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Factors affecting dental biofilm maturity assessed with Quantitative Light-induced Fluorescence-Digital in Korean older adults

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ABSTRACT

Objectives: The study aimed to analyze the factors affecting the maturity of dental biofilm, which was assessed with quantitative light-induced fluorescence-digital(QLF-D), in a sample of Korean older adults. **Methods:** This cross-sectional study included 67 participants, aged 65 years and older. All participants completed a questionnaire and tests to measure their manual dexterity and handgrip strength, which are parameters that indicate hand function abilities. To evaluate dental biofilm maturity, 804 surfaces of six index teeth were imaged using QLF-D and then quantified as ΔR values. All data were collected from May 25, 2017 to April 30, 2018. The independent t-test, one-way analysis of variance, and step-wise multiple linear regression were performed to analyze the factors associated with the maturity of dental biofilm (ΔR). **Results:** The multivariate linear regression analysis revealed that the factor most strongly related to dental biofilm maturity(ΔR) was manual dexterity (β=-0.326), followed by handgrip strength (β=-0.303) and use of interdental cleaning devices (β=-0.283) (p<0.05). **Conclusions:** Manual dexterity, handgrip strength, and use of interdental cleaning devices are factors that can predict dental biofilm maturity in adults aged 65 years or older. Therefore, the hand function of a patient should be evaluated first, before assessing the oral hygiene status of the patient or providing him/her with oral health education, and the dental hygienist should provide differentiated oral hygiene care depending on the patient's hand function ability. Finally, dental hygienists should help older adults to recognize the importance of auxiliary oral hygiene devices such as interdental brushes and keep motivating them to use the devices more frequently.

Key Words : Dental biofilm, Hand function, Interdental cleaning devices

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Introduction

The percentage of the elderly population is rapidly increasing throughout the world. Particularly in South Korea, the population of elderly individuals aged 65 years or older reached 14% of the total population in 2018, marking a transition from an aging society to an aged society within just 18 years [1]. Increased life expectancy is a major achievement brought on by medical advancement, but especially in case of South Korea, it is facing various problems, such as increased medical cost, due to rapid population aging. According to 2015 Korean National Health and Nutrition Examination Survey (KNHANES), the prevalence of dental caries and periodontal disease, which are the main causes of tooth loss in older adults aged 65 years or older, was 25% and 50%, respectively, whereas half of older adults aged 70 years or older had experienced discomfort during mastication or annunciation owing to an oral issue [2]. Moreover, periodontal disease and impairment of teeth and supporting structures are included as the top 10 outpatient diseases for which older adults most often visit a medical institution [3], which has resulted in a significant amount of financial investment for treating such oral issues, on a national level as well as on an individual level by older adults. Therefore, under the circumstance of continued increase in the aged population, efforts are needed to introduce effective oral health policies for the prevention of oral diseases and enhancement of quality of life.

The primary etiology of oral diseases involves a dental biofilm comprising over 700 species of microorganisms [4]. If the dental biofilm is not removed regularly, new bacteria continue to adhere to the film to cause the film to become more mature, which may ultimately cause demineralization of dental hard tissue and periodontal inflammation [4]. Therefore, early removal of the dental biofilm through self-oral hygiene care is needed for the prevention of oral diseases and maintenance of optimal oral health conditions.

To date, dental disclosing agents have been used to make it easy to visually identify the amount of dental biofilm or the area where the dental biofilm has formed [4]. However, such dental disclosing agents have the disadvantage of staining soft deposits or the oral mucosa, in addition to the dental biofilm [5]. Moreover, because it requires quite a bit of time to remove the dental disclosing agent on the tooth surface or soft tissues in the oral cavity, there are limitations in frequent use by older adults. As a method to address these disadvantages, the use of quantitative light induced fluorescence-digital (QLF-D) for assessing the oral hygiene status has increased recently [6]. QLF-D (Biluminator™; Inspektor Research Systems BV, Amsterdam, The Netherlands) is an optical device that uses 405 nm blue visible light to detect red fluorescence emitted by endogenous porphyrins, which are metabolites generated by oral bacteria [7]. This device makes the red fluorescence of the dental biofilm visible without using a dental disclosing agent [8]. An especially outstanding advantage is that a more mature dental biofilm, which has a higher activity level of pathogenic microorganisms, produce red fluorescence that is more intense than a recently deposited dental biofilm [7,8], and thus, QLF-D is highly effective for the quantitative detection of a mature dental biofilm.

Advances in medical technology and improvement in socioeconomic levels have led to a trend of

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gradual increase in the average number of remaining teeth that older adults have [9]. Therefore, studies on factors that interfere with removal of the dental biofilm in older adults should contribute to effectively enhancing their oral health. While there are some previous studies that have reported on factors that that can predict oral hygiene status [10-12], most of these studies only assess the quantity of dental biofilm deposited on the tooth surface. However, quantitative assessment of dental biofilm maturity should contribute to a more accurate analysis of risk factors that have interfered with removal of the dental biofilm for a long time. Further, with the situation of increasing scientific evidence for the mutual relationship between general health and oral health [12], general risk factors that induce poor oral hygiene must be identified and intervention for removing such risk factors must be provided endlessly.

Accordingly, the present study aimed to analyze the factors that affect dental biofilm maturity assessed using QLF-D, in adults aged 65 years or older. The findings of the study are expected to provide meaningful information for developing and operating intervention programs that are effective in enhancing the oral health of older adults.

Methods

1. Study population

The present study was approved by the Institutional Review Board of oo University (IRB No.1044396-201705-HR-084-01). The study period was May 25, 2017 to April 30, 2018. For recruitment of candidates, convenience sampling was applied in selecting 5 senior welfare centers located in Gyeonggi-do and Incheon. Elderly people aged 65 years or older who are right-handed, regular visitors to the selected welfare centers, and have all 6 teeth designated for the study were provided with an explanation of the objectives and methods of the study. Those who consented to participate in the study signed and submitted the informed consent form, and subsequently, a questionnaire survey was conducted on 109 candidates who volunteered to participate in the study. Upon completion of data collection, 34 candidates who may have factors that facilitate dental biofilm deposit were excluded on the basis of the following exclusion criteria: diagnosed with musculoskeletal impairment; taken antibiotics within past 1 month; consumed half a glass or more of alcohol every day for the past 6 years; diagnosed with salivary hypofunction (unstimulated salivary flow rate < 0.1 mL/min) [13] or cognitive impairment by a medical institution; and wearing prosthesis on or have a cavity in any of the index tooth. Moreover, the Korean version of the Mini-Mental State Examination (MMSE-K) was used to assess the cognitive state, and based on the results, 3 additional candidates with score $\leq$ 19 points, indicating suspicion of dementia [14], were also excluded. In addition, 5 more candidates who requested to drop out of the study were also excluded. Consequently, the study excluded data from 42 candidates and analyzed the data from a total of 67 participants. The minimum sample size for linear regression analysis was calculated using G*Power 3.1 program (Informer Technologies, Düsseldorf, Germany) [15]. For a

significance level of 5%, a statistical power of 90%, and an effect size of 0.25, the minimum sample size was determined to be 62.

2. Study tools

The questionnaire consisted of questions on general characteristics (age, gender, and living status), general health status (presence of chronic disease, and daily medication status and reason), and oral health behavior (frequency of daily toothbrushing, toothbrushing time, use of interdental brush, recent dental check-up, recent dental scaling, and smoking status).

The hand function of the participants was assessed based on handgrip strength and manual dexterity. Handgrip strength was assessed using the Baseline® Hydraulic Hand Dynamometer (Fabrication Enterprises Inc., Irvington, New York, USA) [16]. Each participant was instructed to sit in a chair with the back straight and maximum handgrip strength was measured with the right elbow touching the torso and flexed at 90° [17]. The examiner took 3 repeated measurements of handgrip strength in 15-second intervals and the mean of the measured values was calculated. Higher values were interpreted as higher handgrip strength. Manual dexterity was measured using the box and block test (Samson & Preston Company Bolingbrook, IL, USA) [18]. Each participant was instructed to move as many blocks as possible from the right side to the left side within 1 minute using their right hand. Higher number of blocks moved to the left side was interpreted as greater manual dexterity.

For assessment of the oral hygiene status, QLF-D was used to analyze dental biofilm maturity [6]. The participants were instructed not to eat anything or perform any oral hygiene behavior for at least 4 hours prior to QLF-D imaging. The teeth selected and designated as the index teeth were the maxillary right lateral incisor (#12), maxillary right first molar (#16), maxillary left first premolar (#24), mandibular left lateral incisor (#32), mandibular left first molar (#36), and mandibular right first premolar (#44) [19]. For QLF-D imaging, the conditions were set to shutter speed 1/30 s, ISO speed 1,600, and aperture value 5.0 [6]. Each participant was instructed to assume the supine position in a dental chair, while the assessor dried the buccal and lingual aspects of the index teeth and placed the camera lens vertically to the tooth surface being imaged. The distance between the tooth surface and camera lens was kept constant. After imaging a total of 804 surfaces, a software program for QLF-D (QA2 v 1.24; Inspektor Research Systems BV, Amsterdam, Netherlands) was used to calculate ΔR values, which represent dental biofilm maturity [6]. To eliminate the influence of gingival recession, the dental biofilm deposited below the cementoenamel junction was not analyzed. Higher ΔR values were interpreted as higher dental biofilm maturity.

3. Data analysis

Collected data were analyzed using IBM SPSS 23.0 (IBM Co., Armonk, NY, USA). For assessment of the overall oral hygiene status, ΔR values measured from both the buccal and lingual aspects of 6 index teeth were summed, which was then used as the dependent variable in the study. For assessment of handgrip strength and manual dexterity, reference values provided in previous studies [17,20] were

used to calculate a standard score for each. For the cut-off point of handgrip strength and manual dexterity, a standard score of −2 was used [21], whereas participants with standard score of -2 or below for handgrip strength and manual dexterity were allocated to the low handgrip strength and low manual dexterity group, respectively. For analysis of differences in dental biofilm maturity according to the general characteristics, general health status, hand function, and oral health behavior of the participants, the independent t-test or one-way analysis of variance (ANOVA) was performed, while the Scheffe test was used for multiple comparisons of significant variables. Lastly, for analysis of the influence of factors affecting dental biofilm maturity, step-wise multiple linear regression analysis was performed. Factors that showed significance probability of < 0.1 in univariate analysis were inputted as independent variables. The statistical significance level was set to α=0.05.

Results

1. Dental biofilm maturity according to the general characteristics of the participants

There were no statistically significant differences in dental biofilm maturity (ΔR) according to the general characteristics of the participants <Table 1>.

2. Dental biofilm maturity according to general health status and hand function

The results of the analysis of ΔR values according to general health status and hand function are shown in Table 2. The group taking medications for diabetes showed higher ΔR values than the group that did not (p=0.024). The groups with low manual dexterity and handgrip strength showed higher ΔR values than the groups with normal manual dexterity and handgrip strength (p=0.009 and 0.038, respectively).

Table 1. ΔR value according to the general characteristics of the participants

Characteristics	N	ΔR	
		Mean±SD	t(p^*)
Gender			
Male	18	146.19±101.24	0.547(0.589)
Female	49	133.69±103.31	
Age (yr)$^+$			
< 75	37	127.15±100.15	-0.682(0.498)
≥ 75	30	144.35±105.66	
Living status			
Living alone	25	147.49±98.45	0.778(0.439)
Living with spouse/child	42	127.33±104.85	

*by t-test
$^+$Divided by subject's average

3. Dental biofilm maturity according to oral health behaviors

The results of the analysis of ΔR values according to oral health behaviors are shown in <Table 3>. The group not using the interdental brush showed higher ΔR values than the group using it (p=0.003). Moreover, the group that underwent the most recent oral check-up > 2 years ago and the group that underwent the most recent scaling > 3 years ago tended to show higher ΔR values (p=0.090 and 0.088, respectively).

4. The influence factors affecting dental biofilm maturity

The results of multiple linear regression analysis on the influence of factors affecting ΔR values are shown in <Table 4>. The variable that showed the highest association with ΔR values was manual dexterity (β=-0.326), followed in order by handgrip strength (β=-0.303) and use of interdental cleaning devices (β=-0.283) (p<0.05). In other words, ΔR values were higher in groups with decreased manual dexterity and handgrip strength and the group that did not use interdental cleaning devices. The regression model used in the analysis had an explanatory power of 20.2%. Based on the tolerance being > 0.10 and variance inflation factor (VIF) being much smaller than 10, it was determined that multicollinearity was not present.

Table 2. ΔR value according to general health status and hand function

Characteristics	N	ΔR	
		Mean±SD	t or F(p^*)
No. of systemic chronic diseases			
No	13	103.46±110.57	1.124 (0.331)
1	23	122.96±89.79	
≥2	31	154.33±103.81	
Medication use			
Yes	52	139.95±103.72	-0.757 (0.452)
No	15	117.20±98.20	
Medications for high blood pressure[+]			
Yes	24	130.93±106.85	0.233 (0.817)
No	43	137.04±100.78	
Medications for diabetics[+]			
Yes	13	192.03±108.28	-2.320 (0.024)
No	54	121.09±96.77	
Manual dexterity[‡]			
Low	21	182.49±104.49	2.696 (0.009)
Normal	46	113.11±94.51	
Handgrip strength[‡]			
Low	43	154.07±107.20	2.113 (0.038)
Normal	24	100.42±84.11	

[*]by t-test or one-way ANOVA
[+]Only medications that were taken by more than about 20% of the subjects were analyzed
[‡]by cut-off point (-2 standard scores)

Table 3. ΔR value according to oral health behaviors

Characteristics	N	ΔR	
		Mean±SD	t(p^*)
Frequency of toothbrushing (daily)			
< 3 times	36	152.65±108.75	1.551 (0.126)
≥ 3 times	31	114.19±91.49	
Toothbrushing time (min.)			
< 3	52	143.17±104.33	1.245 (0.218)
≥ 3	15	106.02±92.02	
Use of the interdental brush			
Yes	17	86.32±60.05	3.071 (0.003)
No	50	151.35±108.64	
Recent dental check-ups (yrs.)[+]			
≤ 2	45	118.18±88.22	-1.749 (0.090)
> 2	22	168.95±121.35	
Recent dental scaling (yrs.)[+]			
≤ 3	56	125.41±96.82	-1.732 (0.088)
> 3	11	182.94±119.89	
Smoking status			
Former, current	10	147.73±101.06	0.429 (0.669)
Never	57	132.60±103.06	

[*]by t-test
[+]Divided by subject's average score

Table 4. Factors related to dental biofilm maturity

Characteristics	Unstandardized Coefficients		Standardized Coefficients	t	p^*
	B	SE	β		
Manual dexterity	-71.304	24.739	-0.326	-2.882	0.005
Handgrip strength	-100.488	37.715	-0.303	-2.664	0.010
Use of interdental cleaning devices	-66.010	26.423	-0.283	-2.498	0.015
F=6.569(<0.001), R^2=0.238, adj.R^2=0.202					

[*]by stepwise multiple linear regression analysis
Dependent variable: dental biofilm maturity(ΔR)
Manual dexterity and handgrip strength (low = 0, normal = 1), use of interdental cleaning devices (no = 0, yes = 1).
Excluded variables: medications for diabetics, recent dental check-ups, recent dental scaling

Discussion

South Korea has established a policy goal of improving the number of remaining natural teeth among older adults aged 65-74 years up to 20 teeth by 2020 [22]. To keep natural teeth healthy, strict management of the dental biofilm is important. Therefore, dental hygienists need to regularly check for factors that interfere with removal of the dental biofilm and provide endless intervention to remove or reduce such risk factors in older adults to assure that their natural teeth are kept healthy. In the process of providing such interventions, using QLF-D device can allow quantitative assessment of dental biofilm maturity, which can contribute to accurate identification of risk factors for poor oral

hygiene. Accordingly, the present study analyzed the factors that affect dental biofilm maturity, which was assessed using QLF-D, in adults aged 65 years or older.

In the multiple linear regression model, the factors associated with dental biofilm maturity were manual dexterity (β=0.326), handgrip strength (β=0.303), and use of interdental cleaning devices (β=-0.283). In particular, the groups with lower manual dexterity and handgrip strength showed higher dental biofilm maturity, whereas these two factors were found to have the most significant influence on dental biofilm maturity among all factors included in the present study. Based on such findings, it was determined that decline in fine muscle function in the fingers responsible for precise motion and reduced muscle strength resulted in toothbrushing performed regularly not be able to effectively remove dental biofilm. In particular, the bristles of the toothbrush should be used to repeatedly apply short and precise oscillating motion to the area being cleaned to effectively remove the dental biofilm deposited in between the teeth or gingival sulcus, but it is suspected that older adults with decline in manual dexterity could not perform this motion effectively during toothbrushing. Therefore, the findings of the present study suggest that manual dexterity and handgrip strength are factors that can predict dental biofilm maturity in adults aged 65 years or older. Moreover, the importance of comprehensive and integrative approaches is also emphasized. To date, the hand has been viewed as an important factor for independently performing activities of daily living and personal hygiene care [23]. However, very few studies have confirmed the role of hands in oral hygiene care in older adults aged 65 years or older who experience gradual decline in hand function. In other words, although injured fingers or joints have been reported as factors that interfere with oral hygiene care in care facility-residing older adults [24], the importance of hand function with respect to deposit or removal of dental biofilm in older adults who can independently perform activities of daily living has not received much attention. Generally, gradual decrease in the muscle mass and strength occurs with aging and significant decline in hand manipulation ability also appears after the age of 65 years [25]. Therefore, dental hygienists must recognize that hand function status is also a factor that can interfere with oral hygiene in not only care facility-residing older adults, but also in independent community-dwelling older adults. Hence, hand function should be assessed by a musculoskeletal specialist prior to assessment of oral hygiene status, and dental hygienists should provide customized oral hygiene care according to the hand function assessment results. Moreover, the oscillating-rotating electric toothbrush has been proven to be effective in removing dental biofilm [26], and similar to a previous study [27], the present study also reconfirmed the importance of interdental cleaning devices for removing mature dental biofilm. Unfortunately, only approximately 25% of the participants in the present study were using interdental cleaning devices, which indicated that there are very few older adults who recognize the importance of interdental cleaning. Generally, older adults have little interest in the own oral hygiene status [28] and slightly lower practice of oral health behavior [29]. Therefore, dental hygienists must promote awareness about the importance of auxiliary oral care products , such as the interdental brush and electric toothbrush, among older adults with low handgrip strength and manual dexterity, while also endlessly motivating them to increase the use of such products. Further, dental hygienists

must provide regular education on the importance of removing dental biofilm to older adults with weak hand function and operate a more systematic oral hygiene care system to allow regular removal of mature dental biofilm or calculus that has built up on teeth surface over a long time. Furthermore, intervention programs for calculus hand function can not only improve the ability to perform activities of daily living by older adults, but also contribute to the improvement of their oral hygiene status.

The present study had some limitations. First, because a cross-sectional study design was used, it is difficult to prove the causal relationships between the factors used in the study. Second, because the participants were selected by convenience sampling from a limited area, there are limitations in generalizing the findings in the study. Third, the group taking medications for diabetes showed higher dental biofilm maturity in the univariate analysis, but the significance of this was not confirmed in the final regression model. It is believed that the aforementioned result was due to only a small number of older adults taking medication for diabetes among all study participants. Moreover, other oral health behaviors, except use of interdental cleaning devices, did not show a significant association with dental biofilm maturity. Such findings were interpreted as an indication of the toothbrushing method being more important than frequency or duration of toothbrushing for effective removal of dental biofilm. The participants in the present study were not fully aware of how they were brushing their teeth, and thus, the study could not assess their toothbrushing methods. Future studies should expand the study population and use various tools, such as video tools, to accurate accurately assess toothbrushing methods, as well as reanalyzing the associations with dental biofilm maturity. Despite these limitations, the significance of the present study can be found in the fact that it used QLF-D to perform objective and quantitative assessment of dental biofilm maturity in adults aged 65 years or older and proved that manual dexterity, handgrip strength, and use of interdental cleaning devices are factors that can predict dental biofilm maturity.

Conclusions

The present study analyzed factors associated with dental biofilm maturity, which was assessed using QLF-D, in adults aged 65 years or older. The following conclusions were derived:

1. There were no statistically significant differences in dental biofilm maturity (ΔR) according to the general characteristics of the participants.

2. The group taking medications for diabetes showed higher ΔR values than older adults who did not (p=0.024). Groups with low manual dexterity and handgrip strength showed higher ΔR values than healthy older adults (p<0.05).

3. The group not using the interdental brush showed higher ΔR values than older adults using it (p=0.003). Moreover, the group that underwent the most recent oral check-up > 2 years ago and the group that underwent the most recent scaling > 3 years ago tended to show higher ΔR values (p=0.090 and 0.088, respectively).

4. In the final regression model, the factor that showed the highest association with ΔR values was

manual dexterity (β=-0.326), followed in order by handgrip strength (β=-0.303) and use of interdental cleaning devices (β=-0.283) ($p<0.05$).

In this study, we found that manual dexterity, handgrip strength, and use of interdental cleaning devices are factors that can predict dental biofilm maturity in adults aged 65 years or older. Therefore, hand function should be assessed by a musculoskeletal specialist prior to assessment of oral hygiene status, and dental hygienists should provide customized oral hygiene care according to the hand function assessment results. Moreover, intervention programs for strengthening hand function can not only improve the ability to perform activities of daily living by older adults, but also contribute to improving their oral hygiene status. Lastly, dental hygienists must promote awareness about the importance of auxiliary oral hygiene products, such as interdental brush, and endlessly motivate them to increase the use of such products among older adults.

Conflicts of interest

The authors declared no conflict of interest.

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