Journal of Dentistry 173 (2026) 106839

Contents lists available at ScienceDirect

Journal of Dentistry

journal homepage: www.elsevier.com/locate/jdent

Comparing the Effect of Scaling and Polishing on Nine Oral Health and Dental Aesthetic Measures between Current and Never Smokers from the SMILE Study Cohort

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ARTICLE INFO

Keywords:
Smoking
Scaling and polishing
Gingival inflammation
Quantitative light-induced fluorescence
Dental plaque

ABSTRACT

Objectives: To evaluate the short-term effects of professional scaling and polishing on nine oral health and dental aesthetic outcomes in current smokers and never smokers.
Methods: A total of 371 participants from the SMILE Study Cohort (305 smokers and 66 never smokers) were assessed at baseline (V0) and 14 days after scaling and polishing (V1). Outcomes included Modified Gingival Index (MGI), quantitative light-induced fluorescence parameters (ΔR30, reflecting the percentage of tooth surface covered by mature plaque, and ΔR120, reflecting the percentage covered by thicker deposits including calculus), MacPherson-modified Lobene Stain Index (MLSI) for buccal and lingual surfaces, Whitening Index for Dentistry (WID), Simple Oral Hygiene score (SOH), oral health-related quality of life (OHQoL), and general health perception (EQ-VAS). Linear mixed model analysis was used for between-group comparisons of V0-V1 changes.
Results: At baseline, smokers exhibited significantly worse values across all objective indices. Following intervention, significant improvements were observed in MGI, ΔR30, ΔR120, MLSI, and SOH in both groups ($p<0.0001$). MGI improved by a median of -0.5 units in smokers (IQR: -0.8/-0.2) and -0.08 units in never smokers (IQR: -0.3/-0.02); the magnitude of improvement was significantly greater in smokers ($p<0.0001$). Similarly, greater reductions in ΔR120 ($p=0.010$), buccal MLSI ($p<0.0001$), and lingual MLSI ($p<0.0001$) were observed in smokers compared to never smokers. WID showed no significant changes in either group. OHQoL improved slightly without between-group differences; EQ-VAS did not change significantly.
Conclusions: Professional scaling and polishing produced consistent short-term improvements in objective oral health indicators in both smokers and never smokers, with greater gains among smokers reflecting their higher baseline burden.
Clinical Significance: Regular professional mechanical plaque removal is clinically beneficial for smokers, producing measurable short-term improvements in gingival and aesthetic parameters even in the presence of ongoing tobacco exposure, although smoking cessation remains essential for long-term oral health.

1. Introduction

Tobacco use remains a major global public health challenge, affecting ~1.2 billion people and causing over seven million deaths annually [1]. Beyond its well-documented systemic consequences, smoking substantially impairs oral health through multiple interacting

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https://doi.org/10.1016/j.jdent.2026.106839
Received 7 April 2026; Received in revised form 12 June 2026; Accepted 15 June 2026
Available online 17 June 2026

mechanisms: it promotes subgingival microbial dysbiosis, favouring the early acquisition and colonisation of periodontal pathogens in oral biofilms [2], and suppresses key host immune defences, including impaired neutrophil chemotaxis and phagocytosis and altered cytokine production [3]. These biological effects translate into measurably greater dental plaque accumulation in current smokers, as objectively demonstrated by quantitative light-induced fluorescence (QLF) imaging with higher surface coverage by mature plaque (ΔR30: 3.5 [IQR 1.25–6] vs 1.0 [IQR 0–3]) and thicker deposits including calculus (ΔR120: 1.0 [IQR 0–3] vs 0.0 [IQR 0–1]) compared to never smokers [4]. At the global level, smoking has been estimated to account for approximately 38.5 million cases of periodontal disease worldwide, corresponding to 251,160 disability-adjusted life years (DALYs) across 186 countries in 2015, with the highest burden recorded in South-East Asia, East Asia, and high-income regions [5]. Smokers present a significantly higher risk of destructive periodontitis than never smokers, with a clear dose–response relationship: relative risks range from 2.05 (95% CI: 1.47–2.87) in light smokers to 4.75 (95% CI: 3.28–6.91) in heavy smokers [6] supporting causality and highlighting the importance of stratifying smokers by intensity when evaluating oral health outcomes. Chronic exposure to tobacco smoke also causes tooth staining and discoloration [7–9], which can negatively affect dental aesthetics, self-perception, and self-confidence. These aesthetic concerns are relevant outcomes, particularly given their potential influence on patients' motivation toward oral hygiene practices and smoking cessation behaviors [10].

From a therapeutic perspective, smoking consistently impairs clinical responses to periodontal treatment [11–13]. Non-surgical periodontal therapy aims to remove dental plaque and eliminate plaque-retentive factors thereby supporting effective self-performed oral hygiene [14]. Supragingival calculus is removed by manual or ultrasonic scaling, typically followed by polishing with rubber cups and pumice or other prophylactic pastes [14]. Polishing smooths the tooth surface and removes microgrooves and scratches left by scaling [15]. Surface roughness directly influences bacterial adhesion and plaque biofilm formation, with smoother post-polishing surfaces associated with reduced early microbial colonization [16]. Scanning electron microscopy studies and biofilm adhesion models demonstrate that microbial adhesion concentrates preferentially in surface irregularities, where reduced mechanical disruption promotes accelerated plaque maturation [17]. Consistent with this, professional supragingival plaque removal has been associated with a delayed and quantitatively reduced recolonization of pathogenic subgingival species; notably, Feres et al. [18] demonstrated that a significant reduction in red-complex periodontal pathogens following scaling and root planing was sustained at 180 days post-therapy in non-smokers, but not in smokers, who remained more susceptible to the re-establishment of a pathogenic subgingival biofilm.

Early experimental and clinical studies demonstrated that chemicals contained in cigarette smoke interfere with the complex interactions between host immune responses and the oral microbiota, resulting in less favorable healing following periodontal therapy [19,20]. More recent evidence confirms that smokers with periodontitis experience significantly smaller reductions in probing depth and less clinical attachment level gain following non-surgical periodontal therapy compared with non-smokers: a systematic review and meta-analysis of 17 studies reported that smokers achieved 0.33 mm less probing depth reduction (95% CI: −0.49 to −0.17, $p<0.01$) and 0.20 mm less clinical attachment level gain (95% CI: −0.39 to −0.02, $p<0.01$) than non-smokers following non-surgical periodontal therapy [21]. However, despite the well-established detrimental effects of smoking on periodontal health and treatment outcomes, important gaps remain in the current literature. Available studies often suffer from methodological limitations, including heterogeneous study designs, short follow-up periods, inadequate reporting of smoking history, and variability in clinical outcomes assessed [21].

Notably, while the impact of smoking on non-surgical periodontal therapy outcomes has been largely investigated, no study to date has specifically evaluated the short-term effects of professional scaling and polishing using quantitative, objective measures of plaque accumulation such as QLF imaging alongside standardized indices of gingival inflammation, dental staining, tooth shade, and patient-reported outcomes in smokers and non-smokers.

The SMILE Study was initiated in October 2021 as part of a large international research initiative coordinated by the Center of Excellence for the Acceleration of Harm Reduction (CoEHAR) at the University of Catania, with the aim of increasing awareness of oral health and dental aesthetics among cigarette smokers [22].

The broader SMILE project was designed to investigate whether smokers who quit by switching to combustion-free nicotine alternatives (C-F NAs) show improvements in gingival health, tooth color, and dental plaque accumulation. Data generated within this framework are expected to provide valuable insight into the potential role of C-F NAs in reducing periodontal disease risk and, indirectly, cardiovascular risk [22]. The SMILE study design also included an important and innovative feature. Because gum health and dental esthetics are strongly influenced by smoking history, oral hygiene, diet, and alcohol use, baseline variability was minimized by collecting data after scaling and polishing. By removing plaque, calculus, and stains, all participants entered the study with the best achievable oral health status in terms of gingival condition and tooth appearance. This normalized baseline was established 14 days after the procedure, and all subsequent changes were compared against it.

Building on this design feature, specific objective of the present study is to evaluate the short-term effects of scaling and polishing on oral health and aesthetic outcomes, with a particular focus on differences between smokers and never smokers, using standardized clinical, instrumental, and patient-reported measures. We hypothesised that professional scaling and polishing would produce measurable short-term improvements in objective oral health and dental aesthetic outcomes in both current smokers and never smokers, and that the magnitude of improvement would differ between the two groups, reflecting their distinct baseline oral health burden.

2. Methods

2.1. Study design

The current study serves as a secondary analysis of a large prospective multicenter randomized controlled trial (SMILE cohort) of current smokers, designed to evaluate oral health and dental aesthetic changes after switching to C-F NAs [22]. Eligible smokers were randomized to a control arm (Arm A), receiving standard care including smoking cessation counselling, or to an intervention arm (Arm B), receiving cessation counselling plus a participant-selected combustion-free nicotine alternative (C-F NA). Individuals willing to quit smoking or to enroll in smoking cessation programs were excluded to ensure inclusion of persistent smokers, consistent with a harm-reduction framework. A third arm of never smokers (Arm C) was included as a reference group. Participants attended seven clinic visits, including screening, enrollment/randomization, baseline, and follow-up visits up to 76 weeks. The de-identified datasets from the trial were sourced from the open science repository maintained by the Center of Excellence for the Acceleration of Harm Reduction (CoEHAR) at the University of Catania, and subsequently used for this analysis: https://doi.org/10.5281/zenodo.20727523.

2.2. Study objectives

Within this broader framework, the specific objective of this secondary analysis is to evaluate the short-term effects of professional dental scaling and polishing on oral health and dental aesthetic outcomes, comparing current smokers and never smokers using

standardized clinical, instrumental, and patient-reported measures. This study was reported in accordance with the Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) guidelines for cohort studies; the completed STROBE checklist is provided as **Supplementary File S1**.

2.3. Study population

The study population included adult daily smokers and never smokers free from chronic systemic conditions requiring regular medication, defined as ASA I (never smokers) or ASA II (current smokers, in whom tobacco use represents a mild systemic condition per the ASA classification), with no clinical signs of severe irreversible periodontitis. Participants with Stage III or Stage IV periodontitis, as defined by the 2018 international classification of periodontal and peri-implant diseases and conditions [23], were excluded from the study. Participants were recruited using multiple strategies, including referrals from dentists and dental hygienists, targeted advertising among university students, searches within dental clinic patient databases, and outreach to hospital staff. As never smokers were recruited only in Italy and Moldova, the analysis was limited to participants enrolled at study sites in these two countries.

Eligible smokers were adults aged 18 to 50 years who reported smoking at least 5 and fewer than 30 cigarettes per day for a minimum of five consecutive years. Smoking status was biochemically verified using exhaled breath carbon monoxide levels of 7 ppm or higher. Smokers were required to be willing to switch to a combustion-free nicotine alternative if randomized and to decline participation in smoking cessation programs. Additional eligibility criteria included the presence of at least 10 out of 12 natural anterior teeth (cuspid to cuspid in both jaws) and the absence of chronic conditions requiring regular medication.

Never smokers were adults aged 18 to 50 years who reported having smoked fewer than 100 cigarettes in their lifetime and had exhaled breath CO levels below 7 ppm. As for smokers, eligibility required the presence of at least 10 natural anterior teeth (cuspid to cuspid in both jaws) and overall good health without regular medication use.

Exclusion criteria applied to both smokers and never smokers and included the presence of significant oral soft tissue pathology or gingival overgrowth, with the exception of plaque-induced gingivitis. Periodontitis was defined according to the 2018 international classification of Periodontal and Peri-Implant Diseases [23], using interdental clinical attachment loss (CAL) greater than 3 mm at two or more nonadjacent teeth combined with probing pocket depths of 4 mm or greater at two or more teeth. This definition allowed the inclusion of participants with incipient or non-progressive attachment loss within the range of periodontal health. Additional exclusion criteria included the presence of fixed or removable orthodontic appliances or dentures, recent use of medications interfering with the cyclooxygenase pathway within three days prior to study visits, use of antibacterial medications within seven days prior to visits, regular use of nicotine or tobacco products other than cigarettes within 14 days before screening, and pregnancy, breastfeeding, or planned pregnancy during the study period.

The study was conducted in accordance with the Declaration of Helsinki and Good Clinical Practice guidelines and was approved by the ethics committees of all participating dental clinics. All participants provided written informed consent prior to enrollment. The study is registered on ClinicalTrials.gov (NCT04649645) and in the International Registered Report Identifier (IRRID: DERR1-10.2196/53222).

2.4. Scaling and polishing procedure

At screening, sociodemographic characteristics, medical and oral health history, and tobacco or nicotine use were recorded, and participants with severe irreversible periodontitis were excluded. At enrollment (Visit 0 – V0), eligibility criteria were reconfirmed and all participants completed baseline oral health assessments, including clinical, instrumental, and patient-reported evaluations.

Immediately after completion of baseline assessments at V0, all participants underwent full-mouth professional mechanical plaque removal (PMPR). The procedure consisted of supragingival scaling performed using ultrasonic instruments with water irrigation to remove plaque and calculus, followed by tooth surface polishing with a prophylaxis paste to achieve smooth dental surfaces. At the Italian centre, Zircate Prophy Paste (Dentsply Sirona, Charlotte, NC, USA; zirconium silicate-based; fluoride-free; Relative Dentin Abrasivity (RDA) approximately 150) was used, while at the Moldovan centre, ProphyCare Prophy Paste (Sweden & Martina, Due Carrare, Italy; RDA 120; 0.1% fluoride) was employed. PMPR was carried out by trained dental operators under standardized clinical conditions and according to a uniform protocol applied across study sites. No oral hygiene instructions were provided at V0. All participants were asked to maintain their usual oral hygiene routine unchanged for the 14-day period between V0 and V1, in order to reflect habitual behaviour and avoid introducing a confounding intervention.

A subsequent visit (Visit 1 – V1) was scheduled 14 days after PMPR to allow for gingival recovery following scaling and polishing [24]. Measurements collected at this visit were used to define a normalized baseline, providing a standardized reference point for subsequent evaluations. This approach was adopted to minimize baseline variability related to individual differences in smoking exposure, oral hygiene practices, diet, and other lifestyle factors.

Further follow-up visits were conducted to repeat outcome assessments. Tobacco consumption, use of combustion-free nicotine alternatives, and oral hygiene practices were monitored throughout the study using a dedicated tracker application and participant diaries, which were also used to document protocol deviations and adverse events.

2.5. Primary endpoints

2.5.1. Modified gingival index (MGI)

The Modified Gingival Index (MGI) was selected as the primary endpoint as it represents a well-established, sensitive, and reproducible measure of gingival inflammation based on visible changes in gingival appearance [25]. Its non-invasive nature, ease of application, and suitability for repeated assessments make it particularly appropriate for longitudinal, multicenter studies such as SMILE. The MGI has been widely applied in clinical research [26,27]. To ensure consistency and reliability of outcome assessment across study sites, all participating centers received standardized instructions and underwent dedicated training on MGI scoring procedures prior to study initiation [22].

MGI scoring is based on visual inspection of the papillary and marginal gingival units surrounding each tooth and is recorded using a five-point ordinal scale: 0 = normal gingiva; 1 = mild inflammation with slight color change and edema, without bleeding; 2 = mild inflammation involving the entire gingival unit; 3 = moderate inflammation characterized by redness, edema, and glazing; and 4 = severe inflammation with marked redness and edema, ulceration, and a tendency toward spontaneous bleeding [25]. An overall participant-level MGI score is calculated by averaging scores across all assessed sites, yielding a global indicator of gingival inflammatory status. Higher MGI scores reflect greater levels of gingival inflammation and poorer gingival health. A difference of approximately 0.08 MGI units has been used as a reference value in previous clinical trials evaluating gingival health, providing a practical threshold for interpreting longitudinal changes associated with smoking continuation, cessation, or harm reduction strategies [28,29].

2.6. Secondary endpoints

2.6.1. Dental plaque and calculus accumulation by quantitative light-induced fluorescence (QLF)

Plaque and calculus accumulation were assessed using the

Qraycam™ Pro (AIOBIO Co. Ltd., Seoul, Republic of Korea), a handheld high-resolution QLF camera [4,30]. The device emits 405 nm violet-blue excitation light, inducing red autofluorescence from bacterial porphyrins and enabling objective detection and quantification of dental plaque. Images of the anterior teeth were acquired by the same operator under standardized low ambient lighting, following the QLF photography protocol. To ensure consistent positioning, the camera was placed as close as feasible to the teeth using a black rubber collar, with autofocus set on the maxillary lateral incisor–canine region (focal depth 0.32). White-light and QLF images were captured automatically and stored using Q-Ray™ software (v1.41), and vestibular surfaces from cuspid to cuspid in both arches were analyzed.

Two QLF-derived metrics were used: ΔR30, representing the percentage of tooth surface with ≥30% fluorescence increase and reflecting overall mature plaque accumulation, and ΔR120, identifying areas with ≥120% fluorescence increase indicative of thicker, more mature deposits, including calculus.

2.6.2. Dental shade assessment by digital spectrophotometry

Tooth colour was objectively assessed using digital spectrophotometry (Vita Easyshade V). Measurements were performed by the same operator under standardized lighting conditions, with device calibration and operation conducted according to the manufacturer's instructions [7,9]. Tooth shade was recorded from the central area of each anterior tooth (cuspid to cuspid in both arches) using the base shade determination mode. CIELAB parameters (L*, a*, b*) were recorded and averaged at the participant level. Tooth whiteness was additionally summarized using the Whitening Index for Dentistry (WID), calculated as $WID = 0.511L^* - 2.324a^* - 1.100b^*$. Participant-level WID values were obtained by averaging across all assessed anterior teeth. Higher WID values indicate greater tooth whiteness, whereas lower values reflect increased discoloration. Changes in WID were interpreted against the 50:50% acceptability threshold (WAT = 2.90 ΔWID units), with values exceeding this threshold considered visually perceptible [31].

2.6.3. MacPherson-modified lobene stain index

Extrinsic staining of the anterior teeth was assessed using the MacPherson-modified Lobene Stain Index (MLSI) [32], a validated index for the quantification of extrinsic dental discoloration, where higher scores indicate greater staining severity.

2.6.4. Oral health–related quality of life (OHQoL)

Oral health–related quality of life was assessed using a validated 16-item self-administered questionnaire completed independently by participants, where higher scores indicate better perceived oral health–related quality of life across daily activities, social interactions, and communication domains [33].

2.6.5. EuroQoL visual analogue scale (EQ-VAS)

General health status was assessed using the EuroQoL Visual Analogue Scale (EQ-VAS), a self-reported rating component of the EuroQoL EQ-5D instrument that is widely used in health outcomes research, where higher scores indicate better self-perceived general health status [34].

2.6.6. Simple oral hygiene (SOH) score

The Simple Oral Hygiene (SOH) score, also referred to as the Fluorescent Plaque Index (FPI), was derived from fluorescence intensity data using the QLF analysis software, where higher scores indicate greater plaque accumulation and poorer oral hygiene status [35]. This metric provides a standardized, objective, and reproducible method for plaque quantification and is suitable for both clinical and research applications [35–37].

2.7. Data management and quality procedures

Standardized procedures were implemented to ensure consistent data collection and high-quality study outputs. Data were recorded using a secure, web-based electronic case report form (eCRF). Study personnel received standardized training on eCRF completion, and data entry was monitored throughout the trial by an independent data management team.

Prior to participant enrollment, calibration workshops and site-level training sessions were conducted to harmonize assessment procedures across centers, including MGI scoring, QLF imaging, and digital spectrophotometry. Quality assurance measures were maintained throughout the study and included scheduled recalibration activities, inter-assessor agreement checks, device calibration, and verification of image quality. Additional methodological details are previously reported [38].

2.8. Statistical analysis

Summary statistics for baseline demographic information and variables collected at the enrollment visit are presented for the whole sample and separately for the two study classes (smokers and never smokers). Descriptive statistics were used to summarize the data: medians and interquartile ranges (IQRs) were used for non-normally distributed variables, categorical variables were presented as absolute counts and relative frequencies (percentages).

For comparisons between smokers and never smokers, the Mann-Whitney U-test was used. Chi-square tests were conducted to assess differences in frequency distribution of categorical variables. Due to the fact that the variables under study were highly skewed, normalization was performed by mean and standard deviation, resulting in a normally distributed equivalent variable presenting the same mean and standard deviation as the original variable, and suitable for further parametric analysis.

Linear mixed model analysis was used for assessing changes in the evaluated variables with time (baseline – V0, and after polishing – V1) and classification (Smokers - Non Smokers) as fixed effects predictors. Moreover, sex and age were also introduced in the model to take into account the possible effect of baseline demographic variables on dependent variable (i.e., changes after polishing).

With the available sample size and taking into account both the between-group differences at baseline and the within-subject changes due to polishing effect, the post-hoc evaluation of statistical power provided a value higher than 99% for an alpha value of 0.05.

The analyses were carried out using Statistical Package for Social Sciences (SPSS Inc., Chicago, IL, USA), all the tests were 2-sided and a p value < 0.05 was considered significant.

3. Results

3.1. Sample characteristics

We conducted an analysis of data collected at enrollment (V0) and 14 days later (V1, after scaling and polishing) from 308 smokers and 66 never smoker subjects enrolled in the SMILE Study cohort. Three Italian smoker subjects withdrew after randomization, thus, the analysis was conducted on 305 smokers. A total of 371 participants were included in the analysis, comprising 305 smokers (153 from Moldova and 152 from Italy) and 66 never smokers (44 from Moldova and 22 from Italy) (Fig. 1). Number of pack years for Smokers was (median[interquartile range]) 8.0[5.5/14.0].

Although smokers tended to be older than never smokers, no statistically significant difference in age distribution was observed between groups ($p>0.05$, Mann-Whitney U-test). Conversely, sex distribution was statistically significant with 51.5% of females among Nonsmokers and 28.9 among Smokers ($p=0.0004$, χ^2 test) (Table 1).

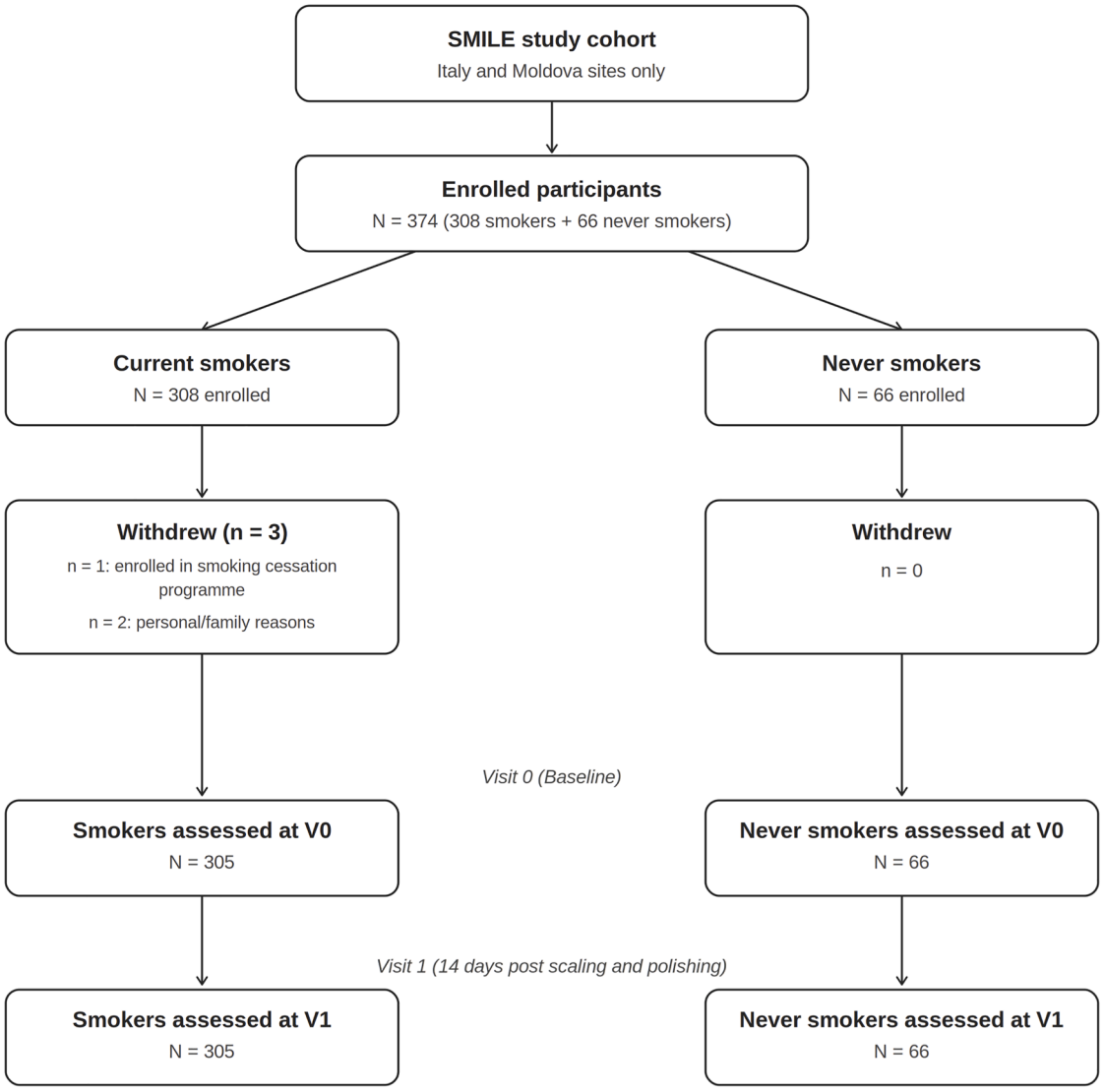

Fig. 1. Participant flow diagram of the SMILE study cohort (Italy and Moldova sites).

Oral hygiene behaviours did not differ significantly between smokers and never smokers (all $p>0.05$), with tooth brushing frequency of twice or more per day reported by 73.3% of smokers and 62.9% of never smokers, mouthrinse use by 50.9% vs 56.5%, and interdental floss use by 39.5% vs 53.2%, respectively.

3.2. Gingival inflammation (modified gingival index)

At baseline (V0), whole-mouth MGI values were higher in smokers than in never smokers ($p<0.0001$, Mann-Whitney U-test) (Fig. 2).

Following scaling and polishing, MGI decreased significantly from V0 to V1 in the whole sample (within-subject comparison, $p<0.0001$). The magnitude of the V0-V1 reduction was greater among smokers ($p<0.0001$, linear mixed model analysis) (Table 2).

3.3. Tooth whiteness (whitening index for dentistry)

At baseline, WID scores were lower in smokers compared with never smokers ($p<0.0001$, Mann-Whitney U-test) (Fig. 3).

After scaling and polishing, WID did not show significant changes from V0 to V1 in the whole sample (within-group comparisons, $p>0.05$). Similarly, no significant difference was found in the magnitude of the V0-V1 changes (between-subjects comparison, $p>0.05$, linear mixed model analysis) (Table 2).

3.4. Extrinsic tooth staining (MacPherson-modified Lobene Stain Index)

3.4.1. Buccal surfaces

At baseline, buccal MLSI scores were higher in smokers than in never smokers ($p=0.0008$, Mann-Whitney U-test) (Fig. 4**A**).

Following scaling and polishing, buccal MLSI scores decreased significantly from V0 to V1 ($p<0.0001$). Linear mixed model analysis showed that the magnitude of the V0-V1 reduction was greater in smokers ($p<0.0001$) (Table 2).

3.4.2. Lingual surfaces

Baseline lingual MLSI scores were higher in smokers ($p<0.0001$, Mann-Whitney U-test) (Fig. 4**B**).

Similarly to buccal MLSI, following scaling and polishing, the V0-V1 comparison showed a significant overall reduction in lingual staining ($p<0.0001$) and the reduction was largely greater in smokers ($p<0.0001$, linear mixed model analysis) (Table 2).

Table 1
Age, sex and investigated variable distribution at Visit 0, separately for Never Smokers and Smokers.

	Whole sample N=371	Never Smokers N=66	Smokers N=305	p value
Age (median[IQR])	30.0[24.0/36.0]	29.0[24.0/34.0]	30.0[24.8/37.7]	0.0927‡
Sex (N [%])	F 122 (32.9%)	F 34 (51.5%)	F 88 (28.9%)	0.0004§
MGI (median[IQR])	1.16[0.54/1.79]	0.45[0.23/0.80]	1.34[0.75/1.84]	<0.0001‡
WID score (median [IQR])	15.63 [12.35/19.73]	18.09 [14.77/23.79]	15.08 [12.09/18.83]	<0.0001‡
MLSI Buccal (median[IQR])	0.17[0.02/0.50]	0.09[0.00/0.20]	0.21[0.06/0.54]	0.0008‡
MLSI Lingual (median[IQR])	0.80[0.25/1.79]	0.07[0.00/0.27]	0.92[0.38/1.97]	<0.0001‡
ΔR30 (median [IQR])	2.00[1.00/5.00]	1.00[0.00/4.00]	2.00[1.00/5.00]	0.0139‡
ΔR120 (median [IQR])	1.00[0.00/2.00]	0.00[0.00/1.00]	1.00[0.00/2.00]	0.0075‡
Simple Oral Hygiene Score (median [IQR])	3.00[1.00/4.00]	2.50[0.00/4.00]	3.00[1.00/5.00]	0.0012‡
OHQoL (median [IQR])	69.00 [60.00/74.75]	69.00 [64.00/78.00]	70.00 [58.75/74.00]	0.2013‡
QOL EQ-VAS (median[IQR])	80.00 [70.00/90.00]	90.00 [80.00/94.00]	80.00 [70.00/90.00]	0.0001‡

IQR: Interquartile range; MGI: Modified Gingival Index; WID score: Whitening Index for Dentistry Score; MLSI: Modified Lobene Staining Index; ΔR30 and ΔR120: percentage of tooth surface with ≥30% and ≥120% fluorescence increase, respectively; OHQoL: Oral Health-related Quality of Life; QOL EQ-VAS: EuroQoL Visual Analogue Scale.
‡ Mann-Whitney U-test.
§ $\chi 2$ test.

3.5. Dental plaque accumulation assessed by quantitative light-induced fluorescence

3.5.1. ΔR30

At baseline, ΔR30 values were higher in smokers than in never smokers (p=0.0139, Mann-Whitney U-test) (Fig. 5**A**).

Overall, following scaling and polishing, ΔR30 values significantly decreased from V0 to V1 (p<0.0001). The magnitude of the V0-V1 changes was greater among smokers, though this difference did not reach statistical significance (p=0.060, linear mixed model analysis) (Table 2).

3.5.2. ΔR120

Baseline ΔR120 values were higher among smokers (p=0.0075, Mann-Whitney U-test) (Fig. 5**B**).

Following scaling and polishing, ΔR120 significantly decreased from V0 to V1 (p<0.0001). The between-group difference in the magnitude of change, again, showed a larger and statistically significant effect among smokers (p=0.010, linear mixed model analysis) (Table 2).

3.6. Simple Oral Hygiene score

At baseline, SOH scores were worse in smokers than in never smokers (p=0.0012, Mann-Whitney U-test) (Fig. 6).

After scaling and polishing, SOH scores largely improved from V0 to V1 in both groups (p<0.0001). The between-group difference in change scores was not statistically significant (p>0.05, linear mixed model analysis) (Table 2).

3.7. Oral health–related quality of life and general quality of life

Baseline OHQoL scores did not differ significantly between smokers and never smokers (p=0.201, Mann-Whitney U-test) (Fig. 7**A**). The V0-V1 comparison showed a slight but statistically significant overall increase (p=0.026) without any difference between Smokers and Non-smokers (p>0.05, linear mixed model analysis) (Table 2).

In contrast, baseline QoL EQ-VAS scores were lower in smokers at V0 (p=0.0001, Mann-Whitney U-test) (Fig. 7**B**). Following scaling and polishing, QoL EQ-VAS scores did not show significant changes from V0 to V1 (p=0.069), with no significant effect between Smokers and Non-smokers (p>0.05, linear mixed model analysis) (Table 2).

4. Discussion

This study represents, to our knowledge, the first trial specifically designed to evaluate the short-term effects of professional scaling and polishing in current smokers and never smokers using a comprehensive set of clinical, instrumental, and patient-reported outcomes. Rather than simply assessing the short-term efficacy of professional mechanical plaque removal, the study provides a structured comparison of how smoking status modulates the biological and aesthetic response to a standardized intervention.

At enrollment, smokers exhibited consistently worse objective

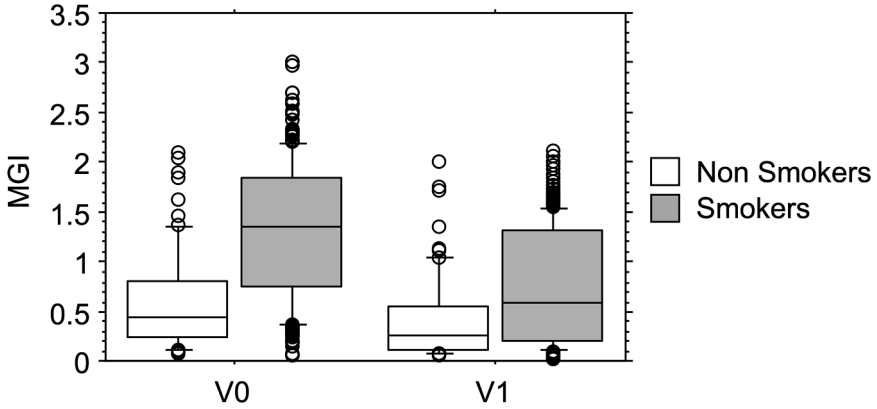

Fig. 2. Modified Gingival Index (MGI) distribution at Visit 0 (pre- scale and polishing – V0) and Visit 1 (post- scale and polishing – V1), separately for Non Smokers and Smokers. MGI was significantly higher in Smokers than in Non Smokers at V0 (p<0.0001, Mann-Whitney U-test). MGI significantly decreased from V0 to V1 (p<0.0001) and the magnitude of the V0-V1 reduction was greater among smokers (p<0.0001, linear mixed model analysis).
Boxplot horizontal bars indicate (from the bottom to the top) 10th, 25th, 50th (median), 75th, and 90th percentiles. Values below 10th and above 90th percentiles are plotted as circles.

Table 2
Effect of polishing, as difference between values at V1 and at baseline (V0), separately for Never Smokers and Smokers, with relevant p values.

	Whole sample N=371	Never Smokers N=66	Smokers N=305	p value‡ (overall§)	p value‡ (effect of class on change†)
MGI (median [IQR])	-0.430 [-0.780/-0.143]	-0.077 [-0.260/-0.021]	-0.500 [-0.820/-0.240]	<0.0001	<0.0001
WID score (median [IQR])	0.011 [-0.966/1.154]	-0.766 [-1.299/0.565]	0.163 [-0.810/1.388]	0.846	0.396
MLSI Buccal (median [IQR])	-0.100 [-0.400/0.000]	0.000 [-0.070/0.008]	-0.170 [-0.480/0.000]	<0.0001	<0.0001
MLSI Lingual (median [IQR])	-0.600 [-1.525/-0.170]	0.000 [-0.070/0.006]	-0.800 [-1.750/-0.340]	<0.0001	<0.0001
ΔR30 (median [IQR])	-2.000 [-4.000/-1.000]	-1.000 [-3.000/0.000]	-2.000 [-4.000/-1.000]	<0.0001	0.060
ΔR120 (median [IQR])	-1.000 [-2.000/0.000]	0.000 [-1.000/0.000]	-1.000 [-2.000/0.000]	<0.0001	0.010
Simple Oral Hygiene Score (median [IQR])	-2.000 [-3.000/0.000]	-2.000 [-3.000/0.000]	-2.000 [-3.000/0.000]	<0.0001	0.717
OHQoL (median [IQR])	0.000 [0.000/4.000]	4.000 [0.000/5.000]	0.000 [0.000/1.000]	0.026	0.185
QOL EQ-VAS (median [IQR])	0.000 [0.000/4.000]	0.500 [0.000/6.000]	0.000 [0.000/2.000]	0.069	0.802

IQR: Interquartile range; MGI: Modified Gingival Index; WID score: Whitening Index for Dentistry Score; MLSI: Modified Lobene Staining Index; ΔR30 and ΔR120: percentage of tooth surface with ≥30% and ≥120% fluorescence increase, respectively; OHQoL: Oral Health-related Quality of Life; QOL EQ-VAS: EuroQoL Visual Analogue Scale.
‡ Linear mixed model analysis;
§ Time effect;
† Effect of class on polishing

indicators of oral health, including higher Modified Gingival Index scores, greater plaque accumulation measured by QLF, higher staining scores on both buccal and lingual surfaces, and poorer SOH values. Tooth whiteness, as quantified by the WID, was also lower among smokers, reflecting greater discoloration. These findings align with the established evidence that chronic exposure to tobacco smoke alters the oral environment, promoting inflammatory changes, dysbiotic biofilm composition, and increased calculus formation [2,4]. The greater prevalence and severity of gingival inflammation among smokers is consistent with prior clinical and epidemiological studies demonstrating a strong association between smoking and periodontal disease progression [39–41]. The baseline aesthetic differences also corroborate existing literature linking tobacco exposure to extrinsic and intrinsic tooth discoloration [7,8]. Furthermore, while oral health–related quality of life did not differ significantly at baseline, smokers reported lower general health status, in line with evidence showing that smoking negatively affects self-perceived health across multiple domains [42,43].

While formal periodontal re-evaluation is often performed around 4 weeks after non-surgical therapy to assess tissue healing [44], the present results suggest that early reductions in gingival inflammation are detectable as early as 14 days. These short-term changes may represent the initial biological response to mechanical debridement, preceding longer-term tissue remodeling [45,46]. Importantly, the magnitude of improvement was consistently greater among smokers for key clinical outcomes such as MGI, staining indices (both buccal and lingual MLSI), and ΔR120. This pattern likely reflects the higher baseline inflammatory and biofilm burden observed in smokers, which creates greater potential for measurable short-term gains once plaque-retentive factors are removed.

Previous studies have reported that smoking adversely affects long-term periodontal healing following non-surgical therapy [21]. Nonetheless, findings across the literature are not entirely uniform, and variability in follow-up intervals may contribute to these differences [18,47,48]. The current results suggest that shortly after intervention, removal of the bacterial biofilm is associated with a significant reduction in inflammatory signs even among active smokers. It is conceivable that early inflammatory resolution represents a phase of response that remains partially preserved despite ongoing tobacco exposure, whereas longer-term reparative processes are more susceptible to smoking-related impairment. Accordingly, the short-term advantage observed in smokers may not be sustained over extended follow-up, potentially explaining the diminished long-term outcomes described in previous reports.

Although both ΔR30 and ΔR120 showed a greater reduction among smokers, this difference reached statistical significance only for ΔR120 (p=0.010), while ΔR30 only approached significance (p=0.060). The

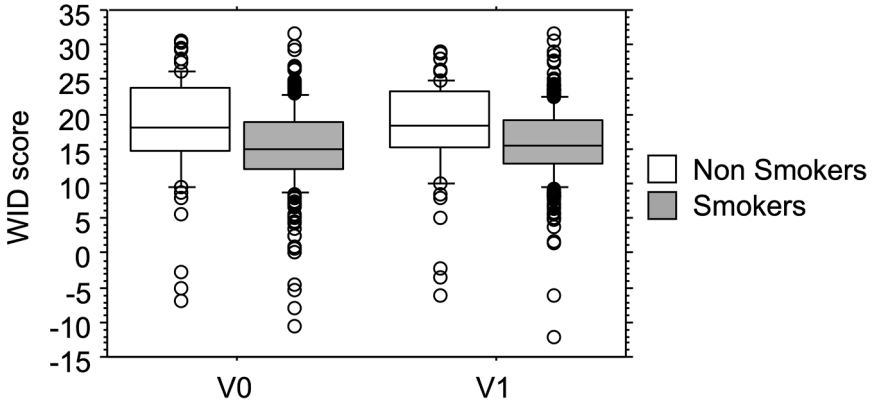

Fig. 3. Whitening Index for Dentistry (WID) score distribution at Visit 0 (pre- scale and polishing – V0) and Visit 1 (post- scale and polishing – V1), separately for Non Smokers and Smokers. WID score was significantly lower in Smokers than in Non Smokers at V0 (p<0.0001, Mann-Whitney U-test) and did not show any significant change from V0 to V1 (p=0.846). Similarly, the magnitude of the V0-V1 change was not different between classes (p=0.396, linear mixed model analysis).
Boxplot horizontal bars indicate (from the bottom to the top) 10th, 25th, 50th (median), 75th, and 90th percentiles. Values below 10th and above 90th percentiles are plotted as circles.

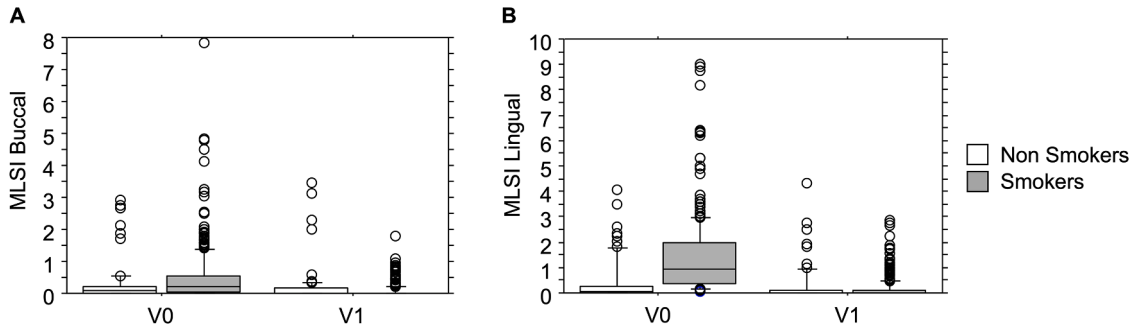

Fig. 4. Left panel (A) - Modified Lobene Staining Index (MLSI) buccal distribution at Visit 0 (pre- scale and polishing – V0) and Visit 1 (post- scale and polishing – V1), separately for Non Smokers and Smokers. MLSI was significantly higher in Smokers than in Non Smokers at V0 (p=0.0008, Mann-Whitney U-test). MLSI significantly decreased from V0 to V1 (p<0.0001) and the magnitude of the V0-V1 reduction was greater among smokers (p<0.0001, linear mixed model analysis). Right panel (B) - Modified Lobene Staining Index (MLSI) lingual distribution at V0 and V1, separately for Non Smokers and Smokers. MLSI was significantly higher in Smokers than in Non Smokers at V0 (p<0.0001, Mann-Whitney U-test). MLSI significantly decreased from V0 to V1 (p<0.0001) and the magnitude of the V0-V1 reduction was greater among smokers (p<0.0001, linear mixed model analysis).
Boxplot horizontal bars indicate (from the bottom to the top) 10th, 25th, 50th (median), 75th, and 90th percentiles. Values below 10th and above 90th percentiles are plotted as circles.

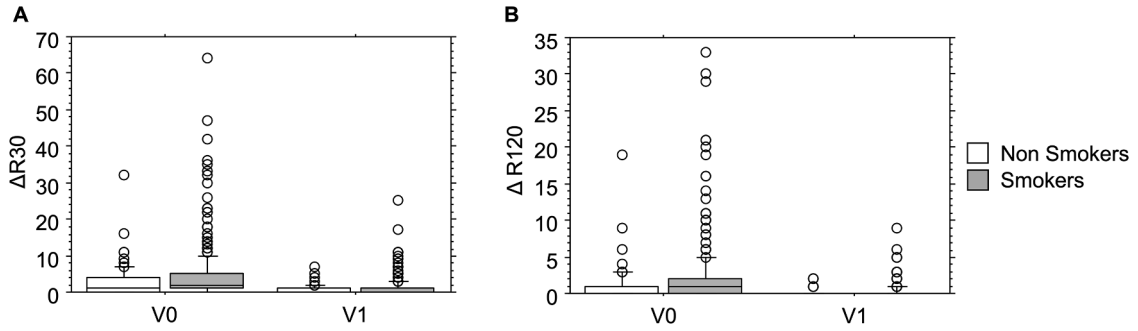

Fig. 5. Left panel (A) - Percentage of tooth surface with ≥30% fluorescence increase (ΔR30) distribution at Visit 0 (pre- scale and polishing – V0) and Visit 1 (post- scale and polishing – V1), separately for Non Smokers and Smokers. ΔR30 was significantly higher in Smokers than in Non Smokers at V0 (p=0.0139, Mann-Whitney U-test) with a significant decrease from V0 to V1 (p<0.0001). The effect of the class on the V0-V1 change was close to the significance level (p=0.060, linear mixed model analysis).
Right panel (B) - Percentage of tooth surface with ≥120% fluorescence increase (ΔR120) distribution at V0 and V1, separately for Non Smokers and Smokers. ΔR120 was significantly higher in Smokers than in Non Smokers at V0 (p=0.0075, Mann-Whitney U-test) with a significant decrease from V0 to V1 (p<0.0001). The magnitude of the V0-V1 change was greater among Smokers (p=0.010, linear mixed model analysis).
Boxplot horizontal bars indicate (from the bottom to the top) 10th, 25th, 50th (median), 75th, and 90th percentiles. Values below 10th and above 90th percentiles are plotted as circles.

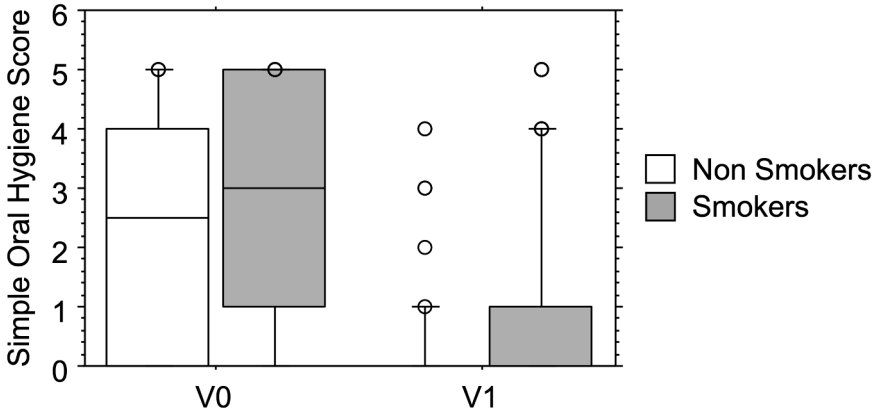

Fig. 6. Simple Oral Hygiene score was higher among Smokers at Visit 0 (pre- scale and polishing – V0) (p=0.0012, Mann-Whitney U-test). It largely decreased from V0 to Visit 1 (post- scale and polishing – V1, p<0.0001) but no effect of Class was detected (p=0.717, linear mixed model analysis).
Boxplot horizontal bars indicate (from the bottom to the top) 10th, 25th, 50th (median), 75th, and 90th percentiles. Values below 10th and above 90th percentiles are plotted as circles.

lack of a significant between-group difference in SOH scores, together with the non-significant ΔR30, suggests that short-term re-accumulation

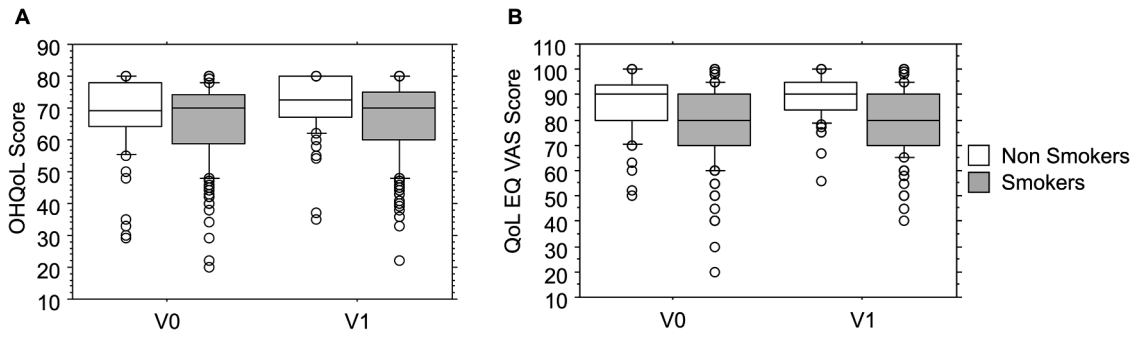

Fig. 7. Left panel (A) - Oral health–related quality of life (OHQoL) score did not differ significantly between smokers and non smokers at Visit 0 (pre- scale and polishing – V0) (p=0.201, Mann-Whitney U-test). OHQoL slightly but significantly increased from V0 to Visit 1 (post- scale and polishing – V1, p=0.026) without any significant effect of Class (p=0.185, linear mixed model analysis).
Right panel (B) - General quality of life (QoL EQ-VAS) score was lower in smokers at V0 (p=0.0001, Mann-Whitney U-test) without any significant effect of Class (p=0.802, linear mixed model analysis).
Boxplot horizontal bars indicate (from the bottom to the top) 10th, 25th, 50th (median), 75th, and 90th percentiles. Values below 10th and above 90th percentiles are plotted as circles.

of fresh plaque proceeded similarly in both groups following professional debridement. In contrast, the significant between-group difference in ΔR120 likely reflects the greater baseline burden of metabolically active and mature biofilm in smokers, which is known to characterize the dysbiotic oral environment associated with tobacco exposure, rather than a differential response to the treatment itself [4].

Tooth whiteness showed no significant changes following the intervention in both groups. This finding is not unexpected. Scaling and polishing primarily remove surface deposits and plaque but do not constitute a bleaching procedure, and intrinsic discoloration associated with long-term tobacco exposure is unlikely to be substantially modified by mechanical polishing alone [49]. The relatively contained effect on WID therefore reflects the biological and structural determinants of tooth color, which involve both extrinsic and intrinsic components [50]. This distinction is clinically relevant when interpreting aesthetic outcomes and when counselling patients regarding expected results from different types of interventions.

Patient-reported outcomes showed modest and largely similar responses across groups. Oral health–related quality of life improved slightly following the intervention, with no significant difference between smokers and never smokers. General health perception (EQ-VAS) showed a trend towards improvement that did not reach statistical significance. The modest magnitude of these changes is consistent with evidence indicating that non-surgical periodontal therapy may produce measurable but limited effects on broader quality-of-life constructs [51]. Given that subjective outcomes are influenced by psychosocial context, individual expectations, and baseline clinical status, their responsiveness to isolated mechanical procedures performed over a brief time frame may be inherently limited, particularly in individuals without severe periodontal disease at baseline.

The sex distribution between groups, with a higher proportion of males among smokers (71.1%) compared to never smokers (48.5%), reflects known sex-related differences in smoking prevalence rather than a sampling bias, and was accounted for by including sex as a covariate in the linear mixed model. Similarly, the restriction of inclusion to participants smoking between 5 and 30 cigarettes per day for a minimum of five consecutive years ensured an implicit standardization of tobacco exposure within the smoker group, limiting extreme heterogeneity in cumulative smoking intensity.

Overall, the data indicate that smoking exerts a marked impact on clinical and instrumental indicators of oral health, while its influence on aesthetic parameters such as whiteness is more complex and partly dependent on the type of intervention performed. Professional scaling and polishing produce clear short-term benefits in both smokers and never smokers, with particularly pronounced improvements in smokers for parameters directly related to inflammation, plaque, and extrinsic staining. However, the procedure alone is insufficient to substantially modify intrinsic tooth color or to generate large shifts in perceived quality of life, reinforcing the need to align patient expectations with the biological scope of the intervention.

Although plaque-related outcomes may be sensitive to individual oral hygiene practices, the non statistically significant distribution of home oral care behaviours between smokers and never smokers reduces the likelihood that the observed between-group differences in clinical and instrumental parameters were confounded by differences in self-performed oral hygiene.

Several limitations should be acknowledged. The analysis focused on short-term outcomes assessed 14 days after the intervention, and longer follow-up is necessary to determine the durability of the observed improvements and their interaction with continued smoking behavior or potential switching to combustion-free nicotine alternatives within the broader SMILE framework. In addition, the present evaluation did not include structural periodontal parameters such as clinical attachment level or probing depth, which are more closely associated with long-term periodontal stability and tissue remodeling. As a result, the findings primarily reflect early inflammatory and biofilm-related changes rather than definitive indicators of sustained periodontal healing. The unequal group sizes between smokers and never smokers reflect the pre-specified design of the SMILE study, in which never smokers were recruited as a reference group; this allocation was intentional and does not affect the validity of the statistical comparisons performed. Finally, the study population was relatively young, with a median age of 30 years among smokers, reflecting the recruitment strategies employed, including outreach to university students and hospital staff, which may limit the generalisability of the findings to older smokers with higher cumulative tobacco exposure and more advanced periodontal disease.

Despite these limitations, the findings carry relevant clinical implications. They confirm that professional mechanical plaque removal yields meaningful short-term reductions in inflammation and biofilm accumulation even among active smokers, reinforcing recommendations for regular periodontal maintenance in this population [10]. At the same time, the limited impact on intrinsic discoloration highlights the need for complementary aesthetic interventions when tooth color improvement is a primary concern. More broadly, integrating structured oral health assessment into smoking-related clinical pathways may provide a tangible and measurable target for preventive strategies and harm-reduction approaches, particularly when objective improvements in gingival and plaque indices can be demonstrated to patients. The observed improvements associated with professional plaque control should be interpreted within the broader context of tobacco-related oral health risks. While preventive dental care may help mitigate some adverse effects of smoking, smoking cessation remains the most effective

strategy for achieving sustained periodontal health, improving overall oral health, and reducing the risk of disease progression.

The present analysis does not include comparisons between study populations of participating countries, which have been reported separately in a recent publication [38].

5. Conclusions

In conclusion, professional scaling and polishing resulted in consistent short-term improvements in objective indicators of oral health in both smokers and never smokers, with greater magnitude of change observed among smokers due to their higher baseline burden. While early inflammatory and plaque-related parameters proved responsive to mechanical biofilm removal even in the presence of ongoing tobacco exposure, aesthetic changes in intrinsic tooth color and broader quality-of-life measures were modest. These findings support the clinical relevance of regular professional plaque control in smokers, while reinforcing the need for longer-term assessment to clarify whether these early improvements translate into sustained periodontal and patient-centered benefits. Finally, smoking cessation remains the cornerstone of oral health promotion and periodontal disease prevention, and should be actively encouraged alongside professional preventive care.

Data availability

The data supporting the findings of this study are available at the following link: https://doi.org/10.5281/zenodo.20727523.

Funding

This work was supported by a grant from the Ministero dell'Università e della Ricerca (MUR), Bando PNRR funds, project code TNE23-0001, "Italy-East Asia cooperation: from local expertise to a global outlook - LEGO" - CUP H71I24000300002, and by a grant from the Department of Clinical and Experimental Medicine, University of Catania (UPB: 6C725202048/2024). The present analysis used de-identified datasets obtained free of charge from an open research repository (https://doi.org/10.5281/zenodo.20727523). The randomized trial from which the datasets were derived was originally funded through an investigator-initiated research grant sponsored by ECLAT Srl, a spin-off of the University of Catania, supported by a competitive grant from Global Action to End Smoking an independent, U.S. nonprofit 501(c)(3) grant-making organization, accelerating science-based efforts worldwide to end the smoking epidemic. The sponsors played no role in designing, implementing, data analysis, or interpretation of the original study results. The contents, selection, and presentation of facts, as well as any opinions expressed, are the sole responsibility of the authors and should not be regarded as reflecting the positions of the sponsors.

Ethical statement

The SMILE study has been approved by the ethics committees of the four participating dental sites and is registered on ClinicalTrials.gov with the identifier NCT04649645 (https://clinicaltrials.gov/ct2/show/NCT04649645) and on the International Registered Report Identifier (IRRID) with the identifier DERR1-10.2196/53222. Further information can be obtained on the website https://smilestudy.coehar.org. The study adhered to the Principles of Good Clinical Practice (GCP) and was conducted in accordance with the Declaration of Helsinki.

Patient consent statement

Informed consent was obtained from all participants included in the study

Clinical trial registration

NCT04649645 (https://clinicaltrials.gov/ct2/show/NCT04649645)

CRediT authorship contribution statement

Giusy Rita Maria La Rosa: Writing – review & editing, Writing – original draft, Visualization, Methodology, Formal analysis, Data curation. **Jan Kowalski:** Writing – review & editing, Methodology, Investigation, Data curation. **Gaetano Isola:** Writing – review & editing, Validation, Data curation. **Fabio Cibella:** Writing – review & editing, Writing – original draft, Software, Formal analysis, Data curation. **Salvatore Urso:** Writing – review & editing, Methodology, Data curation, Conceptualization. **Elisea Tomaino:** Writing – review & editing, Validation. **Riccardo Polosa:** Writing – review & editing, Writing – original draft, Supervision, Resources, Project administration, Methodology, Funding acquisition, Conceptualization.

Declaration of competing interest

GRMLR was awarded a 2026 Scholarship from the Knowledge•Action•Change Tobacco Harm Reduction Programme, an independent public health organization based in the UK and funded by Global Action to End Smoking, a US-based independent non-profit 501(c)(3) grant-making organization, for a project focused on oral health. The content of the present paper is unrelated to that project. She was also awarded Tobacco Harm Reduction Scholarship Programme in 2024/2025.

IC provides consulting advice to various oral healthcare companies, including Unilever, Philips, Haleon, P&G, Johnson & Johnson.

JK, GI, FC, SU, ET, ADS, DG, SAP, EP, LG, UC, VC, SG, GB, VF, RG, AA, MM, GMN, FSL, GLM and **BIK** have nothing to disclose.

RP is full tenured professor of Internal Medicine at the University of Catania (Italy) and Medical Director of the Institute for Internal Medicine and Clinical Immunology at the same University. He has received grants from U-BIOPRED and AIR-PROM, Integral Rheumatology & Immunology Specialists Network (IRIS), Global Action to End Smoking (formerly known as Foundation for Smoke-Free World), Pfizer, GlaxoSmithKline, CV Therapeutics, NeuroSearch A/S, Sandoz, Merk Sharp & Dohme, Boehringer Ingelheim, Novartis, Arbi Group Srl., Duska Therapeutics, Forest Laboratories, Ministero dell Universita' e della Ricerca (MUR) Bando PNRR 3277/2021 (CUP E63C22000900006) and 341/2022 (CUP E63C22002080006), funded by NextGenerationEU of the European Union (EU), and the ministerial grant PON REACT-EU 2021 GREEN- Bando 3411/2021 by Ministero dell Universita' e (MUR) – PNRR EU Community. He is founder of the Center for Tobacco Prevention and Treatment (CPCT) at the University of Catania and of the Center of Excellence for the Acceleration of Harm Reduction at the same university. He receives consultancy fees from Pfizer, Boehringer Ingelheim, Duska Therapeutics, Forest Laboratories, CV Therapeutics, Sermo Inc., GRG Health, Clarivate Analytics, Guidepoint Expert Network, and GLG Group. He receives textbooks royalties from Elsevier. He is also involved in a patent application for ECLAT Srl. He is a pro bono scientific advisor for Lega Italiana Anti Fumo (LIAF) and the International Network of Nicotine Consumers Organizations (INNCO); and he is Chair of the European Technical Committee for Standardization on "Requirements and test methods for emissions of electronic cigarettes" (CEN/TC 437; WG4).

Acknowledgments

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Supplementary materials

Supplementary material associated with this article can be found, in the online version, at doi:10.1016/j.jdent.2026.106839.

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