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Incidence of peri-implant mucositis and peri-implantitis in patients with a maxillary overdenture: A sub-analysis of two prospective studies with a 10-year follow-up period

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Abstract

Background: Though studies on maxillary overdentures show satisfying results on implant survival, patient-related outcomes and prosthetic complications, the epidemiology of peri-implant diseases in this specific group of patients has hardly been reported. While the general patient-level prevalence of peri-implant mucositis and peri-implantitis are estimated at ~45% and ~20%, respectively, the risk of developing these diseases within a specific period is less clear. To fully appreciate the epidemiology of peri-implant diseases, more long-term data on incidence of peri-implant diseases are needed.

Purpose: The purpose of this sub-analysis of two prospective studies was to assess the incidence of peri-implant mucositis and peri-implantitis in fully edentulous patients with implant-retained maxillary overdentures during a 10-year follow-up period.

Materials and Methods: One hundred and sixteen patients treated with implant-supported maxillary overdentures were available from two clinical trials. Data on biological complications, clinical and radiographical parameters were collected for 106 patients at 5-year, for 82 patients at 10-year follow-up. The incidence was calculated following the consensus of the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions. Extent and severity then were calculated to enable an appropriate epidemiological description of peri-implantitis.

Results: The patient-level incidence of peri-implant mucositis was 37.7% after 5 years and 64.6% after 10 years whereas the patient-level incidence of peri-implantitis was 10.4% after 5 years and 19.5% after 10 years. After 10 years, the extent of peri-implant mucositis and peri-implantitis is 52.8% and 43.8%, respectively. In terms of severity, 26.5% of all affected implants suffered from >3 mm bone loss and 17.6% of all affected implants was lost.

Conclusion: Three of five fully edentulous patients with implant-supported maxillary overdentures experience peri-implant mucositis after 10 years. Peri-implantitis

occurs in one of five patients after 10 years. In spite of these incidence rates, implant survival remains high.

KEYWORDS
dental implants, edentulous, incidence, peri-implant mucositis, peri-implantitis

What is known

- Studies on edentulous patients with a maxillary overdenture show satisfying results on implant survival, patient-related outcomes and prosthetic complications
- The incidence of peri-implant mucositis and peri-implantitis for this specific group is still unclear.

What this study adds

- This study enables clinicians to educate their patients on the chance of developing peri-implant mucositis and peri-implantitis in maxillary overdenture therapy.

1 | INTRODUCTION

Patients experiencing problems with their maxillary denture can benefit from implant-supported maxillary overdenture therapy.[1] Studies show satisfying results on implant survival, with high patient-related satisfaction scores and low incidences of prosthetic complications.[2–7] However, the epidemiology of peri-implant mucositis and peri-implantitis has hardly been reported.

Peri-implant mucositis is the mucosal inflammatory lesion surrounding implants, without the loss of supporting peri-implant bone.[8] The general prevalence of peri-implant mucositis is estimated to be 43%–47% at patient level[9,10] and 29% at implant level.[10] Peri-implantitis is the pathological condition occurring in the tissues surrounding dental implants, characterized by inflammation combined with progressive loss of supporting bone.[11]The general prevalence of peri-implantitis is estimated to be 20%–22% at patient level[9,10] and 9% at implant level.[10] Careful interpretation of the prevalence of both unfavorable peri-implant diseases is required since a variety of case definitions is used in literature, causing high heterogeneity across studies.[9,12]

Apart from prevalence (ie, the chance of having a particular disease), the incidence (ie, the chance of developing a disease during a specific period), the extent (ie, the proportion of affected implants in affected patients) and the severity (ie, the degree of bone loss at affected implants) are needed to fully appreciate the epidemiology of peri-implant diseases.[9,13]

Research on the incidence of peri-implant diseases is limited to a few prospective studies.[14–18] Peri-implant mucositis incidence is poorly reported in these studies. If calculated from bleeding-scores, implant-level incidences vary between 17% and 89%. Peri-implantitis incidence ranges between 1% and 65% at patient level and 1% and 39% at implant level after a follow-up ranging from 5% to 13 years. Extent and severity are not reported in these studies.

Stoker and colleagues[19] studied the incidence of peri-implant diseases in fully edentulous patients. They treated a group of 94 patients with mandibular overdentures and reported a peri-implantitis patient-level incidence of 5% after 8.3 years. Using a stricter threshold for peri-implantitis, Meijer and colleagues[20] performed a sub-analysis of two prospective studies on patients with mandibular overdentures. They reported a patient-level incidence of 16.7% and 29.7% after 5 and 10 years, respectively. The peri-implant mucositis incidence was 51.9% and 57.0% after 5 and 10 years, respectively. Lopes and colleagues[21] described peri-implantitis in a small group of fully edentulous patients with fixed prostheses in both jaws and reported a patient-level incidence of 8.7% after 5 years. Regarding the maxilla, Slot and colleagues[6,7] described four groups with implant overdentures and reported a peri-implantitis incidence of between 4.5% and 17.2% and a peri-implant mucositis incidence of between 27.3% and 45.5%, at patient level after 5 years. Long-term results are, however, currently lacking. Therefore, the purpose of this study was to assess the incidence, extent and severity of peri-implantitis and peri-implant mucositis in fully edentulous patients with implant-retained maxillary overdentures, by performing a sub-analysis on the data of two prospective studies trials with a 10-year follow-up.

2 | MATERIALS AND METHODS

The data used for this sub-analysis originate from two randomized clinical trials of which short- and medium-term results were published before.[6,7,22,23] The original studies reported on peri-implant bone change in fully edentulous patients with implant retained maxillary overdentures supported by four or six implants. The research protocols will be described briefly. A complete description can be found in the corresponding publications.[22,23]

2.1 | Patient selection

All consecutive fully edentulous patients referred to the Department of Oral and Maxillofacial Surgery (University Medical Center Groningen,

the Netherlands) between January 2006 and December 2009, suffering from a lack of retention or stability of their maxillary denture, were informed about the study. Patients were included if they were ≥18 years of age and fully edentulous for at least 1 year. Patients were excluded if their American Society of Anesthesiologists (ASA) score was over II, were smoking, had a history of radiotherapy in the head and neck region or previous pre-prosthetic surgery and implant placement. The research protocols were approved by the Medical Ethical Committee of the University Medical Center Groningen (NL32503.042.11) and were registered in the Dutch Trial Register (NL2828) (Available at: Dutch Trial register: https://www.trialregister.nl/). All the participating patients signed an informed consent form.

Patients with sufficient maxillary bone volume to place of endosseous implants in the maxillary anterior region were included in the anterior group ($n = 50$), while patients with insufficient maxillary bone volume were included in the posterior group ($n = 66$). Randomly, four or six implants were placed in either group. Patient characteristics are listed in Table 1.

2.2 | Treatment procedure

All surgical procedures were performed by one experienced oral and maxillofacial surgeon (GMR). In the anterior group, TiO_2-blasted implants with a fluoride-modified surface (OsseoSpeed™ Ø 4.0 S, Astra Tech AB, Mölndal, Sweden) with a length of at least 11 mm were inserted in the maxillary anterior region in a two-stage procedure. Small dehiscences were covered with a mixture of intra-oral bone and organic bovine bone and a resorbable membrane (Bio-Oss and Bio-Gide, Geistlich Pharma AG, Wolhusen, Switzerland).

In the posterior group, implant treatment was preceded by a maxillary augmentation procedure. Large autogenous bone grafts were harvested from the superior anterior medial part of the iliac crest. The cancellous bone was applied on both sinuses during maxillary sinus elevation procedure, while the cortical bone grafts were used as buccal onlay grafts, which were fixated with osteosynthesis screws to cover the exposed maxillary alveolar process. The wound was primarily closed. After 3 months of healing the osteosynthesis screws were removed after which sandblasted, large grit, acid-etched implants were placed into the grafted sites (Straumann Standard SLA Ø 4.1 mm, Institut Straumann AG, Basel, Switzerland) in a one-stage procedure.

Both groups' patients who did not yet have an implant-retained mandibular overdenture received implants in the mandible simultaneously.

After a 3-month osseointegration period, a standard prosthetic procedure was initiated. Since a 2-stage system was used on the anterior group, prosthetic treatment was preceded by second-stage surgery consisting of healing abutment placement. All the patients received bar-retained implant overdentures. The patients received oral hygiene instructions for their overdentures and bars, and annual routine maintenance appointments were scheduled. During maintenance the prostheses and peri-implant tissues were evaluated and if needed, prosthetic repairs or preventive therapy, such as the removal of calculus, was performed. In case of peri-implant mucositis or peri-implantitis, implants were treated following a clinical protocol consisting of non-surgical debridement, supportive oral hygiene instructions, and, in case of persistent inflammation and/or progressive MBLC, additional surgical debridement. Adjunctive antiseptics were applied (chlorhexidine 0.12% mouth rinse for 14 days). No antibiotics were administered.

2.3 | Data collection and analysis

Data on biological complications (ie, implants lost due to peri-implantitis or treated for peri-implantitis and peri-implant mucositis) from the 10-year follow-up were extracted from the patients' medical files. The baseline, 5- and 10-year follow-up (T_5 and T_{10}) data on bleeding and/or suppuration on probing, pocket depth (PD) and marginal bone level change (MBLC) were collected from the original trials. For the clinical data, every implant was probed at four sites, viz. the mesial, labial, distal and lingual site. For bleeding on probing, the Modified Bleeding Index according to Mombelli and colleagues[24] was used in the original studies (score 0: no bleeding when using a periodontal probe, score 1: isolated bleeding spots visible, score 2: a confluent red line of blood along the mucosal margin, score 3: heavy or profuse bleeding). These data were translated to BoP− (in case of a score 0) or BoP+ (in case of a score 1, 2, or 3).

For the MBLC, standardized radiographs were obtained by using the long-cone paralleling technique with an individualized X-ray holder. Using measurement software (Biomedical Engineering, University Medical Center Groningen, the Netherlands) and the known implant dimension as a reference, peri-implant bone change was measured. The reproducibility of this method was evaluated by Telleman and

TABLE 1 Patient characteristics at study baseline

	Anterior group ($n = 50$)	Posterior group ($n = 66$)	Total
Mean age (SD) in years	59.8 (8.0)	59.3 (8.6)	59.5 (8.5)
Gender (male/female)	23/27	33/33	56/60
Mean edentulous maxilla period (SD) in years	14.2 (13.1)	22.4 (13.1)	18.9 (13.7)
Maxillary sinus floor augmentation	No	Yes	
Implant type	2-stage TiO_2-blasted F-modified surface	1-stage Sandblasted, large grit, acid-etched	

Abbreviation: SD, standard deviation.

colleagues[25] and resulted in a Cronbach's alpha of 0.867, which can be interpreted as almost perfect agreement.

A case of peri-implantitis was defined as a site showing bleeding and/or suppuration on probing (BoP+) and a MBLC ≥ −2 mm compared to baseline, whereas peri-implant mucositis was defined as a site showing bleeding and/or suppuration on probing (BoP+) with a radiographic MBLC < −2 mm, following the consensus reached at the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions.[26]

The incidence of peri-implantitis and peri-implant mucositis was calculated for both groups. Data regarding lost implants due to peri-implantitis, and cases that were treated for peri-implantitis during the evaluation period, were added to the data from the evaluation periods. To enhance appropriate epidemiological descriptions of peri-implant diseases, the distribution of MBLC, the extent (the number of affected implants related to the total number of implants in each affected subject) and the severity (the degree of MBLC that occurred around the affected implants) were calculated.

3 | RESULTS

At T_5, 10 patients were lost to follow-up. Four patients had died (two from each group), four were too ill to attend the evaluation (two from each group) and two moved without leaving an address (both from the posterior group), leaving 106 patients for evaluation at T_5. At T_{10}, 10 additional patients had died (five from each group), 12 patients were too ill to attend the evaluation (four from the anterior group) and two moved without leaving an address (one from each group), leaving 82 patients for evaluation at T_{10}. It was assumed that the loss to follow-up was independent of the clinical and radiographic condition.

During the osseointegration phase, two patients with six implants (one from each group) lost one implant. Since a bar-supported prosthesis could be made for the five remaining implants in the above cases, the lost implants were not replaced. At T_5, no additional implants had been lost, resulting in survival rate of 99.6% (anterior group: 99.6%; posterior group 99.7%). At T_{10}, two patients had lost three implants each (one from the anterior group and one from the posterior group), resulting in a survival of 98.2% (anterior group 97.7%; posterior group 98.8%).

Both groups' mean clinical parameters are presented in Table 2. The bleeding scores were low throughout the whole study period. The mean PD at T_5 was 3.6 ± 1.1 mm for the anterior group and 4.3 ± 1.1 mm for the posterior group. At T_{10}, the mean PD had increased to 4.2 ± 1.1 mm and 4.5 ± 1.2 mm, respectively. The mean MBLC at T_5 was −0.4 ± −0.5 mm for the anterior group and −0.5 ± −0.7 mm for the posterior group. At T_{10}, the mean MBLC was −0.4 ± −0.7 mm for the anterior group and −0.5 ± −0.9 mm for the posterior group.

TABLE 2 Median values and inter-quartile ranges of Modified Bleeding Index (possible score 0–3), means and standard deviations of pocket depth (mm) and marginal bone level change (mm) at implant level 5 and 10 years (T_5 and T_{10}) after maxillary overdenture placement

	T_5			T_{10}		
	Anterior	Posterior	Total	Anterior	Posterior	Total
Implants (n)	227	301	528	174	221	395
Median BI [IQR]	0 [0;0]	0 [0;0]	0 [0;0]	0 [0;1]	0 [0;0]	0 [0;0]
Mean PD (SD)	3.6 (1.1)	4.3 (1.1)	4.0 (1.2)	4.2 (1.1)	4.5 (1.2)	4.3 (1.2)
Mean MBLC (SD)	−0.4 (−0.5)	−0.5 (−0.7)	−0.4 (−0.6)	−0.4 (−0.7)	−0.5 (−0.9)	−0.5 (−0.8)

Abbreviations: BI, bleeding index score; IQR, interquartile range; MBLC, marginal bone level change; PD, pocket depth; SD, standard deviation.

TABLE 3 Implant level and patient-level peri-implant mucositis and peri-implantitis incidence and the extent (the number of affected implants related to the total number of implants in each affected subject) of both diseases 5 and 10 years (T_5 and T_{10}) after maxillary overdenture placement

	T_5			T_{10}		
	Anterior	Posterior	Total	Anterior	Posterior	Total
Implants (*n*)	227	301	528	177	224	401
Peri-implant mucositis	17.6%	16.6%	17.1%	33.9%	33.5%	35.2%
Peri-implantitis	1.8%	4.3%	3.2%	6.2%	10.3%	8.5%
Patients (*n*)	46	60	106	36	46	82
Peri-implant mucositis	43.5%	33.3%	37.7%	63.9%	65.2%	64.6%
Peri-implantitis	6.5%	13.3%	10.4%	11.1%	26.1%	19.5%
Peri-implant mucositis extent (SD)	43.3 (28.2)%	48.8 (26.1)%	46.0 (27.0)%	53.6 (32.2)%	52.2 (32.4)%	52.8 (32.0)%
Peri-implantitis extent (SD)	25.0 (8.3)%	34.4 (13.7)%	31.8 (12.8)%	47.9 (37.5)%	42.4 (29.6)%	43.8 (30.5)%

Abbreviation: SD, standard deviation.

3.1 | Peri-implant disease incidence

Both groups' incidences of peri-implant mucositis and peri-implantitis are presented in Table 3. At T_5, the patient-level peri-implant mucositis incidence was 43.5% for the anterior group and 33.3% for the posterior group. At T_{10}, the peri-implant mucositis incidence had increased to 63.9% for the anterior group and 65.2% for the posterior group.

In the anterior group, no patients were treated for peri-implantitis within the first 5 years. At T_5, three patients (four implants) were diagnosed with peri-implantitis, resulting in a patient-level peri-implantitis incidence of 6.5% after 5 years. Between T_5 and T_{10}, one patient lost three implants due to peri-implantitis. At T_{10}, the patient's three other implants were also diagnosed with peri-implantitis. One additional implant was diagnosed with peri-implantitis in a patient that was already affected at T_5, resulting in a patient-level incidence of 11.1% after 10 years.

In the posterior group, two patients (three implants) were treated for peri-implantitis within the first 5 years. Six additional patients (10 implants) were diagnosed with peri-implantitis, resulting in a patient-level incidence of 13.3% after 5 years. Between T_5 and T_{10}, three implants were treated non-surgically in one patient. Three implants were lost by one patient that had been diagnosed with peri-implantitis at T_5. At T_{10}, this patient's remaining three implants were also diagnosed with peri-implantitis. Three additional implants in three patients also presented with peri-implantitis, resulting in a patient-level incidence of 26.1% after 10 years.

3.2 | Extent and severity

The extent of peri-implant mucositis was comparable for both groups: 46.0 ± 27.0% at T_5 and 52.8 ± 32.0% at T_{10} (Table 3), meaning the proportion of affected implants per affected patient remained fairly stable. The extent of peri-implantitis at T_5 was 25.0 ± 8.3% in the anterior group and 34.4 ± 13.7% in the posterior group. At T_{10}, the extent of peri-implantitis had increased in both groups to 47.9 ± 37.5% and 42.4 ± 29.6%, respectively (Table 3). At T_5, all affected implants of the anterior group and 93% of the affected implants of the posterior group had a MBLC between −2 and −3 mm. At T_{10}, the severity in the anterior group increased: 30.2% of all affected implants had lost more than 3 mm of marginal bone and

TABLE 4 Peri-implantitis incidence and severity of affected implants at implant level, 5 and 10 years (T_5 and T_{10}) after maxillary overdenture placement

	T_5				T_{10}			
	Anterior		Posterior		Anterior		Posterior	
MBLC interval	Incidence	Severity	Incidence	Severity	Incidence	Severity	Incidence	Severity
Not affected	98.2%	–	95.7%	–	92.7%	–	86.6%	–
>−2.0 to −2.5 mm	0.9%	50.0%	2.0%	46.5%	3.4%	46.6%	8.5%	63.9%
>−2.5 to −3.0 mm	0.9%	50.0%	2.0%	46.5%	0.0%	–	1.3%	9.8%
>−3.0 to −3.5 mm	0.0%	–	0.3%	7.0%	0.0%	–	0.9%	6.8%
>−3.5 to −4.0 mm	0.0%	–	0.0%	–	1.1%	15.1%	0.4%	3.0%
>−4.0 mm	0.0%	–	0.0%	–	1.1%	15.1%	0.9%	6.8%
Lost due to peri-implantitis	0.0%	–	0.0%	–	1.7%	23.2%	1.3%	9.8%

TABLE 5 Marginal bone level change, distributed into different intervals 5 and 10 years (T_5 and T_{10}) after maxillary overdenture placement

	T_5			T_{10}		
	Anterior	Posterior	Total	Anterior	Posterior	Total
Implants (n)	227	302	529	177	224	401
MBLC Interval						
0 to −1 mm	81.9%	71.9%	76.2%	83.1%	71.4%	76.6%
>−1 to −1.5 mm	11.9%	14.2%	13.2%	6.8%	13.8%	10.7%
>−1.5 to −2 mm	4.4%	7.3%	6.1%	4.5%	4.5%	4.5%
>−2 to −2.5 mm	0.9%	3.6%	2.5%	1.7%	3.6%	2.7%
>−2.5 to −3 mm	0.9%	2.0%	1.5%	0.0%	2.3%	1.3%
>−3 mm	0.0%	1.0%	0.6%	2.3%	3.1%	2.7%
Lost due to peri-implantitis	0.0%	0.0%	0.0%	1.7%	1.3%	1.5%

Abbreviation: MBLC, marginal bone level change.

23.2% of all affected implants were lost due to peri-implantitis. For the posterior group 19.5% of all affected implants lost more than 3 mm of marginal bone and 9.8% of all affected implants were lost (Table 4). Regardless of BoP-score, approximately 80% and 70% of all the implants in the anterior and posterior group, respectively, demonstrated less than −1 mm MBLC. Although this proportion remained stable between 5 and 10 years, the affected implants' MBLC increased over time (Table 5).

4 | DISCUSSION

This study was designed to assess the incidence of peri-implantitis and peri-implant mucositis in two groups of patients with different implant systems and implant-supported maxillary overdentures. The results showed a high peri-implant mucositis incidence in both groups. The peri-implantitis incidence was low after 5 years, but increased at 10 years. Moreover, patients that were affected by peri-implantitis showed an increase in extent over time, with an increase in severity over time, while patients with less than 1 mm of bone loss remained healthy.

Peri-implant diseases in fully edentulous patients may differ from partially edentulous patients. The De Waal and colleagues[27] review posed the possibility of two possible effects. On the one hand, full mouth tooth extraction may affect the quantity and quality of the periodontal microflora, thereby possibly reducing the risk of developing peri-implant diseases. On the other hand, patients eligible for full mouth tooth extraction are often associated with negative socio-behavioral factors or may have a genetic predisposition to developing periodontitis. Moreover, full edentulism increases with age and declining health. Since these factors cannot be altered, they hypothesized that fully edentulous patients may have a higher risk of developing peri-implant diseases. Unfortunately, based on the available literature at that time, no conclusions could be drawn regarding differences between fully and partially edentulous patients.

Recently, Jemt performed a four part analysis on implant survival after 1–30 years in both partially and fully edentulous patients treated with both fixed and removable implant retained prostheses.[28–31] Though limited by the retrospective character of the obtained data, the analysis revealed a higher hazard ratio for the treatment of the maxilla in fully edentulous patients, relative to the mandible, while the opposite was true in partially edentulous patients. The author's results support the importance of analyzing data on maxillary treatment separately from mandibular treatment, as is done in the present study.

As stated in the introduction, literature on peri-implant disease incidence in edentulous patients is limited. Meijer and colleagues[20] conducted a comparable sub-analysis of three clinical trials and concluded that peri-implant diseases do occur in fully edentulous patients. While the incidences of peri-implant mucositis were in accordance with our study, their peri-implantitis incidence was higher. They attributed the relatively high incidences of both peri-implant mucositis and peri-implantitis to the high number of lost and treated implants between 5 and 10 years, but as well as to the lack of information on smoking and a history of periodontitis that may had influenced their incidence. In a comparable study, Stoker and colleagues[19] evaluated mandibular overdentures and reported twice as much MBLC in smokers, compared to non-smokers. They reported a 5% peri-implantitis incidence after 8.3 years, using a MBLC threshold of 3 mm. Recalculating our results with this threshold, the present study's incidence is lower for the anterior group and higher for the posterior group.

Our study's incidence of peri-implant mucositis in fully and partially edentulous patients is in accordance with other recent studies, viz. ~30% after 5 years[17,18] and ~60% after 10 years.[16] Regarding peri-implantitis, a patient-level incidence of 6.6% at 5 years,[18] a 4.2% incidence after 10 years,[16] and a 10.0% incidence after 12 years.[17] These percentages are in accordance with the present study's anterior group, though the increase at T_{10} may have also been caused by a "cluster effect" (more implants affected in the same patients), since only one additional patient was detected. Also, the relatively low sample size and high loss to follow-up may have increased the total incidence in this group. However, non-attendance was assumed to be independent of treatment results, which means that patients that did not attend for follow-up may also have had peri-implant infections. The higher incidence in the posterior group, especially at the 10 years follow-up, may be explained by the possibly less stable bone conditions in the augmented posterior regions, compared to the anterior region's pristine bone sites, which may have resulted into more physiological bone resorption. Krennmair and colleagues[18] reported a higher association of peri-implant bone changes with full arch rehabilitations in the posterior maxilla. They stated that these patients are predominantly affected by generalized periodontitis, which may explain the higher risk of negative MBLC and the small amount of residual bone height. In the present study, the small amount of residual bone height may also be attributed to the posterior group's longer edentulous period. Nevertheless, since different techniques and implant systems were used in both groups, meaningful risk factor analyses cannot be performed on the present data.

Renvert and colleagues[15] reported relatively high implant level incidences of 26.2% and 30.4% at 7 years and 32.1% and 39.7% at 13 years, using a MBLC threshold of 1 mm. Recalculating our results with a threshold of 1 mm provides incidences of 4.0% and 10.3% at 5 years and 9.6% and 19.2% at 10 years for the anterior and posterior group, respectively. The differences between studies in reported outcomes may be explained by the degree of maintenance. While other studies[16–18,20] and the present studies' patients were included in a regular maintenance program, Renvert and colleagues[15] were unable to verify any aftercare since the patients were referred back to their general practitioner. A continued lack of maintenance was studied by Costa and colleagues[32] in a group of partially edentulous patients diagnosed with peri-implant mucositis. They reported a significantly higher peri-implant mucositis and peri-implantitis incidence in patients that were not preventively maintained. Romandini and colleagues[33] studied a group of edentulous patients that did not receive any aftercare for at least 7 years and showed a high prevalence of peri-implantitis and implant loss, especially in the maxilla. Although the latter two studies did not include a well maintained control group, these results suggest a

possible effect of lacking maintenance on peri-implant diseases. Bleeding on probing may be caused by inflammation, but may also be the result of probing with excessive forces.[34] In the present study gentle probing was used as is done in regular measurement of probing depth around natural teeth and implants. This overcomes a large overestimation or underestimation of bleeding on probing.

The results suggest an increase in peri-implantitis severity in affected implants between 5 and 10 years. The extent of peri-implant mucositis and peri-implantitis also seems to increase over time. Yet, Table 5 shows a fairly constant proportion of patients without a MBLC of >−1 mm (~80% in the anterior group and ~70% in the posterior group). This suggests that patients who are susceptible to peri-implantitis have a higher risk of developing more severe and extensive forms of peri-implantitis over time, while the risk for patients with healthy peri-implant tissues is low. It is, however, important to realize that since the original studies were not specifically designed to identify peri-implant diseases, these statements should be interpreted with caution. Moreover, though extent and severity appear to increase over time, the effect on overdenture survival and thus the clinical relevance are debatable, since the implant loss due to peri-implantitis was limited to 1.5%. Nevertheless, as stated by Derks and Tomasi,[9] these calculations can be valuable for a good understanding the epidemiology of peri-implant diseases and may therefore be a valuable addition for future prospective longitudinal studies.

5 | CONCLUSION

Within the limitations of this study, the following conclusions can be drawn:

- Using the case definitions proposed at the 2017 World Workshop on the Classification of Periodontal and Peri-Implant Diseases and Conditions, fully edentulous patients with implant-supported maxillary overdentures show:
  - High incidences of peri-implant mucositis.
  - Peri-implantitis occurs in one of 10 patients after 5 years and in one of five patients after 10 years.
  - High implant survival of 98.2% after 10 years.

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CONFLICT OF INTEREST

The authors declare no conflict of interest.

AUTHOR CONTRIBUTIONS

Pieter Onclin: Drafting article, data analysis/interpretation of data, statistics, approval of article, agreement to be accountable for all aspects of the work. **Wim Slot**: Data-collection, critical revision of article, approval of article. Agreement to be accountable for all aspects of the work. **Gerry M. Raghoebar**: Interpretation of data, critical revision of article, approval of article agreement to be accountable for all aspects of the work. **Arjan Vissink**: Interpretation of data, critical revision of article, approval of article agreement to be accountable for all aspects of the work. **Henny J. A. Meijer**: Data-analysis/interpretation of data, critical revision of article, approval of article agreement to be accountable for all aspects of the work.

DATA AVAILABILITY STATEMENT

Data available on request from the authors.

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