regular, individually tailored maintenance care program
Östman et al <sup>60</sup>	Prospective cohort study Private office	46 completely and partially edentulous patients, 121 implants (Brånemark TiUnite) 22 single, 23 partial, 7 complete restorations Observation time > 10 y, exam at 10 y 24 patients with immediate loading, 97 unloaded healing period	Clinical and radiographic check-ups after 3, 6, 12 mo, and thereafter annually up to 10 y (OH, peri-implant mucosa examined by probing, individual program for hygiene controls and professional cleaning) SPT frequencies: 20 patients with good OH and healthy soft tissue conditions annually, 24 patients with acceptable OH 2×/y, 2 patients (smokers) with poor OH every 3 mo
Buser et al <sup>22</sup>	Retrospective cohort study University clinic	Records of 358 patients, 303 patients participated, 511 implants (tissue-level SLA, Straumann) Inserted 1997–2001 Partially edentulous patients Observation time: 10 y with exam	SPT not clearly specified in the text
Degidi et al <sup>61</sup>	Prospective cohort study Private office	59 patients, 210 implants (Brånemark TiUnite) SCs, partial or complete restorations Observation time: 10 y  22.4% of implants not examined due to patient drop-out (refused recall), at 10-y exam: 48 patients with 158 implants Immediate loading protocol, healed and extraction sites	All patients received precise OH instruction and were recalled for professional cleaning by dental hygienists every 6 mo

Results	Remarks from authors	NOS
<p>Survival overall 92.5%:            - PCP N group: 95%            - PCP S group: 85%            - PHP N group: 95%            - PHP S group: 95%</p> <p>Mean peri-implant marginal bone loss at N/S implants: PCP 2.78/2.32, PHP 1.95/1.43            Number of implants <math>\geq</math> 3 mm bone loss:            PCP 13/9, PHP 3/2</p>		8
<p>Annual visit rate: 1.5 at dental hygienist, 2.4 at dentist (including restoration remakes)            Regular recall attendance 93.4% (with <math>\geq</math> 1 SPT visit/y)</p>	Same patient cohort as in Ueda et al <sup>58</sup>	5
<p>Survival 85.9% after 24 y (13 implants removed in 10 patients, 4 due to peri-implantitis)            Mean crestal bone loss 0.54 after 16.5 y</p>	Same patient cohort as in Rentsch-Kollar et al <sup>57</sup>	5
<p>Survival overall 90% (4 implant losses):            -PCP N group: 90%            -PCP S group: 80%            -PHP N group: 90%            -PHP S group: 100%            4 implant failures were related to marginal bone loss</p> <p>Mean peri-implant marginal bone loss at N/S implants: PCP 3.47/3.77, PHP 2.65/2.51            Number of implants <math>\geq</math> 3 mm bone loss: PCP 6/9, PHP 3/1</p>	Same protocol as in Matarasso et al <sup>56</sup>	8
<p>Survival 99.2% after 10 y (1 implant lost)            11 sites (9.2%) with BoP+, 2 sites with pus            12 (11.3%) implants with <math>&gt;</math> 2 mm bone loss,            5 (4.7%, all smokers and poor OH) implants with <math>&gt;</math> 3 mm bone loss; all 5 implants with <math>&gt;</math> 3 mm bone loss were BoP+ and 2 (1.9%) had suppuration</p>		6
<p>Survival 98.8% at 10 y, success 97%            Peri-implantitis: 1.8% (acute infection with suppuration and progressive bone loss)            PPD <math>\geq</math> 5 mm: 11.5%            Distance implant shoulder to bone-to-implant contact <math>\geq</math> 4 mm (corresponds to <math>\geq</math> 1.2 mm bone loss): 15.6% (<math>\geq</math> 4.5 mm: 4.4%)</p>	Personal communications: SPT according to CIST protocol (at university clinic or private practice), average of 1.7 visits/y over 10 y	6
<p>2.4% implant losses (5/210), all due to recurrent peri-implantitis            29 (18.4%) implants had soft tissue adverse events over the whole follow-up period:            10.1% with peri-implant mucositis, 8.2% with peri-implantitis requiring surgical treatment</p>		5

**Table 2 continued Publications Included in the Systematic Review**

Study	Study type	Materials and methods	SPT used
Rocuzzo et al <sup>62</sup>	Prospective case-control study  Private specialist practice	112 partially edentulous patients (11 patients lost); 246 TPS implants (Straumann) with HC, HS, S  10 y follow-up exam with 101 patients -28 PHP -37 moderate PCP -36 severe PCP	SPT individualized (motivation, reinstruction, instrumentation, and treatment of reinfected sites)  Adhering/ not adhering to SPT: -24/4 PHP -26/11 moderate PCP -29/7 severe PCP
Frisch et al <sup>63</sup>	Retrospective cohort study  Private practice	36 nonsmoking edentulous patients (1991–2002), 14 drop-outs, 22 patients included who participated in regular SPT with 89 implants (Ankylos, Brånemark, IMZ, ITI Bonefit, Frialit2) Mean observation: 14.1 y (range: 10.2–18.9) Reevaluation in 2011  Overdentures (9 maxilla, 13 mandible) retained at implant-telescopes	Professional maintenance program with 1–4 appointments per year (evaluating PII, PPD, BoP, with remotivation and professional cleaning) Practice internal aftercare program for peri-implantitis prophylaxis

NOS = Newcastle-Ottawa Scale (max of 9 stars for cohort or case-control studies); CIST = cumulative interceptive supportive therapy; SPT = supportive periodontal therapy; PPD = probing pocket depth; BoP = bleeding on probing; PII = Plaque Index; OH = oral hygiene; SC = single crown, FDP = fixed dental prosthesis; HS = hollow screw; HC = hollow cylinder; AHC = angulated hollow cylinder; S = solid screw; PHP = periodontally healthy patient; PCP = periodontally compromised patient; I-I = implant-implant supported FDP; I-T = implant-tooth supported FDP; FMPS = full-mouth plaque score; FMBS = full-mouth bleeding score.

**Table 3 Supplemental Publications Providing Comparative Data on Patient Cohorts with/without SPT or Residual Periodontitis**

Study	Study type	Materials and methods	SPT used
Costa et al <sup>64</sup>	Prospective cohort study  University clinics	Baseline 80 partially edentulous patients after periodontal treatment and with peri-implant mucositis (in 2005) Observation time: 5 y after diagnosing peri-implant mucositis -39 with SPT (GTP, 156 implants) -41 without SPT (GNTP, 180 implants)  Implant types: Nobel Biocare, 3i Implant Innovation, Intralock International	With and without preventive maintenance during a 5-y period
Lee et al <sup>65</sup>	Retrospective case-control study  Private specialist periodontal practice	30 periodontally healthy patients (PHP) with 61 implants, with observation time 8.2 y (5.0–13.5) 30 treated periodontally compromised patients (PCP) with 56 implants, with observation time 8 y (5.0–14.4), subgroups RP (residual periodontitis) and NRP (non-residual periodontitis) RP: patients with $\geq 1$ site with PPD $\geq 6$ mm at follow-up examination Tissue level implants (Standard and Standard Plus, Straumann)	individually tailored SPT program within the practice, or in conjunction with the referring practitioner
Pjetursson et al <sup>21</sup>	Retrospective cohort study  University clinic	70 partially edentulous patients after perio treatment, with 165 implants placed during initial corrective phase plus 12 implants additionally placed during SPT (Straumann Dental Implant system)  - 115 S implants - 50 HS and HC implants  Mean observation time: 7.9 y (range: 3–23 y)  Peri-implantitis definitions: - Level 1: PPD $\geq 5$ mm and BOP+ - Level 2: PPD $\geq 6$ mm and BOP+ radiographic bone level $\geq 5$ mm below implant shoulder (corresponding to $\geq 2$ mm bone loss with 2.8 mm transmucosal neck)	SPT at university clinic or in private practice

NOS = Newcastle-Ottawa Scale (max of 9 stars for cohort or case-control studies); CIST = cumulative interceptive supportive therapy; SPT = supportive periodontal therapy; PPD = probing pocket depth; BoP = bleeding on probing; PII = Plaque Index; OH = oral hygiene; SC = single crown, FDP = fixed dental prosthesis; HS = hollow screw; HC = hollow cylinder; AHC = angulated hollow cylinder; S = solid screw; PHP = periodontally healthy patient; PCP = periodontally compromised patient.

Results	Remarks from authors	NOS
<p>PII: 16.1% PHP, 29% moderate PCP, 23.1% severe PCP            BoP+: 12.3% PHP, 31% moderate PCP, 30.9% severe PCP            Mean PPD: 3.1 mm PHP, 3.5 mm moderate PCP, 3.9 mm severe PCP            Mean deepest PPD during SPT: 4.2 mm PHP, 5.1 mm moderate PCP, 5.5 mm severe PCP            Implants with deepest PPD <math>\geq</math> 6 mm during SPT: 6.6% PHP, 29.5% moderate PCP, 45.6% severe PCP</p> <p>Attendance/no regular attendance of SPT affected only PCP with more pronounced signs of inflammation:            PII: 25/38.5% moderate PCP, 20.3/39.6% severe PCP            BoP+: 23/50% moderate PCP, 27.2/52.1% severe PCP            Mean deepest PPD during SPT: 4.5/6.3 mm moderate PCP, 5.1/7.2 mm severe PCP            implants with deepest PPD <math>\geq</math> 6 mm during SPT: 15.6/58.1% moderate PCP, 34.7/88.9% severe PCP</p> <p>Survival: 98.9% (1 implant lost due to peri-implantitis)            Peri-implant mucositis: 21.3% of implants/ 36.4% of the patients            Peri-implantitis (PPD <math>\geq</math> 5 mm, BOP+, radiographic bone loss &gt; 3.5 mm): 8% of implants/            9.1% of the patients</p> <p>Overall mean marginal bone loss after 14 y: 1.6 mm (65% implants with &lt; 2 mm bone loss,            27% with 2–3.5 mm, 8% with &gt; 3.5 mm)</p>	<p>Same patients as in Roccuzzo et al<sup>55</sup></p>	<p>8</p> <p>5</p>

Results	Remarks from authors	NOS
<p>Incidence of peri-implantitis: 31.2%            -GTP (with SPT) 18%            -GNTP (without SPT) 43.9%            At final exam:            -GTP: 30.5% healed, 51.5% mucositis, 18.0% peri-implantitis (periodontitis in 28.2% of the patients)            -GNTP: 0% healed, 56.1% mucositis, 43.9% peri-implantitis (periodontitis in 41.5% of the patients)</p> <p>Implants PPD <math>\geq</math> 5 mm and BoP+ (implant level): PHP 13.1%, PCP 26.7% (RP 43.5%, NRP 15.2%)            Implants PPD <math>\geq</math> 5 mm and BoP+ (patient level): PHP 16.7%, PCP 6.7% (RP 53.8%, NRP 23.5%)</p> <p>Bone level &gt; 3 mm (implant level): PHP 3.3%, PCP 8.9% (RP 17.4%, NRP 3.0%); overall 6%            Bone level &gt; 3 mm (patient level): PHP 6.7%, PCP 16.7% (RP 30.8%, NRP 5.9%); overall 11.7%</p>	<p>At baseline exam all implants had peri-implant mucositis and were already in place for 6 mo to 5 y (details in Ferreira et al<sup>66</sup>)</p> <p>Personal communications: 14 patients had follow-up data greater than 10 y (6/30 in PHP and 8/30 in PCP)</p>	<p>7</p> <p>7</p>
<p>Cumulative survival rate of 165 implants: 95.8%            -S: 99.1%            -HS and HC: 89.7%</p> <p>Peri-implantitis (related to 165 plus 12 implants)            -Level 1: 22.2% of implants and 38.6% of patients with <math>\geq</math> 1 implants with peri-implantitis            -Level 2: 8.8% of implants and 17.1% of patients with <math>\geq</math> 1 implants with peri-implantitis</p> <p>PPD <math>\geq</math> 5 mm at the end of active periodontal therapy was a risk for development of peri-implantitis and implant loss</p> <p>Patients developing re-infections during SPT were at greater risk for peri-implantitis and implant loss compared with periodontally stable patients</p>	<p>Personal communication: all patients had regular (<math>\geq</math> 1<math>\times</math>/y) recalls with SPT</p>	<p>6</p>

After this 5-year period, the incidence of peri-implantitis was 31.2%, with 18% in the subgroup with SPT and 43.9% in the subgroup without SPT. While 30.5% of the mucositis sites had healed in GTP and 51.5% still presented with peri-implant mucositis, no sites in GNTP showed healthy tissues, but 56.1% had mucositis. The incidence of periodontitis among the patients slightly increased after the 5-year period in GTP (from 26.5% to 28.2%) and was almost twice as high in GNTP (from 22% to 41.5%). Univariate analysis revealed an association of the following variables with peri-implantitis: presence of periodontitis, plaque (PII), BoP+, width of keratinized mucosa at implants  $\geq 1$  mm, and PPD  $\geq 4$  mm. In addition, PAL  $\geq 3$  mm showed an association only in GNTP. Logistic regression analysis showed that in GTP peri-implantitis was associated with  $> 50\%$  of sites with BoP+ and  $> 5\%$  of sites with PPD  $\geq 4$  mm, while in GNTP peri-implantitis was related to  $> 5\%$  of sites with PPD  $\geq 4$  mm and the presence of periodontitis.

Another study<sup>56</sup> not included due to the limited mean observation period (8.2 years) compared the peri-implant conditions of 30 partially edentulous patients with a history of treated periodontitis (PCP) with those of 30 patients with healthy periodontal conditions (PHP) (Table 3). The PCP group was subdivided in a residual periodontitis group (RP, 13 patients) when at least one periodontal site with PPD  $\geq 6$  mm was present during the final examination, or in a no residual periodontitis group (NRP, 17 patients). In RP patients, 43.5% of the implants and 53.8% of the subjects were affected by PPD  $\geq 5$  mm and BoP+, while only 15.2% of the implants (23.5% of the patients) in NRP and 13.1% of the implants (16.7% of the patients) in PHP showed these clinical signs of peri-implantitis. Similarly, the prevalence of bone levels  $> 3$  mm was 17.4% of the implants (30.8% of the patients) in RP, while only 3.0% of the implants (5.8% of the patients) in NRP and 3.3% of the implants (6.7% of the patients) in PHP showed progressive bone loss. The authors concluded that absence of residual periodontal pockets and maintenance of periodontal health played a more important role for the increased risk of peri-implantitis than a previous history of treated periodontitis.<sup>65</sup>

The susceptibility to peri-implantitis was assessed in a retrospective cohort study on 70 patients treated for periodontitis and rehabilitated with 165 dental implants<sup>21</sup> (Table 3). All patients were enrolled in a regular SPT program either at the University or in private practice. The follow-up time ranged from 3 to 23 years (mean: 7.9 years). The findings indicated that residual periodontal pockets represented a reservoir for bacterial colonization of dental implants.<sup>21</sup> More specifically, residual PPD  $\geq 5$  mm at the end of active periodontal therapy represented a significant risk for the development of peri-implantitis and implant loss during SPT. Moreover, patients experienc-

ing periodontal disease recurrence during SPT displayed a significantly greater risk for the development of peri-implantitis and implant loss compared with control patients with stable periodontal conditions during SPT.<sup>21</sup>

## DISCUSSION

The aim of the present systematic review was to evaluate the effects of anti-infective preventive measures on the occurrence of biologic implant complications and implant loss in edentulous and partially edentulous patients. Out of 15 included studies, only one comparative study assessed the effects of adherence to recommended SPT on the occurrence of biologic complications and implant loss after a mean observation period of at least 10 years. Overall, the results of the present systematic review confirmed that adherence to recommended SPT of fully and partially edentulous patients yielded beneficial effects with respect to the occurrence of biologic complications and implant loss. In order to evaluate the effects of adherence to SPT on the incidence of peri-implant diseases and implant loss, a randomized clinical trial (RCT) with and without SPT would be ideal but cannot be justified for ethical reasons, although RCTs of different maintenance care frequencies would be ethical. Therefore, observational studies including adherence and lack of adherence to recommended SPT were considered valuable in order to estimate the effects of SPT on implant longevity and the occurrence of biologic complications.

So far, findings from one systematic review<sup>67</sup> on a similar topic as the present one had been reported. Hultin et al<sup>67</sup> concluded that "no evidence is available to suggest the frequency of recall intervals or to propose specific hygiene treatments" and that "there is an urgent need for such studies to be initiated."

Owing to the importance of SPT for periodontal disease progression and tooth loss, it was assumed that patients with dental implants could also benefit from regular adherence to SPT with respect to implant success and survival. This assumption was based on the outcomes of a study in patients with dental implants enrolled in a 3-month SPT program.<sup>68</sup> In that study, no significant differences between periodontal and peri-implant conditions were recorded up to 5 years.<sup>68</sup>

In all studies included in the present systematic review, SPT was offered to the patients and recall intervals were mostly scheduled on an individual basis. However, the modalities, content, and frequency of SPT varied among the different study protocols. Lack of adherence of partially edentulous patients with dental implants to recommended SPT was associated with a higher incidence of peri-implantitis and implant loss compared with those of patients adhering to recommended SPT.<sup>55,62,64</sup> In addition, recent data indicated

that patients with a history of treated periodontitis who received dental implants as part of their oral rehabilitation displayed a higher rate of adherence to scheduled SPT appointments compared with patients who underwent periodontal surgery without receiving dental implants.<sup>69</sup>

Outcomes of a prospective cohort study with a 5-year follow-up indicated that implants placed in patients with treated periodontal conditions and adhering to a SPT program yielded a 20% prevalence of mucositis.<sup>70</sup> In that study,<sup>70</sup> upon diagnosis of mucositis or peri-implantitis, all implants with the exception of one were successfully treated according to a cumulative anti-infective protocol.<sup>42</sup> Findings from a 3-month randomized placebo-controlled clinical trial revealed that mechanical debridement with and without local application of chlorhexidine gel in conjunction with optimal self-performed oral hygiene was effective in reducing soft tissue inflammation and probing depths around implants with mucositis.<sup>71</sup> Among patients not adhering to regular SPT, however, peri-implant mucositis was reported to be a common finding with a prevalence of 48% during an observation period of 9 to 14 years.<sup>31–33</sup> In partially edentulous patients, pre-existing peri-implant mucositis in conjunction with lack of adherence to SPT was associated with a higher incidence of peri-implantitis over a 5-year follow-up period.<sup>64</sup> The characteristics of 212 partially edentulous patients rehabilitated with dental implants reported by Ferreira et al<sup>66</sup> formed the target sample of the study by Costa et al.<sup>64</sup> The outcomes of that study yielded a 5-year incidence of peri-implantitis of 18.0% in the group of patients with SPT and of 43.9% in the group without SPT, respectively.<sup>64</sup> The logistic regression analysis<sup>64</sup> revealed that lack of adherence to SPT within the overall patient sample was significantly associated with peri-implantitis with an odds ratio (OR) of 5.92. Moreover, a diagnosis of periodontitis was significantly associated with the occurrence of peri-implantitis in the overall patient sample (OR = 9.20) and particularly in patients without SPT (OR = 11.43).<sup>64</sup>

Outcomes from long-term comparative studies revealed that patients with a history of treated periodontitis and rehabilitated with dental implants were more prone to develop peri-implantitis compared with non-periodontitis patients.<sup>44,55,56,62,72,73</sup> Patients with a history of moderate to severe periodontitis and not adhering to regular SPT displayed significantly higher incidences of implant losses and peri-implant bone loss  $\geq 3$  mm compared with patients adhering to SPT after an observation period of 10 years.<sup>55,62</sup> High implant survival rates and low incidence of peri-implant bone loss in patients treated for moderate to advanced chronic periodontitis were reported in a 5-year study.<sup>74</sup> In that study, all patients adhered to a regular SPT program (2 to 3 $\times$  per year) after implant placement and prosthetic rehabilita-

tion.<sup>74</sup> In this well-maintained patient sample, the 5-year implant survival rate was high (97.3%), the amount of bone level change during the final 4 years was 0.02 mm per year, and only 11% of the implants yielded  $> 2$  mm bone loss during the 5-year observation period.<sup>74</sup>

Although it is clinically meaningful that in partially edentulous patients active periodontal therapy precedes implant placement, the endpoints of periodontal therapy were shown to impact on the survival and success rates of natural teeth and dental implants. Results from long-term studies indicated that periodontally treated teeth could be maintained even though a significantly increased risk for tooth loss was reported for PPD  $\geq 6$  mm and BoP+  $\geq 30\%$ ,<sup>14</sup> and furcation involvement<sup>75–77</sup> was still present after completion of active periodontal therapy and adherence to SPT. Results from two recent studies confirmed that the presence of these risks for natural teeth (ie, residual PPD and BoP+) after completion of periodontal therapy could also be assessed in periodontally compromised patients with dental implants.<sup>21,65</sup> Residual PPD  $\geq 5$  mm at the end of active periodontal therapy represented a significant risk for the onset of peri-implantitis and implant loss over a mean follow-up period of 7.9 years.<sup>21</sup> Furthermore, patients adhering to regular SPT who had re-infections were at greater risk for peri-implantitis and implant loss compared with periodontally stable patients.<sup>21</sup> In a retrospective case-control study, the effects of periodontal conditions on the outcomes of implant therapy were evaluated in periodontally compromised patients stratified according to the presence of  $\geq 1$  residual PPD  $\geq 6$  mm after a mean follow-up period of 8.2 years.<sup>65</sup> Patients with  $\geq 1$  residual PPD  $\geq 6$  mm displayed a significantly greater mean peri-implant PPD and radiographic bone loss compared with both periodontally healthy and periodontally compromised patients without residual PPD, respectively.<sup>65</sup> Moreover, patients with  $\geq 1$  residual PPD  $\geq 6$  mm had significantly more implants with PPD  $\geq 5$  mm with BoP+ and radiographic bone loss compared with either of the other two groups of patients.<sup>65</sup>

## CONCLUSIONS

The following conclusions and clinical implications were determined based on the reviewed studies:

- High long-term survival and success rates of dental implants can be achieved in partially and fully edentulous patients adhering to regular SPT. Enrollment in an individual SPT program with regular intervals and including anti-infective preventive measures should be implemented.
- Peri-implant mucositis (ie, inflammation without crestal bone loss) represents a common finding

among patients with dental implants. Pre-existing peri-implant mucositis in conjunction with lack of adherence to SPT is associated with a higher incidence of peri-implantitis. Therapy of peri-implant mucositis should be considered as a preventive measure for the onset of peri-implantitis.

- Long-term implant survival and success rates in patients with a history of treated periodontitis are lower compared with those in periodontally healthy patients. Control of periodontal infection should precede implant placement.

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