





# Periodontitis in young individuals: Important factors for disease progression

Carolina Modin<sup>1,2</sup>  | Caroline Dolk Rinon<sup>1</sup> | Ali Faham<sup>1</sup> | Anders Gustafsson<sup>2</sup>  |  
Tülay Yucel-Lindberg<sup>3</sup>  | Leif Jansson<sup>1,2</sup> 

<sup>1</sup>Department of Periodontology, Folk tandvården Stockholms län AB, Folk tandvården Eastmaninstitutet, Stockholm, Sweden

<sup>2</sup>Division of Periodontology, Department of Dental Medicine, Karolinska Institutet, Huddinge, Sweden

<sup>3</sup>Division of Pediatric Dentistry, Department of Dental Medicine, Karolinska Institutet, Huddinge, Sweden

## Correspondence

Carolina Modin, Department of Periodontology, Folk tandvården Stockholms län AB, Eastmaninstitutet, Dalagatan 11, Box 6031, SE-102 31 Stockholm, Sweden.  
Email: [carolina.modin@regionstockholm.se](mailto:carolina.modin@regionstockholm.se)

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## Abstract

**Aim:** To investigate the progression of periodontitis in young individuals and identify factors that contribute to progression rate and whether periodontitis stage and grade have an impact on disease progression.

**Materials and Methods:** This retrospective cohort study was based on patients younger than 36 years at two periodontal clinics between 2003 and 2009. At least 10 years later, a clinical and radiographic examination was performed on 215 patients. The marginal bone loss between baseline and follow-up for the tooth with the most severe bone loss at follow-up was estimated by radiographic measurements. Linear regression analysis was used to investigate the influence of potential risk indicators on periodontitis progression.

**Results:** Most patients (83%) were classified as periodontitis stage III at baseline. At follow-up, 70% of these patients remained in stage III. The frequency of patients with grade C decreased from 79% to 17% at follow-up. The median (Q25%; Q75%) of the longitudinal marginal bone loss was 0.5 mm (0.0; 2.0). High bleeding on probing (BOP) index at baseline, smoking and interruption of periodontal treatment were found to significantly increase longitudinal bone loss.

**Conclusions:** High levels of BOP at baseline, smoking and interruption of periodontal treatment increased the risk of marginal bone loss. The stage and grade at baseline had no significant impact on disease progression.

## KEYWORDS

bone loss, disease progression, grade, periodontitis, stage

## Clinical Relevance

*Scientific rationale for study:* The knowledge about the long-term prognoses of periodontitis among young patients is lacking, especially for those not being well maintained over time.

*Principal findings:* Most of the young individuals included in this cohort showed stable periodontal conditions after at least 10 years of follow-up. However, high levels of bleeding on probing at baseline, smoking and interruption of periodontal treatment increased the risk of disease progression.

*Practical implications:* Treating young individuals with periodontitis can be challenging because of low compliance. Our results underline the importance of continuing periodontal treatment in this patient group.

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## 1 | INTRODUCTION

Periodontitis mostly affects adults with clinical signs usually after 40 years of age. Most adults worldwide have mild to moderate signs of the disease (Demmer & Papapanou, 2010; Frencken et al., 2017; Papapanou & Susin, 2017). Severe periodontitis is more unusual and affects approximately 10%–12% of the adult population (Kassebaum et al., 2014). Periodontitis affecting younger people is, on the other hand, very rare. The prevalence of the former diagnosis aggressive periodontitis (AgP) is between 0.5% to 5% (Bouziane et al., 2020).

Research on young individuals with periodontitis often includes a small number of patients. Consequently, the optimal treatment and disease progression over time are not clear. Currently, the treatment concept and goal are mostly the same for all forms of periodontitis (Teughels et al., 2014). A systematic review by Nibali et al. (2013), based on 16 studies, investigated tooth loss and disease progression in patients with AgP. Despite the high heterogeneity between the studies, most patients affected by AgP seemed to have a good prognosis if enrolled in a maintenance program. However, the authors stated that 'it is important to highlight that limited data exist on AgP patients not treated or not undergoing regular maintenance, that could exhibit different progression patterns'. Bäumer et al. (2020) recently presented a study with long-term follow-up of 100 AgP patients. They investigated tooth loss 25 years after active periodontal therapy and found that tooth loss rarely occurred in this group. It is important to know that these patients were well maintained in private practice. Several studies have reported similar results (Baumer, El Sayed, et al., 2011; Baumer, Pretzl, et al., 2011; Diaz-Faes et al., 2016; Graetz et al., 2017; Miller et al., 2017). In contrast, one study from 2018 by Goh et al. (2018) showed that AgP patients who smoked and neglected maintenance care after active periodontal treatment had a higher risk of disease progression.

Knowledge regarding the long-term prognosis of periodontitis in young patients without regular supportive periodontal care (SPC) after active periodontal therapy is limited. The purpose of this study was to investigate the long-term progression ( $\geq 10$  years) of periodontitis in young individuals by measuring the longitudinal marginal bone loss for the tooth with the most severe bone loss at follow-up and to identify factors that contribute to disease progression. The cohort included a mixed sample of patients, both with and without regular SPC. In addition, we aimed to evaluate the new periodontal classification system in this context and investigate whether periodontitis stage and grade at baseline have an impact on disease progression.

## 2 | MATERIALS AND METHODS

### 2.1 | Ethical approval and informed consent

The study was conducted in accordance with the Declaration of Helsinki and was approved by the Regional Ethics Board in Stockholm (Application number 2017/1757-31), and it was registered at [ClinicalTrials.gov](https://clinicaltrials.gov) (556574-3597). All individuals were informed of the

purpose of the study and voluntary participation before providing written consent. The guidelines on Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) were followed (von Elm et al., 2008).

### 2.2 | Study design and patient selection

This was a retrospective cohort study based on patients aged <36 years who had been referred to the periodontal clinics in the Public Dental Service, Stockholm, between 2003 and 2009. At least 10 years (mean 12.8, range 10–17) after periodontal diagnosis, all patients with the earlier diagnosis of aggressive or chronic periodontitis were invited by mail to a free of charge clinical and radiographic examination at Eastmaninstitutet in Stockholm (follow-up investigation) if they fulfilled the following additional inclusion criteria: having full-mouth x-ray results from baseline examination and living in Stockholm County. The exclusion criteria were as follows: not living in Stockholm County, or had passed away since the baseline exam. All participants provided written consent to participate in the study. We attempted to reach non-responders with a second letter, SMS and telephone calls.

Five calibrated periodontists performed the examinations, which took place from October 2018 to March 2020. The clinical examination included complete periodontal status, and the radiographic examination consisted of an orthopantomogram, vertical bitewing x-rays and two periapical x-rays in the maxillary/mandibular incisor regions. The participants also completed a questionnaire comprising 36 questions.

### 2.3 | Data collection and variables

Baseline variables and variables from the treatment period at the periodontal clinic were collected from the dental records by two calibrated periodontists. These variables, including those registered at the follow-up investigation, are presented in Table 1. Alveolar bone levels and root lengths on radiographs were assessed using a software program (Romexis 5.3; Planmeca, Finland).

The questionnaire consisted of two parts. The first part comprised a set of questions about general health, smoking, oral hygiene habits, supportive dental care after active periodontal treatment, occupation and education level, while the second part was based on 18 questions regarding self-perceived oral health from the Oral Health Impact Profile (OHIP-CP) (He et al., 2017). The questions were divided into three focus areas: pain and functional limitations; psychological discomfort; and psychological disability/social handicap.

One periodontist (C.M.) classified all patients according to the new periodontal classification system, both baseline and follow-up data (Papapanou et al., 2018; Tonetti et al., 2018). The periodontitis progression rate during the previous 5 years was estimated from radiographs if available; otherwise, the percentage of bone loss/age ratio was calculated. Another periodontist (L.J.) classified the same

**TABLE 1** Characteristics of the study population at baseline and at follow-up.

Variable	n	Baseline	n	Follow-up	p-Value
Age	215	30 (23; 33)	215	43 (36; 46)	-
Male/female	215	89 (41.4)/126 (58.6)	215	89 (41.4)/126 (58.6)	-
Systemic disease	215		215		
Diabetes		3 (1.4)		9 (4.2)	.031 <sup>a</sup>
Cardio-vascular disease		2 (0.9)		8 (3.7)	.11 <sup>a</sup>
Rheumatoid arthritis		1 (0.5)		3 (1.4)	.50 <sup>a</sup>
Psychiatric diagnosis		2 (0.9)		4 (1.9)	.69 <sup>a</sup>
Other		5 (2.3)		7 (3.3)	.75 <sup>a</sup>
Education	-	-	202		-
Elementary school/gymnasium				102 (48.8)	
Folk high school				9 (4.3)	
High school/university				98 (46.9)	
Occupation	209		209		
Student		56 (26.8)		8 (3.8)	.001 <sup>a</sup>
Working		129 (61.7)		179 (85.6)	<.001 <sup>a</sup>
Unemployed		8 (3.8)		9 (4.3)	1.0 <sup>a</sup>
Other		16 (7.7)		13 (6.2)	.61 <sup>a</sup>
Smoking habit	211		215		
Non-smoker		150 (71.1)		141 (65.6)	.22 <sup>a</sup>
Current smoker		50 (23.7)		34 (15.8)	.023 <sup>a</sup>
Former smoker		11 (5.2)		40 (18.6)	<.001 <sup>a</sup>
Number of teeth	215	28 (28; 31)	215	28 (26; 30)	<0.001 <sup>b</sup>
General marginal bone loss (% of root length)	213		215		<0.001 <sup>c</sup>
<15%		132 (61.4)		121 (56.3)	
≥15% and <33%		65 (30.5)		74 (34.4)	
≥33%		16 (7.5)		20 (9.3)	
Oral hygiene	-	-	214		-
Good				72 (33.6)	
Partly poor				84 (39.3)	
Poor				58 (27.1)	
Bleeding on probing index (BOP) (%)	180	34 (17; 54)	215	16 (9; 29)	.001 <sup>b</sup>
Number of sites with probing depth >4 mm	180	13 (7; 23)	215	5 (2; 11)	<.001 <sup>b</sup>
Number of sites with probing depth >6 mm	180	2 (1; 5)	215	0 (0; 2)	<.001 <sup>b</sup>
Periodontal classification	215		215		<.001 <sup>c</sup>
Gingival health on a reduced periodontium		0		16 (7.4)	
Gingivitis on a reduced periodontium		0		9 (4.2)	
Periodontitis stage I		5 (2.3)		7 (3.3)	
Periodontitis stage II		27 (12.5)		27 (12.5)	
Periodontitis stage III II		179 (83.3)		135 (62.8)	
Periodontitis stage IIV		4 (1.9)		21 (9.8)	
Periodontitis grade	215		190 <sup>d</sup>		<.001 <sup>c</sup>
A		1 (0.5)		89 (46.8)	
B		45 (20.9)		65 (34.2)	
C		169 (78.6)		36 (18.9)	
Extent of periodontitis	215		190 <sup>d</sup>		
Generalized		89 (41.4)		51 (26.8)	<.001 <sup>a</sup>

**TABLE 1** (Continued)

Variable	n	Baseline	n	Follow-up	p-Value
Localized		74 (34.4)		112 (58.9)	
Molar/incisor pattern		52 (24.2)		27 (14.2)	

Note: Data are presented as median (Q25%; Q75%) or as number (percentage).

Abbreviations: Q25%, 25th percentile; Q75%, 75th percentile.

<sup>a</sup>McNemar test.

<sup>b</sup>Paired *t*-test.

<sup>c</sup>Wilcoxon sign rank test.

<sup>d</sup>Cases with gingival health or gingivitis on a reduced periodontium were excluded.

patients, and in cases where the assessments differed, the cases were discussed until a consensus was reached. The inter-examiner reliability of the periodontal classifications was estimated by repeating the assessments of 20 cases about 2 months after the initial assessments, and the kappa values were found to be .75 (C.M.) and .73 (L.J.). The kappa value of the inter-examiner reliability at repeated measurements was .71.

The marginal bone loss between baseline and follow-up for the tooth with the most severe bone loss at follow-up (primary outcome variable) was estimated by radiographic measurements on mesial or distal surfaces on intra-oral x-rays by two examiners (C.M. and L.J.). Teeth with bone loss due to endodontic complications and cases not having x-rays from baseline examination were excluded ( $n = 8$ ) from the study. The intra-examiner agreements according to measurement error were  $0.30 \pm 0.30$  mm (L.J.) and  $0.32 \pm 0.33$  mm (C.M.), while the inter-examiner agreement was  $0.33 \pm 0.44$  mm. Finally, the measurements were rounded to the nearest 0.5 mm.

## 2.4 | Statistical analysis

Descriptive statistics and statistical analyses were performed using IBM SPSS Statistics 26 software (SPSS Inc., Chicago, IL, USA). The McNemar test, Wilcoxon signed-rank test and paired *t*-test were used for pairwise comparisons. Comparisons between independent groups stratified according to periodontitis grade at follow-up were made using one-way analysis of variance (ANOVA) for numerical variables and the chi-squared test/Fisher's exact test for categorical variables. Bonferroni correction was used for multiple comparisons within groups. The correlation between the periodontitis grades at baseline and at follow-up was calculated using Spearman's correlation. The influence of the variables registered at baseline on bone loss between baseline and follow-up was calculated using the Kruskal-Wallis test. Backward linear regression using marginal bone loss between baseline and follow-up for the tooth, with the most severe bone loss at follow-up as the dependent variable, was used to investigate the influence of potential risk indicators on periodontitis progression. Two-way interactions between independent variables were tested for significance. As the distribution was positively skewed, logarithmic transformation ( $\log_{10}[x + 4.5]$ ) was performed before the analysis. Independent variables were included in the regression model if  $p$  was  $<.10$ . Multicollinearity was measured by calculating the variance inflation factor (VIF). Missing data were excluded in the analyses, and complete-case

analysis was performed. The progression model was evaluated by using an independent random sample from the initial dataset. The results were considered statistically significant at  $p < .05$ .

## 3 | RESULTS

### 3.1 | Study population

A total of 684 patients were included, of whom 471 fulfilled the inclusion criteria (Figure S1). The response rate was 46%, and 215 patients accepted the invitation for clinical periodontal examination  $\geq 10$  years after diagnosis (108 with AgP and 107 with chronic periodontitis). The baseline and follow-up characteristics of the study sample are shown in Table 1. The median age at baseline and at follow-up was 30 (range 13–35) and 43 (range 24–52) years, respectively, and the majority of the participants were females (59%). The frequency of smokers decreased significantly from 24% at baseline to 16% during the follow-up investigation. The general marginal bone loss increased significantly during the follow-up period ( $p < .001$ ). However, the BOP scores and the number of sites with probing depths  $>4$  and  $>6$  mm were significantly lower at follow-up.

The patients who declined clinical examination ( $n = 256$ ) had a significantly higher BOP index and more sites with deepened periodontal pockets compared with those examined at baseline (Table 2). In addition, these patients more frequently discontinued specialist periodontal treatment.

### 3.2 | Periodontal classification

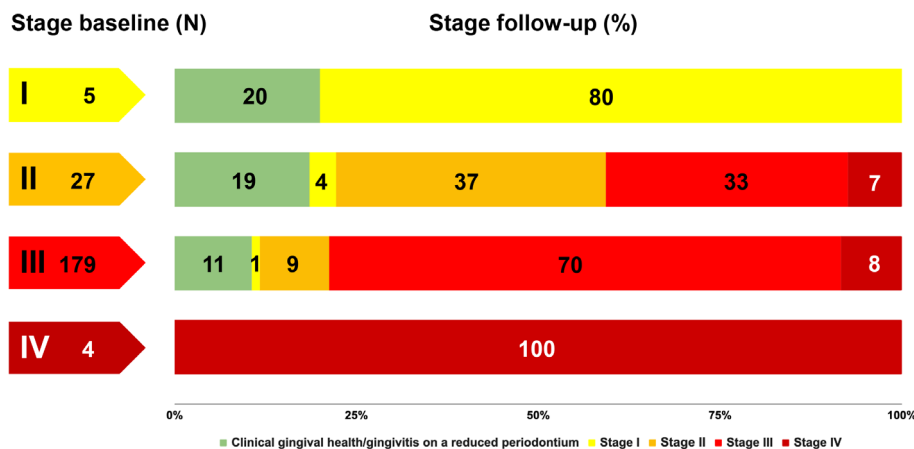
The majority (83%) of the patients were classified as periodontitis stage III at baseline (Table 1 and Figure 1). Seventy percent ( $n = 126$ ) of these patients remained in stage III at follow-up, 8% had shifted to stage IV and 11% were classified as “Clinical gingival health” on a reduced periodontium is a new classification since 2018 (Chapple et al) and we presume that the readers of this paper is aware of this (Figure 1). Thirteen percent were classified as periodontitis stage II at baseline; 40% in this group had shifted to stages III or IV at follow-up and 19% were classified as healthy or gingivitis (Figure 1).

The relationship between the periodontitis grade at baseline and at follow-up is presented in Figure 2. Forty-one percent were

**TABLE 2** Characteristics at baseline for clinically examined and non-examined subjects.

Variable	n	Examined	n	Non-examined	p-Value
Age	215	27.9 (6.3)	256	27.5 (6.6)	.46
Male/female	215	89 (41.4)/126 (58.6)	256	116 (45.3)/140 (54.7)	.39
Systemic disease		13 (6.1)		26 (10.2)	.11
Smoking habit	211		253		
Non-smoker		150 (71.1)		155 (61.3)	.08
Current smoker		50 (23.7)		78 (30.8)	
Former smoker		11 (5.2)		20 (7.9)	
Number of teeth	215	28.9 (2.1)	255	28.8 (2.5)	.47
Bleeding on probing index (BOP)	180	36.8 (24.3)	234	49.2 (27.5)	<.001
Number of sites with probing depth >4 mm	180	17.4 (14.8)	236	22.4 (18.1)	.003
Number of sites with probing depth >6 mm	180	4.3 (5.8)	236	5.8 (7.9)	.030
Periodontitis stage	215		253		.002
I		5 (2.3)		10 (4.0)	
II		27 (12.5)		31 (12.3)	
III		179 (83.3)		187 (73.9)	
IV		4 (1.9)		25 (9.9)	
Interrupted periodontal treatment	215	86 (40.0)	256	160 (62.5)	<.001

Note: Data are presented as mean ± standard deviation or number (percentage). Unpaired *t*-test was used for continuous variables and chi-squared test for categorical variables.

**FIGURE 1** Change of periodontitis stage from baseline to follow-up.

classified as grade A at follow-up compared with 0.5% at baseline (Figure 2). In addition, the frequency of patients with periodontitis grade C decreased from 79% at baseline to 17% at follow-up (Figure 2). Among those with grade B at baseline, four patients (9%) shifted from grade B to grade C (Figure 2). The correlation between periodontitis grade at baseline and at follow-up was not significant ( $p = .33$ ).

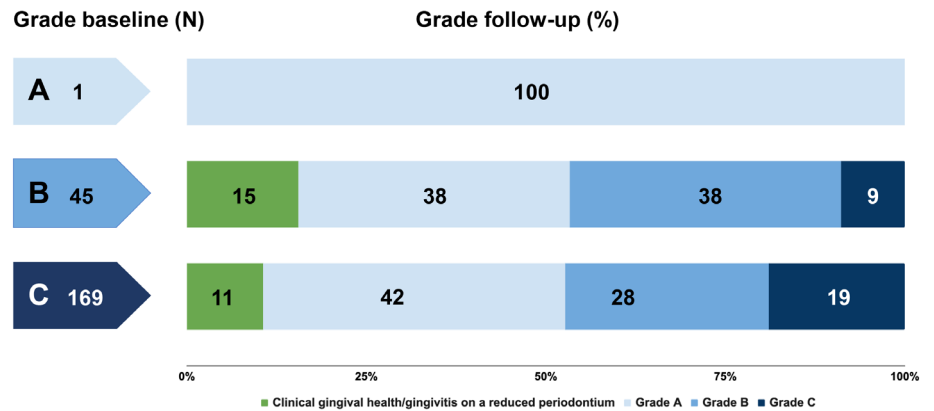
### 3.3 | Periodontal treatment

The mean treatment duration at the specialist clinic, including both active periodontal treatment (APT) and supportive care, was 3.5 ± 3.2 years. APT included non-surgical treatment (89%), resective

periodontal surgery (29%), regenerative periodontal surgery (25%), extraction therapy (33%) and systemic antibiotic treatment (5.1%). Forty percent of the participants discontinued their APT or supportive care at the periodontal clinics. Sixteen patients (7.4%) remained with the specialist clinic during the whole follow-up period.

### 3.4 | Association between periodontitis grade and investigated variables at follow-up

The sample was stratified according to clinical gingival health/gingivitis on a reduced periodontium and periodontitis grade A, B or C at follow-up. These four groups were compared according to the investigated follow-up variables (Table 3).

**FIGURE 2** Change of periodontitis grade from baseline to follow-up.

The number of smokers differed significantly between the groups (Table 3). The highest frequency of smokers (33%) was found in group 4 (grade C). The BOP score and the number of sites with deepened periodontal pockets (>4 and >6 mm) differed significantly between the groups. The frequency of diabetes also differed significantly ( $p = .013$ ) between the groups (Table 3). In addition, the education level differed significantly between the groups ( $p = .044$ ), whereas no significant difference according to occupation was observed (Table 3). The patients in group 4 received supportive care less frequently during the follow-up period (11%) than those in group 2 (Table 3). Finally, the OHIP-18 scores differed significantly between the groups; the scores were highest in groups 3 and 4 (Table 3). The individual's experience of pain and functional limitation was significantly greater in group 4 than in group 2.

### 3.5 | Association between periodontitis progression and investigated variables

The median (Q25%; Q75%) of the marginal bone loss for the tooth with the most severe bone loss between baseline and follow-up was 0.50 mm (0.0; 2.0). The distribution was right-skewed (Figure S2). The marginal bone measurements showed bone gain in 10.6% of the cases, while 22% showed a bone loss of  $\geq 2$  mm. In the bivariate analyses, eight variables were significantly correlated to marginal bone loss between baseline and follow-up (Table 4). The bone loss was significantly increased for those who were smokers at baseline ( $p = .019$ ). Three variables remained in the last step of the regression analysis (Table 5). High BOP at baseline, smoking and interruption of the periodontal treatment at the specialist clinic significantly increased the longitudinal bone loss.

## 4 | DISCUSSION

Our results demonstrated that the majority of the young individuals included in this cohort showed stable periodontal conditions after at least 10 years of follow-up. The frequency of individuals classified as periodontitis grade C reduced from 79% at baseline to 17% at the

follow-up examination. Unfortunately, the group with the most severe disease profile tended to discontinue periodontal specialist treatment more often, which entailed a significantly higher risk of disease progression. Our results showed that the longitudinal bone loss was significantly increased for those with high BOP, for smokers and for those discontinuing periodontal specialist treatment. In addition, this group's experience of pain and functional limitation was significantly greater, which is in accordance with a recent study in a non-specialist setting (Sharma et al., 2023).

To date, few studies have investigated the new classification system of periodontal disease and its predictive value for disease progression. Existing research has mainly focused on tooth loss, and the conclusion is that a higher stage and grade correlate well with a high risk of tooth loss due to periodontitis (Dukka et al., 2022; El Sayed et al., 2021; Ravidà et al., 2020, 2021). However, these studies included older patients with a mean age of 45–47 years at baseline compared with 28 years in our study. Our results showed that the overwhelming majority of this young cohort were diagnosed with stage III and grade C disease at baseline, indicating that most patients had severe periodontal disease, which corresponds well with a referral to a specialist clinic. At the follow-up examination, most patients were still diagnosed with stage III. Only 26 of the cases (12%) were classified with a higher stage at follow-up, while 45 cases (21%) were classified with a lower stage or considered healthy/gingivitis on a reduced periodontium. The classification from 2018 describes that periodontitis stage is based on the worst affected tooth. Interdental clinical attachment loss (CAL), radiographic bone loss and tooth loss describe the severity. The framework pointed out that, in general, the stage should not be moved downwards except in the case of successful periodontal regeneration (Tonetti et al., 2018; Tonetti & Sanz, 2019). In our cohort, 25% of the patients with localized periodontitis were treated with regenerative surgery, which could explain the lower stage at follow-up. In our experience, switching to a lower stage is highly possible for a young individual with periodontitis. The majority of the patients were diagnosed with periodontitis grade A at follow-up, indicating stable periodontal conditions for many of the included participants. In addition, there were also individuals diagnosed with 'gingival health on a reduced periodontium'.

**TABLE 3** Comparison at follow-up between the groups stratified according to clinical gingival health/gingivitis on a reduced periodontium and periodontitis grade.

Variable	n	Group 1: Healthy/ gingivitis	n	Group 2: Periodontitis grade A	n	Group 3: Periodontitis grade B	n	Group 4: Periodontitis grade C	p- Value
Age	25	39.6 (8.1)	89	40.8 (6.6)	65	41.1 (6.5)	36	40.5 (7.5)	.83
Male	25	6 (24.0)	89	39 (43.8)	65	26 (40.0)	36	18 (50.0)	.21
Female		19 (76.0)		50 (56.2)		39 (60.0)		18 (50.0)	
Non-smokers	25	24 (96.0)	89	89 (100.0)	65	44 (67.7)	36	24 (66.7)	<.001
Smokers		1 (4.0) <sup>ab</sup>		0 (0) <sup>cd</sup>		21 (32.3) <sup>ac</sup>		12 (33.3) <sup>bd</sup>	
Systemic disease	25	3 (12.0)	89	9 (10.1)	65	11 (16.9)	36	8 (22.2)	.31
Diabetes	25	0 (0)	89	1 (1.1) <sup>a</sup>	65	3 (4.6)	36	5 (13.9) <sup>a</sup>	.013
Education	25		87		62		35		.044
Elementary school/ gymnasium		7 (28.0)		45 (51.7)		32 (51.6)		18 (51.4)	
Folk high school		4 (16.0)		3 (3.4)		2 (3.2)		0 (0)	
High school/university		14 (56.0)		39 (44.8)		28 (45.2)		17 (48.6)	
Occupation	25		87		62		35		.054
Student		1 (4.0)		1 (1.1)		2 (3.2)		4 (11.4)	
Working		21 (84.0)		80 (92.0) <sup>a</sup>		53 (85.5)		25 (71.4) <sup>a</sup>	
Unemployed		2 (8.0)		1 (1.1)		2 (3.2)		4 (11.4)	
Other		1 (4.0)		5 (5.7)		5 (8.1)		2 (5.7)	
General marginal bone loss (% of root length)	25		89		65		36		.014
<15%		19 (76.0) <sup>a</sup>		55 (61.8)		32 (49.2)		15 (41.7) <sup>a</sup>	
≥15% but <33%		6 (24.0)		29 (32.6)		26 (40.0)		13 (36.1)	
≥33%		0 (0.0)		5 (5.6) <sup>a</sup>		7 (10.8)		8 (22.2) <sup>a</sup>	
Periodontitis stage	-	-	89		65		36		<.001
I				6 (10.0)		1 (3.1)		0 (0.0)	
II				22 (25.6) <sup>ab</sup>		5 (6.2) <sup>a</sup>		0 (0.0) <sup>b</sup>	
III				58 (61.1) <sup>a</sup>		55 (84.6) <sup>ab</sup>		22 (61.1) <sup>b</sup>	
IV				3 (3.3) <sup>a</sup>		4 (6.2) <sup>b</sup>		14 (38.9) <sup>ab</sup>	
Extent of periodontitis	-	-	89		65		36		<.001
Generalized				7 (7.9) <sup>a</sup>		21 (32.3) <sup>a</sup>		23 (63.9) <sup>a</sup>	
Localized				64 (71.9) <sup>a</sup>		39 (60.0) <sup>b</sup>		9 (25.0) <sup>ab</sup>	
Molar/incisor pattern				18 (20.2)		5 (7.7)		4 (11.1)	
Number of teeth	25	27.1 (3.0)	89	27.8 (2.8) <sup>a</sup>	65	27.5 (2.9)	36	26.1 (4.3) <sup>a</sup>	.040
Bleeding on probing index (BOP)	25	11.1 (12.7) <sup>ab</sup>	89	17.3 (13.5)	65	22.1 (14.9) <sup>a</sup>	36	34.0 (22.2) <sup>b</sup>	<.001
Number of sites with probing depth >4 mm	25	0.80 (0.91) <sup>ab</sup>	89	5.0 (6.4) <sup>cd</sup>	65	11.1 (10.9) <sup>ace</sup>	36	23.6 (18.1) <sup>bde</sup>	<.001
Number of sites with probing depth >6 mm	25	0.12 (0.44) <sup>a</sup>	89	0.30 (0.79) <sup>bc</sup>	65	2.3 (4.0) <sup>bd</sup>	36	7.0 (7.7) <sup>acd</sup>	<.001
Oral hygiene level	25		88		65		36		<.001
Good		15 (60.0) <sup>ac</sup>		35 (39.8) <sup>b</sup>		17 (26.1) <sup>a</sup>		5 (13.9) <sup>cb</sup>	
Partly poor		6 (24.0)		39 (44.3)		25 (38.5)		14 (38.9)	
Poor		4 (16.0)		14 (15.9) <sup>ab</sup>		23 (35.4) <sup>a</sup>		17 (47.2) <sup>b</sup>	
Regular supportive care during follow-up period	25	9 (36.0)	88	38 (43.2) <sup>a</sup>	62	23 (37.1)	36	4 (11.1) <sup>a</sup>	.008
OHIP-18 score	22	33.3 (11.8)	82	33.7 (10.3)	60	38.8 (13.5)	30	40.1 (12.2)	.013
Pain and functional limitation	23	17.8 (5.5)	85	17.7 (4.9) <sup>a</sup>	61	20.0 (5.7)	33	21.4 (5.2) <sup>a</sup>	.002

TABLE 3 (Continued)

Variable	n	Group 1: Healthy/ gingivitis	n	Group 2: Periodontitis grade A	n	Group 3: Periodontitis grade B	n	Group 4: Periodontitis grade C	p- Value
Psychological discomfort	23	10.0 (4.9)	82	10.3 (4.5)	62	11.9 (6.2)	32	12.0 (5.2)	.139
Psychological disability and social handicap	24	4.5 (2.8)	86	4.1 (1.9)	61	5.1 (2.7)	33	5.1 (2.7)	.053

Note: Data are presented as mean  $\pm$  standard deviation or number (percentage). One-way ANOVA was used for continuous variables and chi-squared test/Fisher's exact test for categorical variables. Each subscript letter denotes a subset of the group categories whose column proportions differ significantly from each other ( $p < .05$ ).

Smoking is a well-established risk factor for periodontitis (Leite et al., 2018; Nociti et al., 2015). In the present study, smoking at baseline had a significant impact on periodontitis progression. The overall proportion of smokers decreased from 24% at baseline to 16% at the follow-up. However, in the group with periodontitis grade C the proportion of smokers remained unchanged. Earlier research had shown odds ratios for developing periodontitis and periodontal attachment loss to vary between 2 and 7 for smokers compared with non-smokers (Albandar, 2002; Kinane et al., 2017; Stabholz et al., 2010). Similarly, in most studies on young patients with periodontitis, smoking is one of the most common risk factors for disease progression (Bäumer et al., 2020; Baumer, El Sayed, et al., 2011; Baumer, Pretzl, et al., 2011; Diaz-Faes et al., 2016; Goh et al., 2018; Hughes et al., 2006). The research by Hughes et al. (2006) concluded that smoking was a major negative factor for disease progression in a group of 79 patients with AgP. In addition, Linden and Mullaly showed that young adult smokers aged 20–33 years had 14 times higher risk of severe loss of periodontal attachment compared with non-smokers (Linden & Mullaly, 1994). These findings reinforce the importance of smoking cessation in young patients with periodontitis.

Life-long SPC is well known to prevent the recurrence of periodontal disease (Axelsson & Lindhe, 1981; Cortellini & Tonetti, 2004; Kamma & Baehni, 2003; Wennström et al., 1986). Unfortunately, patient compliance with maintenance care is often unsatisfactory, and several studies have highlighted this problem. A systemic review from 2020, including 39 studies that investigated compliance with supportive periodontal and peri-implant therapy, showed that the percentage of compliers and non-compliers ranged from 3.3% to 86.8% and from 1.69% to 64.4%, respectively (Amerio et al., 2020). The most common reason for the lack of compliance was inadequate information or motivation, which was 3 times more important than economic issues. They also highlighted that patients' attitudes towards their oral health can influence the rate of compliance. However, studies investigating treatment compliance in young individuals with periodontitis are limited. In our study, significantly fewer individuals in the periodontitis grade C group at follow-up (11%) had followed a regular supportive care program, compared with those classified as grade A at follow-up (43%). Recently, a retrospective study of patients treated for periodontitis at the University of Michigan found that maintenance variables had a

differential effect on tooth loss depending on the stage and grade (Ravida et al., 2021). Non-compliant patients with stage III/IV and grade C, but not stage I/II or grade A/B, had an increased risk of tooth loss due to periodontitis.

Dropout from APT has been reported to be a problem among young patients with periodontitis. An earlier study investigated adolescents with high periodontal risk and showed that 18% dropped out before the periodontal treatment was completed (Jansson et al., 2013). In an earlier retrospective cross-sectional study from our clinics, the frequency of individuals who discontinued the APT (40%) was consistent with this study (Modin et al., 2017). Smokers, patients diagnosed with AgP and the frequency of sites with PPD > 4 mm at baseline were significantly and positively correlated with treatment interruption. In the present study, the relative frequency of individuals who discontinued the APT in the group with periodontitis grade C was 61% compared with ~30% for those with gingival health/gingivitis on a reduced periodontium or periodontitis grade A. In addition, longitudinal bone loss was significantly higher for individuals who discontinued periodontal treatment. This indicates that the completion of ongoing periodontal treatment is of great importance for achieving good long-term treatment results.

Periodontitis in young individuals is an uncommon disease, which makes it difficult to obtain a sufficiently large research sample. To our knowledge, there are few studies on periodontitis progression in young individuals with a long follow-up period and a sample size of >100 individuals (Bäumer et al., 2020; Miller et al., 2017), which increases the importance of research and the urgency to gain increased knowledge in the field. This cohort study included a clinical follow-up investigation conducted >10 years after the baseline examination. A total of 215 patients diagnosed with periodontitis and below the age of 36 years were included. The patient sample was mixed with respect to education and profession, which is an additional strength of the study.

However, this study has some limitations. Periodontitis progression was estimated by assessments on the tooth with the most severe bone loss at re-evaluation. This tooth was selected because it forms the basis for assessment of periodontitis grade, and the measure may be considered as an estimate of the individual's general marginal bone loss. Baseline data were missing for some of the clinical variables, and



**TABLE 4** Change in marginal bone loss (mm, median [Q25%; Q75%]) between baseline and follow-up for the investigated baseline variables.

Variable	n	Median (Q25%; Q75%)	p-Value
Age (years)			.802
<20	35	0.5 (0.0; 1.0)	
≥20 but <30	61	0.5 (0.0; 2.0)	
≥30	111	0.5 (0.0; 2.5)	
Male	87	0.5 (0.0; 2.5)	.840
Female	120	0.5 (0.0; 1.4)	
Periodontal diagnosis at baseline			.012
Localized chronic periodontitis	50	0.0 (0.0; 0.5)	
Generalized chronic periodontitis	50	0.5 (0.0; 2.6)	
Localized aggressive periodontitis	64	0.5 (0.0; 2.0)	
Generalized aggressive periodontitis	39	0.5 (0.0; 3.0)	
Periodontitis stage			.302
I	5	0.0 (−0.5; 0.5)	
II	26	0.5 (0.0; 2.5)	
III	172	0.5 (0.0; 2.0)	
IV	4	1.5 (0.0; 6.0)	
Periodontitis grade			.218
A	1	0.50 (−)	
B	43	0.50 (0.0; 1.0)	
C	163	0.50 (0.0; 2.0)	
Extent of periodontitis			.009
Generalized	87	0.50 (0.0; 3.0)	
Localized	70	0.25 (0.0; 1.0)	
Molar/incisor pattern	50	0.50 (0.0; 2.0)	
Systemic disease			.276
No	194	0.5 (0.0; 1.6)	
Yes	13	1.0 (0.0; 3.2)	
Smoker			.019
No	154	0.5 (0.0; 1.0)	
Yes	49	0.5 (0.0; 3.0)	
Occupation			.217
Student	53	0.5 (0.0; 2.0)	
Working	126	0.5 (0.0; 1.6)	
Unemployed	7	1.0 (0.5; 5.0)	
Other	15	0.5 (−0.5; 1.0)	
General marginal bone loss (% of root length)			.045
<15%	125	0.5 (0.0; 1.5)	
≥15% but <33%	64	0.5 (0.0; 1.9)	
≥33%	16	1.2 (0.5; 3.7)	
Bleeding on probing index (BOP)			0.028
<20%	49	0.5 (0.0; 1.0)	
≥20% but <50%	75	0.5 (0.0; 2.0)	
≥50%	50	0.75 (0.0; 3.1)	
Number of sites with probing depth >4 mm			.007
<10	65	0.0 (0.0; 0.7)	
≥10 but <20	56	0.5 (0.0; 2.7)	
≥20	53	0.5 (0.0; 3.5)	

**TABLE 4** (Continued)

Variable	n	Median (Q25%; Q75%)	p-Value
Number of sites with probing depth >6 mm			.997
0	36	0.5 (0.0; 1.9)	
1–2	53	0.5 (0.0; 3.0)	
≥3	85	0.5 (0.0; 2.0)	
Interrupted periodontal treatment			<.001
No	123	0.5 (0.0; 0.5)	
Yes	84	1.0 (0.0; 3.4)	

Note: Kruskal–Wallis test.

Abbreviations: Q25%, 25th percentile; Q75%, 75th percentile.

**TABLE 5** Backward linear regression analysis with change in marginal bone loss between baseline and follow-up as dependent variable.

Independent variables	$\beta$	Standard error	95% CI	p-Value
Bleeding on probing index (%) at baseline	.002	0.001	0.000–0.003	.005
Interrupted periodontal treatment	.075	0.026	0.025–0.126	.004
Smoking at baseline	.069	0.029	0.013–0.126	.016

Note: Independent variables were included in the model if  $p < .10$ .  $N = 173$ .  $R^2 = 0.15$ .

Abbreviation: CI, confidence interval.

to prevent data distortion, missing data were excluded and complete-case analysis was adopted. However, the reduced number of cases increased the risk that the estimates of the associations may be biased. In addition, missing data reduces the statistical power. Multicollinearity may occur if the predictors in the regression models are highly correlated. However, the VIF for the independent variables in the model showed values well below the rule-of-thumb of 4 (O'Brien, 2007).

The patients who dropped out of the clinical investigation had a significantly higher BOP index and more sites with deepened periodontal pockets compared with those investigated at baseline. In addition, they discontinued periodontal specialist treatments more frequently (62.5%). Thus, the presence of these patients in the clinical investigation could have had a significant impact on the outcome, as the dropout rate was 54%. Consequently, this could influence the external validity of the results. However, the dropout frequency in this study was similar to those of other studies on AgP patients. Responder rates between 20% and 48% have been reported (Baumer, El Sayed, et al., 2011; Diaz-Faes et al., 2016; Goh et al., 2018). One of these studies reported a responder rate of 25.8%, but only 19.7% could be included in the multivariate analysis because of incomplete records (Goh et al., 2018). This reflects the difficulties that exist in this patient group.

The current study had a retrospective design, and baseline data were recorded by several periodontists and dentists under specialist training employed at the two clinics during the years baseline data were collected. The distinction between aggressive and chronic periodontitis can sometimes be difficult to make (Armitage, 2002). In this study, the new periodontal classification from 2018 was adopted at the follow-up examination, and the

baseline diagnoses were translated into the same classification system by two calibrated investigators, which we hope increased the likelihood of a correct diagnosis. The kappa value of the inter-examiner reliability of the periodontal classification was .71, which may be considered a substantial agreement. However, the judgments were made by two experienced periodontists, and the kappa value underlines the complexity of the assessments. Thus, the implementation of this new classification system has involved a learning curve and identification of some grey zones (Kornman & Papapanou, 2020).

## 5 | CONCLUSIONS

Our results showed that young individuals with severe periodontitis generally responded well to periodontal treatment. A high BOP index at baseline, smoking and interruption of periodontal treatment increased the risk of marginal bone loss, while the stage and grade at baseline had no significant impact on disease progression. This underlines the importance of undergoing complete periodontal treatment in this patient group.

## AUTHOR CONTRIBUTIONS

Carolina Modin and Leif Jansson contributed to the conception and design, data acquisition, interpretation of data and data analysis, and drafted and critically revised the manuscript. Caroline Dolk Rinon and Ali Faham contributed to data acquisition and data interpretation and critically revised the manuscript. Anders Gustafsson and Tülay Yucel-Lindberg contributed to the conception and design of the study and interpretation of data, and drafted and critically revised the

manuscript. All authors gave their final approval and agreed to be accountable for all aspects of this work.

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## CONFLICT OF INTEREST STATEMENT

The authors declare no conflicts of interest.

## DATA AVAILABILITY STATEMENT

The data that support the findings of this study are available on request from the corresponding author. The data are not publicly available due to privacy or ethical restrictions.

## ORCID

Carolina Modin  <https://orcid.org/0000-0002-6729-3990>

Anders Gustafsson  <https://orcid.org/0000-0001-6481-858X>

Tülay Yucel-Lindberg  <https://orcid.org/0000-0003-0129-8809>

Leif Jansson  <https://orcid.org/0000-0001-5923-5777>

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