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ORIGINAL ARTICLE

Risk factors, diagnosis, and treatment of peri-implantitis: A cross-cultural comparison of U.S. and European periodontists' considerations

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[Correction added on Sep 1, after first online publication: The copyright line was changed.]

Abstract

Background: Peri-implantitis (PI) is a growing concern in the dental community worldwide. The study aimed to compare U.S. versus European periodontists' considerations of risk factors, diagnostic criteria, and management of PI.

Methods: A total of 393 periodontists from the United States and 100 periodontists from Europe (Germany, Greece, Netherlands) responded to anonymous surveys electronically or by mail.

Results: Compared to U.S. periodontists, European respondents were younger, more likely to be female and placed fewer implants per month (9.12 vs 13.90; $P = 0.003$). Poor oral hygiene, history of periodontitis, and smoking were considered as very important risk factors by both groups (rated > 4 on 5-point scale). European periodontists rated poor oral hygiene (4.64 vs 4.45; $P = 0.005$) and history of periodontitis (4.36 vs 4.10; $P = 0.006$) as more important and implant surface (2.91 vs 3.18; $P = 0.023$), occlusion (2.80 vs 3.75; $P < 0.001$) and presence of keratinized tissue (3.27 vs 3.77; $P < 0.001$) as less important than did U.S. periodontists. Both groups rated clinical probing, radiographic bone loss, and presence of bleeding and suppuration as rather important diagnostic criteria. They rated implant exposure/mucosal recession as relatively less important with U.S. periodontists giving higher importance ratings than European periodontists (3.99 vs 3.54; $P = 0.001$). Both groups nearly always used patient education, plaque control and mechanical debridement when treating PI. U.S. periodontists were more likely to use antibiotics (3.88 vs 3.07; $P < 0.001$), lasers (2.11 vs 1.68; $P = 0.005$), allograft (3.39 vs 2.14; $P < 0.001$) and regenerative approaches (3.57 vs 2.56; $P < 0.001$), but less likely to use resective surgery (3.09 vs 3.53; $P < 0.001$) than European periodontists.

Conclusions: U.S. and European periodontists' considerations concerning risk factors, diagnosis and management of PI were evidence-based. Identified differences between the two groups can inform future educational efforts.

KEYWORDS
attitudes, diagnosis, peri-implantitis, risk factors, surveys and questionnaires, therapeutics

1 | INTRODUCTION

With implant therapy being a significant part of dental care, peri-implantitis (PI) is becoming a growing problem encountered by dental health professionals worldwide.[1] PI is characterized by the presence of inflammation in the peri-implant soft tissues and progressive loss of supporting bone.[2] Although it is difficult to estimate the prevalence of PI and possible regional differences, studies with similar PI case definition and follow-up time showed approximately 10% higher prevalence in the United States as compared to Europe (26% vs 16% at patient level).[3,4]

Despite potential differences in PI prevalence, consensus exists that biofilm plays an important role in the etiology of PI, as an initial trigger for inflammatory reactions.[5] Furthermore, systemic, local, genetic, behavioral and iatrogenic factors have been accepted as being associated with the onset and progression of this disease.[2] Diabetes mellitus is the systemic risk factor most extensively studied in relation to PI.[6] Other systemic diseases such as osteoporosis and cardiovascular diseases, as well as the treatment with oral bisphosphonates have been reported as possible risk factors; however, the evidence is weak.[7] Local factors including the presence of dental plaque, lack of keratinized tissue, and implant surface roughness have also been associated with greater risk for peri-implant pathologies.[2,8,9] Research also showed the relevance of iatrogenic factors such as improper implant position, presence of residual cement, and poor prosthesis design that limits oral hygiene accessibility.[10,11] In addition, occlusal overload has been associated with mechanical implant complications[12] and peri-implant bone loss.[13] However, a causal relationship and specific strain thresholds have not been established yet.[13] Although genetic traits may influence inflammatory responses and thus may be a risk indicator, the relationship between PI and genetic predisposition remains unclear.[14] Patient-related factors such as smoking[15], history of periodontitis[15] and lack of maintenance care[16] have been associated with higher prevalence and severity of PI.

The diagnosis of PI is based on clinical parameters such as probing depth, bleeding and suppuration on probing, and on radiographic evidence of bone loss following initial bone remodeling.[17] Monitoring the changes in the clinical and radiographic parameters following the completion of the implant-supported prosthesis is important for the diagnosis of PI.[1] In the absence of previous clinical and radiographic evaluations, the diagnosis is based on the presence of a peri-implant pocket ≥6 mm accompanied by bleeding, purulent exudate and bone loss ≥3 mm from the implant platform.[18]

Although various treatment strategies for PI have been suggested, there is no consensus as to which one is the most effective intervention.[19] The non-surgical treatment is always a first option which could lead to improvements in bleeding tendency and in some cases to pocket reduction of ≤1 mm.[20] In more severe cases, non-surgical treatment alone is insufficient to arrest the disease and to eliminate bacteria from the rough surfaces of implants.[20,21] The use of local antiseptics,[22] systemic antibiotics,[23] lasers[24] and photodynamic therapy[25] have been proposed as adjunctive measures to mechanical debridement. However, existing evidence has only shown minimal additional benefits of these adjunctive measures for improving clinical parameters.[22–25] Surgical therapy has proven to be more effective, resulting in reduction of probing depths and bleeding on probing and in radiographic evidence of defect fill.[26] Open flap debridement, resective surgery with or without implantoplasty and reconstructive approaches including the use of various bone grafts with or without the use of barrier membranes were some of the surgical approaches reported in the literature.[27]

Given the high prevalence of PI worldwide, one question of interest is to which degree periodontists in different parts of the world share their PI-related considerations. The objectives of this study were therefore to compare the responses of periodontists in the United States versus Europe concerning PI-related risk factors, diagnostic criteria and treatment approaches.

2 | MATERIALS AND METHODS

2.1 | Study design and questionnaire

The research in the United States was determined to be exempt from Institutional Review Board (IRB) oversight by the Health Sciences and Behavioral Sciences IRB at the University of Michigan, Ann Arbor, MI (#HUM00102795). An amendment (Ame00080866) to conduct the research in the Netherlands, Greece and Germany was approved on June 29, 2018 (# HUM00129701). The study followed the Declaration of Helsinki Ethical Principles. No written consent from the participants was required because

responding to this anonymous survey was considered as giving implicit consent.

A survey was designed based on a review of the literature and on previously validated questionnaires.[28,29] The survey consisted of five parts. Part 1 addressed the respondents' background and educational characteristics. Part 2 asked how much eight factors could put a patient at risk for PI. Part 3 inquired how important five parameters were for diagnosing PI. Part 4 asked how frequently the respondents used 15 different treatment strategies in their professional practice. The final part consisted of seven questions concerning the respondents' PI-related attitudes. The questions in Part 2 to 5 were answered on 5-point rating scales. All survey questions are provided in a supplementary document in the online *Journal of Periodontology*. The respondents answered the surveys anonymously either online or as a paper-pencil survey that they returned by regular mail to the research team in a provided stamped return envelope. The data were collected between June 2017 and December 2018.

2.2 | Study population

A recruitment email was sent to all 4,588 active members of the American Academy of Periodontology explaining the study and providing a web link to an anonymous survey. Follow-up reminder emails were sent 2 weeks and 2 months later. The recipients could use the link to the survey only once.

The research material (invitation letter and questionnaire) was translated into Dutch, German and Greek, following the process of forward and backward translation.[30] Dental specialists who were native speakers of these three languages translated the materials into their native tongue. These materials were then back translated into English, compared with the original English version, and further adjustments were made as necessary.

The Greek survey was mailed to all 224 members of the Hellenic Society of Periodontology. In the Netherlands, a recruitment email with a link to an anonymous survey was sent to all 86 registered periodontists of the Dutch Society of Periodontology. A follow-up email was sent 4 months later. In Germany, a recruitment email with a link to an online survey was sent to the 311 members of the German Society of Periodontology. Five months later, a survey was mailed to 107 periodontists for whom postal addresses were available.

2.3 | Statistical analysis

The statistical analyses were performed with a commercial software package (IBM SPSS Statistics for Windows, Version 25.0. Armonk, NY: IBM Corp). Descriptive statistics such as frequency distributions, means and standard deviations were calculated to provide an overview of the responses of the European versus U.S. periodontists. Four factor analyses (Extraction Method: Principal Component Analysis; Rotation Method: Varimax Rotation with Kaiser Normalization) were computed with the four sets of questions (risk factors/indicators, diagnostic criteria, treatment modalities, Pi-related attitudes). Cronbach alpha coefficients were calculated to determine if the sets of items loading on a specific factor had sufficient reliability to allow creating an index. Cronbach alpha values above 0.7 were considered acceptable inter-item consistencies.[31] Indices were computed by averaging the responses to the items that loaded on each respective factor. Comparisons between the two groups were performed using independent sample t-tests for responses measured on rating scales and Chi-square tests for categorical variables. The level of significance was set at 5%.

3 | RESULTS

3.1 | Response rates and participant background characteristics

Of the 4,588 U.S. and 621 European periodontists who were invited to participate in this study, 393 (8.6%) and 100 (16.1%) respectively completed the questionnaire. The breakdown of the European response rates is as follows; 37.21% ($n = 32$) in the Netherlands, 8.04% ($n = 25$) in Germany, and 19.20% ($n = 43$) in Greece. To assess if the sample sizes were large enough to compare the mean responses of U.S. versus European respondents, an a priori power analysis with the G3.1.3. Power Analysis Program (http://www.psycho.uni-duesseldorf.de/abteilungen/aap/gpower3/) was performed. Assuming a two-sided hypothesis, a medium-to-small effect size of 0.35 on the 5-point scales, a statistical significance of 0.05, a power of 0.80 and a ratio of 4:1, we would require 81 European and 323 U.S. respondents. Our actual sample sizes exceeded this requirement.

The demographic, educational and practice management characteristics of the U.S. versus European respondents are provided in Table 1. The European sample had more female respondents (31% vs 19%; $P = 0.009$) and was on average younger than the U.S. sample (46.34 vs 51.49 years; $P < 0.001$). In both groups, approximately 77% of the respondents reported working in private practice. The European periodontists worked on average 7 h more (37.72 vs 30.38 h; $P < 0.001$) and treated nine patients more (43.90 vs 34.63 patients; $P = 0.009$) per week compared to U.S. periodontists. However, in the United States the periodontists performed more implant surgeries per

TABLE 1 Overview of respondents' background characteristics and professional activities

Background characteristics	Periodontists in U.S. ($n = 393$)	Periodontists in Europe ($n = 100$)	P value
Sex			
- male	81%	69%	0.009
- female	19%	31%	
Age (mean ± SD)	51.49 ± 13.671	46.34 ± 10.038	<0.001
Dental school graduation year (mean ± SD)	1991.42 ± 13.823	1995.34 ± 9.695	0.001
Graduate program graduation year (mean ± SD)	1995.99 ± 14.003	2002.82 ± 8.626	<0.001
Lengths of residency in years (mean ± SD)	2.92 ± 2.411	2.97 ± 1.124	0.841
% residency time spent on implant surgeries (mean ± SD)	20.90% ± 21.769	19.86% ± 18.365	0.652
Did you treat patients with PI during your residency?	Yes: 39.7%	Yes: 49%	0.092
How well were you educated about (mean ± SD):			
- risk factors of PI?	3.02 ± 1.676	3.82 ± 1.290	<0.001
- how to diagnose PI?	2.99 ± 1.697	3.85 ± 1.351	< 0.001
- treating PI?	2.56 ± 1.563	3.10 ± 1.307	0.001
Percentage of current time at work spent (mean ± SD):			
- in a private practice setting	76.85% ± 38.129	76.77% ± 36.563	0.870
- in a hospital setting	2.04% ± 11.133	5.20% ± 18.134	0.191
- as a faculty member	13.0% ± 28.777	12.11% ± 27.668	0.811
- in another setting	3.77% ± 18.206	2.80%± 12.233	0.625
Number of hours per week spent at work (mean ± SD)	30.38 ± 13.288	37.72 ± 10.724	<0.001
Number of patients treated per week (mean ± SD)	34.63 ± 30.072	43.90 ± 27.356	0.009
Number of implant surgeries per month (mean ± SD)	13.90 ± 13.323	9.12 ± 13.709	0.003
Number of PI cases per month (mean ± SD)	2.71 ± 3.498	3.45 ± 4.936	0.100

month (13.90 vs 9.12; $P = 0.003$) than European periodontists. Both groups reported seeing on average between three and four PI cases per month.

The European periodontists graduated from dental schools and graduate programs more recently than the U.S. periodontists (dental school graduation year: 1995.34 vs 1991.42; $P = 0.001$ / graduate program graduation year: 2002.82 vs 1995.99; $P < 0.001$). However, the two groups did not differ in the length of the residency program nor in the percentage of time spent on implant surgeries during their residencies. The European periodontists reported being better educated during their residency about PI-related risk factors (5-point scale with 5 = best education: 3.82 vs 3.02; $P < 0.001$), diagnostic criteria (3.85 vs 2.99; $P < 0.001$), and treatment approaches (3.10 vs 2.56; $P < 0.001$) than the periodontists in the United States Less than half of the respondents in both groups had treated patients with PI during their residency.

3.2 | Risk factors/indicators for PI

The periodontists' responses concerning the risk factors/indicators for PI are presented in Table 2. A factor analysis showed that the answers to the eight items loaded on two factors which can be described as a "patient-related" factor and an "implant-related" factor, respectively. Both groups evaluated poor oral hygiene, history of periodontitis and smoking as highly important "patient-related" risk factors and diabetes and genetic predisposition as relatively less important. However, European periodontists considered poor oral hygiene (5-point answer scale: 4.64 vs 4.45; $P = 0.005$), history of periodontitis (4.36 vs 4.10; $P = 0.006$) and genetic predisposition (3.77 vs 3.53; $P = 0.021$) as more important than did U.S. respondents.

The "implant-related" risk indicators implant surface, occlusion and presence of keratinized tissue, were overall rated as less important. However, U.S. periodontists evaluated them as more important than did European periodontists (3.18 vs 2.91; $P = 0.023$, 3.75 vs 2.80; $P < 0.001$; 3.77 vs 3.27; $P < 0.001$).

In response to an open-ended question, 153 participants (31%) provided additional comments concerning risk factors. They frequently named the presence of excess cement, improper restoration, and improper implant position. Less frequently reported factors included systemic diseases, poor surgical skills, type and quality of bone, and lack of patient compliance with maintenance.

JOURNAL OF Periodontology

TABLE 2 United States and European respondents' considerations concerning risk factors/indicators for peri-implantitis

Patient-related risk factors	**Who?**	**1**[a]	**2**	**3**	**4**	**5**	**Mean ± SD, *P* value**
Poor oral hygiene	**U.S.**	0%	3.4%	10.9%	23.6%	62.2%	4.45 ± 0.818
	Europe	0%	0%	4.1%	27.6%	68.4%	4.64 ± 0.561 0.005
History of periodontitis	**U.S.**	0.5%	4.9%	17.8%	38.0%	38.8%	4.10 ± 0.895
	Europe	0%	1.0%	11.1%	38.4%	49.5%	4.36 ± 0.721 0.006
Smoking	**U.S.**	0%	1.6%	14.5%	31.1%	52.8%	4.35 ± 0.783
	Europe	0%	1.0%	12.1%	32.3%	54.5%	4.40 ± 0.741 0.554
Diabetes mellitus	**U.S.**	0.3%	7.0%	24.0%	40.2%	28.5%	3.90 ± 0.906
	Europe	0%	9.1%	28.3%	40.4%	22.2%	3.76 ± 0.905 0.177
Genetic predisposition	**U.S.**	3.7%	12.6%	29.6%	35.1%	19.1%	3.53 ± 1.051
	Europe	0%	6.1%	31.3%	42.4%	20.2%	3.77 ± 0.843 0.021
Patient related risk factor index[b] ***(alpha = 0.66)***	***U.S.*** ***Europe***	***Mean = 4.07*** ***Mean = 4.18***		***SD = 0.587*** ***SD = 0.458***			***P = 0.051***
Implant-related risk indicators[c]	**Who?**	**1**[a]	**2**	**3**	**4**	**5**	**Mean ± SD *P* value**
Implant surface	**U.S.**	6.0%	20.1%	36.5%	24.7%	12.8%	3.18 ± 1.081
	Europe	11.1%	17.2%	45.5%	22.2%	4.0%	2.91 ± 1.001 0.023
Occlusion	**U.S.**	2.4%	13.1%	22.6%	31.0%	31.0%	3.75 ± 1.102
	Europe	13.1%	22.2%	42.4%	16.2%	6.1%	2.80 ± 1.059 < 0.001
Presence of keratinized tissue	**U.S.**	2.3%	7.8%	24.4%	41.5%	24.1%	3.77 ± 0.978
	Europe	7.1%	17.2%	32.3%	28.3%	15.2%	3.27 ± 1.132 < 0.001

Legend:.

[a]The answers to the question "*How much do the following factors put a patient at risk for developing peri-implantitis?*" ranged from "1" = "not at all" to "5" = "very much".

[b]This index was computed by averaging the responses loading on the respective factor in the factor analysis of the responses concerning risk factors.

[c]No index was computed for the responses concerning the implant related risk indicators because Cronbach alpha is 0.426.

3.3 | PI diagnostic criteria

Table 3 provides an overview of the responses related to diagnostic criteria for PI. Both groups rated radiographic bone loss, clinical probing, suppuration and bleeding as the most important diagnostic factors. However, European respondents considered clinical probing as more important than U.S. respondents did (5-point scale with 5 = very important: 4.64 vs 4.04; $P < 0.001$). Although exposure of implant surface/recession of mucosal margin was considered less important by both groups, U.S. periodontists rated this factor as more important than European periodontists did (3.99 vs 3.54; $P = 0.001$).

3.4 | Management of PI

Table 4 summarizes the frequency of use of 15 different treatment modalities for the management of PI. Both groups reported using oral hygiene approaches, namely patient education and plaque control, nearly always. However, European periodontists used patient education even more frequently (4.95 vs 4.86; $P = 0.005$) than did U.S. periodontists.

A comparison of the mean index of the responses concerning the frequency of use of three non-surgical treatment approaches and five regenerative approaches showed that U.S. periodontists utilized these techniques more

TABLE 3 United States versus European respondents' considerations concerning diagnostic criteria for peri-implantitis

Diagnostic criteria[a]	Who?	1[b]	2	3	4	5	Mean ± SD, *P* value
Clinical probing	**U.S.**	1.8%	7.8%	19.8%	25.8%	44.8%	4.04 ± 1.060
	Europe	0.0%	0.0%	6.1%	24.2%	69.7%	4.64 ± 0.597 < 0.001
Radiographic bone loss	**U.S.**	0.0%	1.6%	2.1%	17.1%	79.3%	4.74 ± 0.572
	Europe	0.0%	0.0%	1.0%	20.2%	78.8%	4.78 ± 0.442 0.551
Presence of bleeding	**U.S.**	1.0%	4.9%	18.9%	26.4%	48.7%	4.17 ± 0.970
	Europe	0.0%	5.1%	15.2%	25.3%	54.5%	4.29 ± 0.906 0.249
Presence of suppuration	**U.S.**	0.3%	0.8%	7.3%	17.9%	73.8%	4.64 ± 0.674
	Europe	0.0%	0.0%	3.0%	21.2%	75.8%	4.73 ± 0.511 0.172
Implant exposure and gum recession	**U.S.**	1.6%	6.8%	20.3%	33.6%	37.8%	3.99 ± 0.997
	Europe	7.1%	11.1%	30.3%	24.2%	27.3%	3.54 ± 1.206 0.001

Legend:.

[a]No index was computed for the diagnostic criteria responses because Cronbach alpha is 0.453.

[b]The answers to the question "*How important are the following criteria to you when you make a diagnosis of peri-implantitis?*" ranged from "1" = "not at all" to "5" = "very much".

frequently (3.05 vs 2.27; $P < 0.001$) than did European periodontists. For example, mechanical debridement (4.77 vs 4.17; $P < 0.001$), local/systemic antibiotic therapy (3.88 vs 3.07; $P < 0.001$) and regeneration (3.57 vs 2.56; $P < 0.001$) were on average more frequently used in the United States

A group of five items that loaded on a third factor did not have sufficiently high inter-item consistency to justify creating an index.[31] Although resective surgery (3.53 vs 3.09; $P < 0.001$) was used more frequently in Europe than in the United States, the opposite held true for laser systems which were used more frequently in the United States than in Europe (2.11 vs 1.68; $P = 0.005$).

3.5 | PI-related attitudes

Table 5 provides an overview of the two groups' PI-related attitudes. The factor analysis of the responses to the seven attitudinal items showed that they loaded on two factors. The first factor captures the respondents' thoughts concerning the seriousness of the problem of PI. The European periodontists considered PI an even more serious problem than did the U.S. periodontists (4.75 vs 4.64; $P = 0.042$). However, the majority of periodontists in both groups agreed/agreed strongly that PI was a serious problem (U.S.: 90% vs Europe: 94.3%) and that it will become a more serious problem in the future (U.S.: 95% vs Europe: 100%).

Four items loaded on a second factor that can be described as the need for better PI-related education. The majority in both groups agreed/agreed strongly that there was a great need for a standardized treatment protocol (U.S.: 87.3% vs Europe: 96.6%), with the European periodontists agreeing on average even more strongly than did the U.S. periodontists (4.66 vs 4.43; $P = 0.002$). Nearly all respondents in both groups agreed/agreed strongly that general dentists need to be better trained to diagnose PI, to refer PI cases, and to offer maintenance care for dental implants. In addition, the European periodontists agreed more strongly with the statement "I would like to attend continuing education courses about the treatment of PI" compared to the U.S. periodontists (4.47 vs 4.17; $P = 0.004$).

4 | DISCUSSION

To the best of the authors' knowledge, this is the first study comparing the PI-related considerations, professional behavior and attitudes of periodontists practicing in the United States versus Europe. The overall response rate in Europe was 16.1% (the Netherlands: 37.2%, Germany: 8.0%, and Greece: 19.2%). The response rates of web-based and postal mail surveys were reported to be 11% and 26%, respectively.[32] In the present study, the data in the Netherlands and most of the German data were collected with web-based surveys, whereas the Greek and some German data were collected via postal mail. The overall response rate for the European countries is therefore within the expected range. The response rate in the United States (8.6%) was slightly smaller than the percentage reported

JOURNAL OF Periodontology

TABLE 4 Percentage of use of different treatment strategies for peri-implantitis by respondent group

Oral hygiene related treatment	**Who?**	**1**[a]	**2**	**3**	**4**	**5**	**Mean ± SD, *P* value**
- Educating the patient about oral hygiene	**U.S.**	0.0%	1.3%	1.8%	7.0%	89.9%	4.86 ± 0.488
	Europe	0.0%	0.0%	0.0%	5.1%	94.9%	4.95 ± 0.220 0.005
- Plaque control	**U.S.**	0.0%	1.0%	1.6%	7.0%	90.4%	4.87 ± 0.456
	Europe	0.0%	0.0%	0.0%	7.1%	92.9%	4.93 ± 0.258 0.080
Oral hygiene treatment index[b] ***(alpha = 0.97)***	***U.S.***	***Mean = 4.86***		***SD = 0.467***			***P = 0.020***
	Europe	***Mean = 4.93***		***SD = 0.228***			
Non-surgical and regenerative treatment	**Who?**	**1**[1]	**2**	**3**	**4**	**5**	**Mean ± SD, *P* value**
- Mechanical debridement	**U.S.**	0.3%	0.8%	3.4%	13.2%	82.4%	4.77 ± 0.570
	Europe	7.4%	4.3%	12.8%	14.9%	60.6%	4.17 ± 1.250 < 0.001
- Antiseptic cleansing	**U.S.**	2.4%	5.0%	13.9%	22.8%	56.0%	4.25 ± 1.024
	Europe	5.1%	5.1%	19.2%	22.2%	48.5%	4.04 ± 1.160 0.077
- Local/systemic antibiotic therapy	**U.S.**	3.1%	8.3%	21.9%	31.0%	35.7%	3.88 ± 1.085
	Europe	7.1%	26.3%	27.3%	31.3%	8.1%	3.07 ± 1.090 < 0.001
- Regeneration	**U.S.**	4.0%	10.1%	30.9%	35.2%	19.7%	3.57 ± 1.042
	Europe	15.3%	33.3%	33.3%	16.7%	1.4%	2.56 ± 0.991 < 0.001
- Autogenous bone graft	**U.S.**	32.3%	24.7%	19.9%	16.3%	6.7%	2.40 ± 1.274
	Europe	38.9%	26.3%	23.2%	8.4%	3.2%	2.11 ± 1.115 0.026
- Allograft	**U.S.**	9.6%	10.7%	26.0%	39.1%	14.8%	3.39 ± 1.150
	Europe	38.9%	21.1%	28.4%	10.5%	1.1%	2.14 ± 1.088 < 0.001
- Xenograft	**U.S.**	31.7%	15.9%	19.8%	24.4%	8.2%	2.61 ± 1.363
	Europe	29.0%	25.8%	29.0%	14.0%	2.2%	2.34 ± 1.108 0.048
Regenerative treatment	**Who?**	**1**[a]	**2**	**3**	**4**	**5**	**Mean ± SD, *P* value**
- GTR with a membrane	**U.S.**	7.7%	11.6%	25.1%	40.7%	14.8%	3.43 ± 1.113
	Europe	27.7%	21.3%	28.7%	19.1%	3.2%	2.49 ± 1.180 < 0.001
Non-surgical and regenerative treatment index[b] ***(alpha = 0.79)***	***U.S.***	***Mean = 3.05***		***SD = 0.848***			***P < 0.001***
	Europe	***Mean = 2.27***		***SD = 0.824***			
Single items	**Who?**	**1**[1]	**2**	**3**	**4**	**5**	**Mean ± SD, *P* value**
- Alloplast	**U.S.**	64.5%	14.5%	11.0%	7.0%	2.9%	1.69 ± 1.098
	Europe	56.3%	21.1%	15.5%	5.6%	1.4%	1.75 ± 1.010 0.699

(Continues)

TABLE 4 (Continued)

Regenerative treatment	Who?	1[a]	2	3	4	5	Mean ± SD, *P* value
- Resective surgery	**U.S.**	10.6%	16.4%	34.1%	31.2%	7.7%	3.09 ± 1.096
	Europe	5.2%	13.5%	19.8%	45.8%	15.6%	3.53 ± 1.076 < 0.001
- Implantoplasty	**U.S.**	19.6%	26.9%	25.3%	21.0%	7.3%	2.69 ± 1.210
	Europe	25.6%	20.0%	17.8%	26.7%	10.0%	2.76 ± 1.360 0.693
- Laser systems	**U.S.**	55.9%	11.6%	9.6%	11.6%	11.3%	2.11 ± 1.459
	Europe	72.0%	8.6%	7.5%	3.2%	8.6%	1.68 ± 1.270 0.005
- Photodynamic therapy	**U.S.**	81.1%	9.5%	6.0%	3.2%	0.3%	1.32 ± 0.751
	Europe	75.0%	13.0%	5.4%	3.3%	3.3%	1.47 ± 0.977 0.184

Legend:

[a]The answers to the question "*How often do you use the following treatment strategies when you treat a patient with peri-implantitis?*" ranged from "1" = "never" to 5 = "always".

[b]Indices were computed by averaging the responses loading on the respective factor for which an index was created.

for web-based surveys.[32] Responses to web-based surveys might have decreased over the past decade because of survey fatigue.[33]

The European and U.S. samples were different in terms of gender and age. Although both groups were predominantly male, the European sample included more female respondents than the U.S. sample. Even though the percentage of women in dentistry has been rising during the past decades, women are still underrepresented in specialties, academia and leadership roles.[34] Furthermore, European periodontists were younger and graduated from dental schools and specialty programs more recently than U.S. periodontists. This could be explained by the different education systems; In the United States, it takes about 8 years to become a dentist (4 years of college and 4 years of dental school), whereas it takes only 5 to 6 years after high school in Europe. The more recent graduation years might also explain why the European periodontists reported being better educated about PI-related risk factors, diagnostic criteria, and treatment approaches during their residency compared to the periodontists in the United States The majority of participants in both groups worked in private practices. Although the European periodontists treated more patients per week, they placed fewer implants per month than the U.S. periodontists. The increasing prevalence of dental implants in the U.S. compared to Europe, might explain this difference.[35] According to the European Implant Market Report, the recent economic crisis in Europe limited implant treatments to some degree.[36] Furthermore, possible differences in selection criteria for implant placement in Europe versus United States, might account for the lower number of implants placed by the European periodontists.

Poor oral hygiene, history of periodontitis and smoking were the most strongly endorsed patient-related risk factors by both groups. These results are in line with the current literature[2,37] and are consistent with the results of previous studies.[28,38,39] However, in the present study, poor oral hygiene and history of periodontitis were considered as even more important by the European periodontists compared to the U.S. periodontists. Although the prevalence of periodontitis in Europe is similar to that in the United States, and is increasing with age,[40,41] overall, the population in Europe is older.[42,43] It is therefore possible that the European periodontists have encountered more older patients in their practices, and thus treated patients who were more prone to PI. On the other hand, whereas both groups considered implant-related risk indicators such as implant surface, occlusion and presence of keratinized tissue as less important, the aforementioned factors were rated more highly by the U.S. periodontists than by the European periodontists. Other studies also showed that adverse occlusal loading was a more popular risk indicator among specialists in the United States than among specialists in Australia and U.K.[28,38] When the participants were asked to provide additional comments on the risk factors for PI, they highlighted the presence of cement, poor emergence profile of restoration, improper implant position, systemic diseases and medications, poor surgical skills, type and quality of bone and lack of patient compliance with maintenance. Recent research also identified these factors as important.[9,44,45]

The most frequently used diagnostic criteria by both groups included radiographic bone loss, clinical probing and presence of bleeding and suppuration. Both groups evaluated implant exposure and mucosal recession as

JOURNAL OF Periodontology

TABLE 5 United States versus European periodontists' attitudes related to peri-implantitis

Attitudes towards peri-implantitis	**Who?**	**1**[a]	**2**	**3**	**4**	**5**	**Mean ± SD, *P* value**
I consider peri-implantitis a serious problem currently.	**U.S.**	0.3%	1.3%	8.4%	23.2%	66.8%	4.55 ± 0.725
	Europe	0.0%	0.0%	5.7%	17.0%	77.3%	4.72 ± 0.566 0.021
Peri-implantitis will become a more serious issue in the future.	**U.S.**	0.0%	1.0%	3.9%	15.4%	79.6%	4.74 ± 0.580
	Europe	0.0%	0.0%	0.0%	18.5%	81.5%	4.81 ± 0.391 0.137
PI seriousness index [b] ***(alpha = 0.69)***	***U.S .***	***Mean = 4.64***		***SD = 0.573***		***P = 0.042***	
	Europe	***Mean = 4.75***		***SD = 0.433***			
Need for better education	**Who?**	**1**[1]	**2**	**3**	**4**	**5**	**Mean ± SD, *P* value**
There is a great need for a standardized protocol for the treatment of peri-implantitis.	**U.S.**	0.8%	2.9%	9.1%	27.2%	60.1%	4.43 ± 0.834
	Europe	0.0%	0.0%	3.4%	27.6%	69.0%	4.66 ± 0.546 0.002
General dentists need to be better educated:	**Who?**	**1**[1]	**2**	**3**	**4**	**5**	**Mean ± SD, *P* value**
- about how to diagnose peri-implantitis.	**US**	0.0%	0.3%	2.1%	15.9%	81.7%	4.79 ± 0.473
	Europe	1.1%	1.1%	2.2%	12.2%	83.3%	4.76 ± 0.659 0.554
- about when to refer a patient for the treatment of peri-implantitis.	**US**	0.0%	0.0%	1.0%	10.2%	88.8%	4.88 ± 0.359
	Europe	0.0%	1.1%	3.3%	14.1%	81.5%	4.76 ± 0.562 0.061
- about how to offer maintenance care for implants.	**U.S.**	0.3%	0.5%	2.9%	15.1%	81.2%	4.77 ± 0.548
	Europe	2.5%	1.2%	3.7%	17.3%	75.3%	4.62 ± .830 0.129
Need for better education index [b] ***(alpha = 0.79)***	***U.S .***	***Mean = 4.81***		***SD = 0.389***		***P = 0.186***	
	Europe	***Mean = 4.72***		***SD = 0.587***			
Single item	**Who?**	**1**[1]	**2**	**3**	**4**	**5**	**Mean ± SD, *P* value**
I would like to attend continuing education courses about the treat-ment of peri-implantitis.	**U.S.**	3.4%	3.9%	16.5%	24.7%	51.4%	4.17 ± 1.058
	Europe	0.0%	4.5%	7.9%	23.6%	64.0%	4.47 ± 0.827 0.004

Legend:

[a]Answers ranged from "1" = "disagree strongly" to "5" = "agree strongly".

[b]Indices were computed by averaging the responses loading on the respective factor for which an index was created.

relatively less significant for the diagnosis of PI. These responses are in line with the current consensus report, which described recession of the mucosal margin as a clinical sign of PI, but did not include it in the diagnostic criteria.[1] A previous study that assessed New Zealand specialists' attitudes towards the diagnosis and treatment of PI also reported that the most frequently used diagnostic criteria were clinical probing and radiographs, whereas the presence of implant exposure and gingival recession were considered as less significant.[29] However, this study did not include the inflammatory parameters bleeding and suppuration upon probing.[29]

The results of the present study reflect the therapeutic complexity of PI, and the lack of a standardized therapeutic protocol.[19] Although both groups nearly always used patient education, plaque control and mechanical debridement, the European periodontists used patient education more frequently and mechanical debridement and antiseptics/ antibiotics less frequently than did the U.S. periodontists. The prescription of antibiotics has been higher in the United States than Europe, which may account for the higher preference of the U.S. periodontists towards the use of antibiotics for the treatment of PI.[46] Other adjunctive measures including lasers and photodynamic therapy were relatively less frequently used by both groups, with lasers being used more frequently in the United States than in Europe. This finding is in line with a report by iData Research which stated that in Europe, the use of lasers in dentistry was more limited than in the United States[47] One of the reasons European dentists were more reluctant to invest in laser technologies was the lack of government reimbursement for laser treatment in several European countries.[47]

Concerning surgical treatment, U.S. periodontists, used regenerative approaches more frequently and resective surgery less frequently than European periodontists did. These results are in contrast with a survey which investigated the treatment modalities used by periodontists in the United States and reported that surgical debridement was selected more often than resective or regenerative approaches.[38] Another study showed that 66.7% of the periodontists in New Zealand often used surgical procedures for the treatment of PI, although no distinction was made between different surgical techniques.[29] Schmidlin et al. evaluated the management of PI in private practices of specialists versus non-specialists in Switzerland and reported that approximately 80% of the specialists tended to use regenerative approaches.[39] However, direct comparisons among these studies cannot be made because of the heterogeneities in aims, study population, and question format. A recent systematic review on the long-term outcomes of surgical treatment concluded that the use of reconstructive approaches resulted in more successful clinical and radiographic outcomes.[48] Regarding the use of different bone fillers, it is worth noting that U.S. periodontists used allograft more frequently than did European periodontists. This preference could be attributed to the fact that in Europe, the use of allografts is very limited compared to the United States because of strict regulations.[49]

In our research, both groups agreed that PI is a serious problem and that there is a need for better education of general practitioners about the diagnosis of PI, the referral of such cases to specialists, and the maintenance care offered to patients with dental implants. Both groups also agreed that there is a need for a standardized treatment protocol. These results are consistent with the findings of Russel et al. who assessed the attitudes towards PI of periodontists and oral and maxillofacial surgeons in New Zealand and reported that both groups of specialists considered PI a significant disease and highlighted the need for better education of general practitioners and referral of PI cases to specialists.[29]

This study has several limitations. First, we cannot necessarily assume that the three European countries are truly representative of all European countries. Future research should continue to explore PI related professional activities in different countries to allow for better understanding of the complexity of PI related professional behavior and the role of context for this behavior. Second, although combining the responses from the three European countries resulted in a sufficient sample size that allowed comparisons with the U.S. responses, subgroup analyses of the European responses were not possible. In addition, this survey did not assess whether the respondents were board certified. It only considered that the respondents were members of professional periodontology societies in their countries. Future studies should explore if board certified professionals differ from non-board certified professionals in their responses regarding PI in the United States or other countries. Finally, a survey consists of a limited number of questions. The fact that the respondents named some additional risk factors in their open-ended responses is important information for future research.

5 | CONCLUSIONS

All respondents engaged in evidence-based professional behavior related to PI. Regarding PI-related risk factors/indicators, both groups rated poor oral hygiene, history of periodontitis, and smoking as very important, and, implant surface, occlusion and presence of keratinized tissue as relatively less important. However, European periodontists put a higher value on history of periodontitis and a lower value on implant surface, occlusion and presence of keratinized tissue as risk factors than did U.S

periodontists. Similarly, although all periodontists assessed radiographic bone loss as the most important diagnostic factor and implant exposure/gum recession as the least important factor, U.S. and European periodontists differed in their assessment of the relative importance of clinical probing and implant exposure/gum recession. European periodontists put a higher value on clinical probing than did their U.S. counterparts, whereas U.S. periodontists ranked implant exposure/gum recession as a more important diagnostic factor than did European periodontists.

For the management of PI, both groups nearly always relied on patient education, plaque control and mechanical debridement. Significant differences were found in relation to surgical treatments and the use of lasers and antibiotics. The U.S. periodontists were more likely to use antibiotics, lasers, allograft and regenerative approaches and less likely to use resective surgery than European periodontists. Both groups acknowledged that PI is an emerging, significant concern and that there is a need to educate general dentists better about identifying risk factors, diagnosing and referring PI cases for treatment to specialists.

AUTHOR CONTRIBUTIONS

Marita R. Inglehart and Sharon Aronovich conceived and designed the study and the original survey and collected the data in the United States. Marita R. Inglehart, Angeliki Polymeri, Bruno G. Loos, and Larissa Steigmann worked on the translations and pilot studies of the surveys into Dutch, German, and Greek. Angeliki Polymeri and Bruno G. Loos collected the data in the Netherlands; Angeliki Polymeri collected the data in Greece; Marita R. Inglehart and Larissa Steigmann collected the data in Germany. Marita R. Inglehart and Angeliki Polymeri analyzed the data, and all authors worked on drafting the manuscript and gave final approval of the submitted version. The authors report no conflicts of interest related to this study.

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SUPPORTING INFORMATION

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