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Manual dexterity and dental biofilm accumulation in independent older adults without hand disabilities: A cross-sectional study

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ABSTRACT

Background: This study investigated the relationship between manual dexterity and dental biofilm accumulation in independent older Koreans using Quantitative Light-Induced Fluorescence-Digital (QLF-D).
Methods: This cross-sectional study included 44 participants recruited from senior welfare facilities in South Korea and aged ≥65 years. Participants were surveyed using face-to-face structured interviews; manual dexterity was assessed using the Box and Blocks Test. To evaluate dental biofilm accumulation, the 528 surfaces of six index teeth were imaged using QLF-D and then quantified into Simple Plaque Scores (SPS) and ΔR_{20} values. The *t*-test and one-way analysis of variance were used to analyze differences in SPS and ΔR_{20} according to general characteristics and manual dexterity.
Results: Those who brushed their teeth ≤2 times per day had higher SPS and ΔR_{20} values on the lingual surface of tooth #24 than those who brushed ≥3 times per day ($p < 0.05$). The low manual dexterity group had higher SPS on lingual surfaces of teeth #12, #24, and #32, as well as higher ΔR_{20} values on the lingual surfaces of teeth #12, #24, #32, and #44 ($p < 0.05$) than the normal group.
Conclusions: The low manual dexterity group had more dental biofilm—particularly on the lingual surfaces of teeth—and more mature biofilm than the normal group. These findings indicate that reduced manual dexterity could be a predictor of poor oral hygiene in independent older adults without hand disabilities. Therefore, we suggest manual dexterity be assessed in advance of dental biofilm assessment and tooth brushing instruction.

1. Introduction

Rapid growth of the elderly population is a global trend. South Korea, in particular, is one of the world's fastest-aging countries, necessitating effective measures to manage health issues for older adults [1]. As people age, they are more exposed to risk factors for oral disease, leading to high prevalence of oral diseases such as periodontal disease [2]. Since poor oral health directly and indirectly affects the overall health and quality of life [3], health professionals should enhance interdisciplinary collaboration in health care to optimize the oral health of older adults.

The poor oral hygiene status of older adults has long been attracting attention from the world of dentistry [4]. Dental biofilm, consisting of bacteria, fungi, and virus, is related to the onset of dental caries, periodontal disease, bad breath, and tooth loss, eventually causing a decline in oral function [5]. Therefore, the management of dental biofilm, the primary etiologic factor for oral disease, is critically important for maintaining oral health [6]. Unfortunately, in general, oral self-care to remove dental biofilm decreases as people age, leading to more oral health problems [7]. Hence, oral health professionals must pay more attention to oral hygiene care ability and thoroughly monitor systemic factors that disturb the oral health of older adults.

Thus far, disclosing agents have been used to identify colorless dental biofilm [6], however, this traditional method has several limitations. The process of applying disclosing agents to tooth surfaces and removing them afterwards is cumbersome, and the agents stain not only dental biofilm, but also stain soft debris and pellicles [8]. To overcome these limitations, the Quantitative Light-Induced Fluorescence (QLF) technology, an optical device, has recently been used in dentistry for dental biofilm assessment [9,10]. Specifically, the QLF-Digital (QLF-D)

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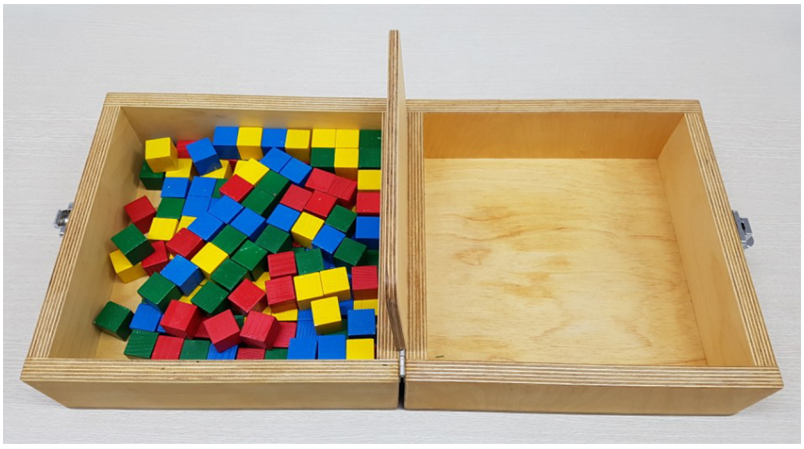

Fig. 1. Box and Blocks Test for manual dexterity.

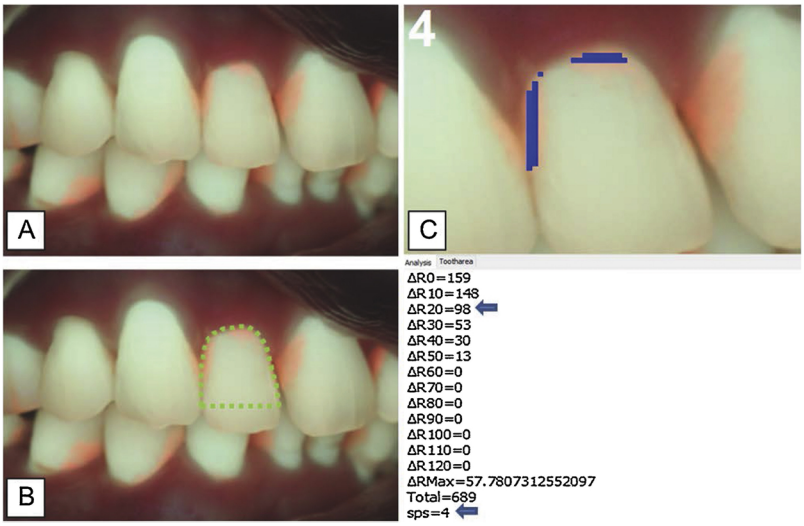

Fig. 2. Procedure for analyzing dental biofilm accumulated on tooth surfaces (A) Fluorescence image of the dental biofilm detected by Quantitative Light-Induced Fluorescence-Digital (QLF-D; Inspektor Research Systems BV, Amsterdam, The Netherlands); (B) contouring of index teeth for measurement of Simple Plaque Scores and ΔR_{20} values of dental biofilm using an image analysis software program (QA2 version 1.24; Inspektor Research Systems BV, Amsterdam, The Netherlands); and (C) analysis results of red fluorescent dental biofilm.

system (Biluminator™; Inspektor Research Systems BV, Amsterdam, The Netherlands), a new version of the QLF technology, is a digital camera with an embedded special filter (D007; Inspektor Research Systems BV, Amsterdam, The Netherlands) that can detect endogenous porphyrins, a metabolite produced by oral bacteria [11]. QLF-D is advantageous as it precisely visualizes dental biofilm as red fluorescence by irradiating teeth with 405-nm blue light [12]. In particular, when dental biofilm is more mature, meaning it has not been removed from the tooth surface for a long period of time, the intensity of red fluorescence of dental biofilm increases [9]. Thus, this system can quantitatively assess dental biofilm, which is difficult to see with the naked eye, with high accuracy and can even evaluate the pathogenic status of dental biofilm.

By assessing the accumulation of dental biofilm in people with vulnerable oral health and monitoring factors related to biofilm formation, dental professionals will be able to provide valuable information that can help improve oral health status. To promote the oral health of older adults, more research is needed on the specific factors that predict poor oral hygiene. Hand disorders have been reported to affect oral self-care. In particular, diminished or impaired skills in the digits or joints due to rheumatoid arthritis or osteoarthritis can lead to poor oral hygiene status [13]. Although a few studies have reported on the impact of manual dexterity on dental biofilm control [14,15], their subjects were limited to institutionalized or dependent older adults. Additionally, while it has been reported that in-hand manipulation skills start to decline in one's middle years and this decline is further accelerated after the age of 65 years [16], there is relatively little information on what impact manual dexterity has on dental biofilm removal, especially in independent older adults. Moreover, more qualitative results could be expected if pathogenic status of dental biofilm was evaluated, which would be of more help for establishing effective oral hygiene intervention programs.

Therefore, the aim of this study was to quantitatively evaluate the correlation between dental biofilm accumulation and manual dexterity of independent older adults without hand disabilities using the dental

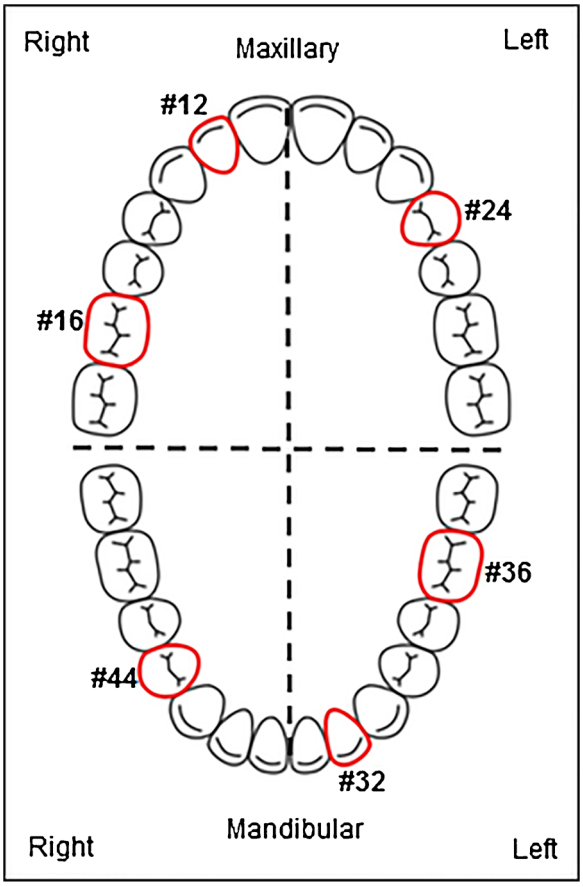

Fig. 3. Locations and symbols of six index teeth.

diagnostic tool, QLF-D. In particular, this study intended to identify the tooth areas in which dental biofilm accumulation is related to reduced manual dexterity. It was hypothesized that reduced manual dexterity would have a negative impact on the effective removal of dental biofilm in independent older adults without hand disabilities.

2. Materials and methods

2.1. Participants

This was a cross-sectional study approved by the Institutional Review Board of Gachon University (IRB No. 1044396-201804-HR-094-01). This research was conducted in accordance with the World Medical Association's Declaration of Helsinki.

Five facilities were randomly selected among senior welfare facilities located in Yeonsu-gu, Incheon. The examiner provided sufficient explanation of the purpose and the method of study to older adults visiting the selected facilities who were aged ≥65 years, were right-handed, and appeared healthy. After receiving signed informed consent documents from 67 people who voluntarily agreed to participate, the examiner conducted questionnaires and assessed manual dexterity and dental biofilm accumulation from April 24, 2018 through June 30, 2018. The minimum sample size required for an independent t-test was calculated using G*power 3.1 software (Informer Technologies, Düsseldorf, Germany) with the following parameters: 95% power, 5% significance level, and 0.8 effect size [17]. The minimum sample size was determined to be 42. Seventeen people were excluded from the study because they had factors that can facilitate dental biofilm accumulation. Among those, sixteen were people who were edentulous; experienced hyposalivation (unstimulated salivary flow rate < 0.1 mL/min) [18]; had taken antibiotics in the previous month; drank more than a half glass of alcohol every day; had prosthetics, crowding, or no crown on their index teeth, and one was a suspected dementia patient based on the result of the Mini-Mental State Examination (Korean version). In addition, another six people were excluded because they complained of discomfort or wanted to discontinue the process. Hence, data from 44 participants were analyzed.

2.2. Measurements

Three types of data were collected: general characteristics (age, sex, systemic diseases, daily medication intake, and frequency of tooth brushing), manual dexterity, and dental biofilm accumulation. The Box and Blocks Test was conducted to assess manual dexterity [19] (Fig. 1) Manual dexterity is a neuromotor ability of the hand that enables people to grasp and manipulate objects accurately [20], and is one of the critical determinants of hand function [21]. Participants were told to move as many as blocks as possible into a box within 1 min using their dominant hand (right hand). High numbers of blocks were interpreted as indicating high levels of manual dexterity [22]. Based on the standards suggested by a previous study that evaluated manual dexterity according to sex and age, when the number of blocks moved by a participant was within the normal range, the participant was put into the normal group; when the number of blocks was lower than age and sex-matched norms, the participant was assigned to the low manual dexterity group [22].

Dental biofilm accumulation was evaluated using QLF-D and the associated image analysis software program (QA2 version 1.24; Inspektor Research Systems BV, Amsterdam, The Netherlands) (Fig. 2). The participants were asked to refrain from any oral hygiene behaviors or food intake for at least 4 h before the visit. Six teeth were selected as the index teeth for the study: 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) [23] (Fig. 3). Dental biofilm was imaged on 528 facial (buccal) and lingual surfaces (tongue-side) of the six index teeth. All index teeth were dried with compressed air for at least 15 s before the QLF-D measurements [24]. The blue light image shooting conditions of the QLF-D were set as follows: shutter speed: 1/30 s; aperture value: 5.0; and ISO speed: 1600 [9,10]. The amount of dental biofilm accumulated on tooth surfaces was quantified into SPS [9], and the maturation of dental biofilm was quantified into ΔR_{20} values [25]. An ΔR value represents the percentage difference in the red/green ratio of dental biofilm compared with the biofilm free-reference [26]. This study used ΔR_{20} as the threshold level for mature dental biofilm [10]. Higher SPS indicated more accumulated dental biofilm on tooth surfaces, and high ΔR_{20} values indicated more mature dental biofilm. All the analyses were performed by one trained examiner.

Table 1
Simple Plaque Score by general characteristics of participants.

Variables /teeth		#12		#16		#24		#32		#36		#44	
		Buccal	Lingual	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual
Sex													
Male	11	0.09 ± 0.30	0.45 ± 1.21	0.18 ± 0.40	0.90 ± 1.51	0.54 ± 1.50	1.18 ± 1.99	0.36 ± 0.92	0.90 ± 1.70	0.63 ± 1.28	1.54 ± 2.20	0.36 ± 0.67	1.90 ± 2.46
Female	33	0.22 ± 0.64	0.63 ± 1.19	0.39 ± 0.89	1.18 ± 1.89	0.42 ± 1.22	0.90 ± 1.82	0.18 ± 0.52	0.69 ± 1.53	0.42 ± 1.25	1.21 ± 1.90	0.36 ± 1.05	1.75 ± 2.06
t (p)		−0.594 (0.556)	−0.436 (0.665)	−0.753 (0.456)	.-0.432 (0.668)	0.268 (0.790)	0.420 (0.677)	0.810 (0.422)	0.387 (0.700)	0.484 (0.631)	0.484 (0.631)	0.000 (1.000)	0.201 (0.842)
Age													
65–69	14	0.21 ± 0.57	0.21 ± 0.57	0.35 ± 1.08	1.28 ± 2.09	0.14 ± 0.36	1.07 ± 2.12	0.14 ± 0.36	0.35 ± 0.74	0.35 ± 1.33	0.92 ± 1.73	0.35 ± 0.92	1.64 ± 2.06
70–79	23	0.17 ± 0.65	0.87 ± 1.48	0.39 ± 0.72	1.17 ± 1.80	0.52 ± 1.44	1.13 ± 1.91	0.21 ± 0.59	1.13 ± 2.00	0.52 ± 1.30	1.39 ± 2.01	0.39 ± 1.07	2.00 ± 2.25
≥ 80	7	0.14 ± 0.37	0.42 ± 0.78	0.14 ± 0.37	0.57 ± 1.13	0.85 ± 1.86	0.28 ± 0.75	0.42 ± 1.13	0.28 ± 0.48	0.57 ± 0.97	1.71 ± 2.36	0.28 ± 0.75	1.42 ± 2.14
F (p)		0.038 (0.963)	1.431 (0.251)	0.251 (0.780)	0.386 (0.682)	0.780 (0.465)	0.575 (0.567)	0.456 (0.637)	1.475 (0.241)	0.095 (0.909)	0.421 (0.659)	0.031 (0.969)	0.235 (0.792)
Systemic diseases													
Yes	34	0.17 ± 0.62	0.67 ± 1.29	0.38 ± 0.88	1.14 ± 1.92	0.55 ± 1.43	1.05 ± 1.92	0.20 ± 0.64	0.76 ± 1.55	0.44 ± 1.15	1.29 ± 1.93	0.44 ± 1.07	1.76 ± 2.13
No	10	0.20 ± 0.42	0.30 ± 0.67	0.20 ± 0.42	1.00 ± 1.33	0.10 ± 0.31	0.70 ± 1.63	0.30 ± 0.67	0.70 ± 1.63	0.60 ± 1.57	1.30 ± 2.16	0.10 ± 0.31	1.90 ± 2.28
t (p)		0.111 (0.912)	−0.879 (0.384)	−0.625 (0.535)	−0.225 (0.823)	−0.993 (0.326)	−0.535 (0.595)	0.403 (0.689)	−0.114 (0.910)	0.350 (0.728)	0.008 (0.993)	−0.981 (0.332)	0.174 (0.863)
Taking daily medications													
Yes	35	0.20 ± 0.63	0.68 ± 1.27	0.37 ± 0.87	1.08 ± 1.91	0.54 ± 1.42	1.02 ± 1.90	0.20 ± 0.63	0.74 ± 1.54	0.31 ± 0.96	1.14 ± 1.86	0.42 ± 1.06	1.57 ± 2.06
No	9	0.11 ± 0.33	0.22 ± 0.66	0.22 ± 0.44	1.22 ± 1.30	0.11 ± 0.33	0.77 ± 1.71	0.33 ± 0.70	0.77 ± 1.71	1.11 ± 1.96	1.88 ± 2.31	0.11 ± 0.33	2.66 ± 2.34
t (p)		−0.405 (0.688)	−1.495 (0.147)	−0.491 (0.626)	0.201 (0.841)	−0.898 (0.375)	−0.359 (0.721)	0.551 (0.584)	0.059 (0.953)	1.181 (0.268)	1.019 (0.314)	−0.876 (0.386)	1.383 (0.174)
Tooth brushing frequency (daily)													
≤2	20	0.20 ± 0.52	0.90 ± 1.51	0.25 ± 0.71	1.50 ± 2.13	0.65 ± 1.53	1.90 ± 2.38	0.05 ± 0.22	1.10 ± 1.68	0.50 ± 1.19	1.15 ± 1.89	0.40 ± 0.82	2.05 ± 2.23
≥3	24	0.16 ± 0.63	0.33 ± 0.76	0.41 ± 0.88	0.79 ± 1.41	0.29 ± 1.04	0.20 ± 0.58	0.37 ± 0.82	0.45 ± 1.41	0.45 ± 1.31	1.41 ± 2.04	0.33 ± 1.09	1.58 ± 2.08
t (p)		0.187 (0.852)	1.518 (0.141)	−0.679 (0.501)	1.268 (0.214)	0.920(0.363)	**3.098 (0.005)**	−1.852 (0.075)	1.375 (0.176)	0.109 (0.914)	−0.445 (0.658)	0.225 (0.823)	0.716 (0.487)

Significant values are shown in bold: $p < 0.05$ by *t*-test.

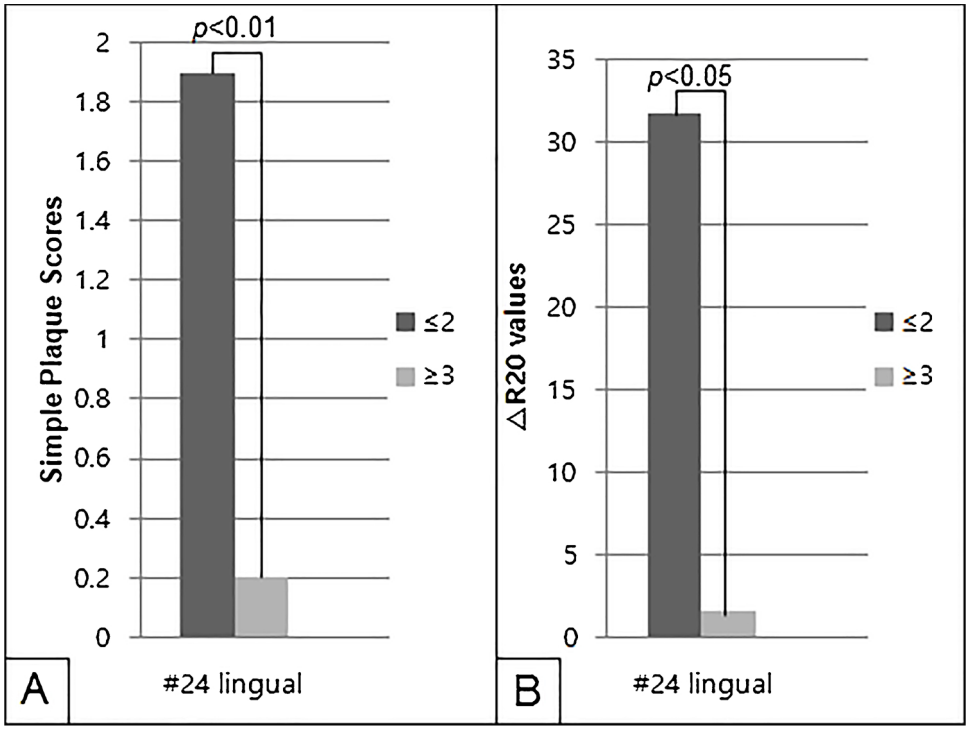

Fig. 4. Simple Plaque Score and $\triangle R_{20}$ value of tooth # 24 according to tooth brushing frequency.

2.3. Statistical analyses

The collected data were analyzed using IBM SPSS Statistics, version 23.0 (IBM Corp., Armonk, NY, USA), with statistical significance set at $p < 0.05$. The *t*-test and one-way analysis of variance were performed for each index tooth to analyze the differences in SPS and ΔR_{20} values according to participants' general characteristics and manual dexterity.

3. Results

3.1. SPS according to general characteristics of participants

Results of the analysis of SPS according to general characteristics are presented in Table 1. There were no significant differences in SPS based on sex, age, systemic diseases, or medication ($p > 0.05$). The group brushing their teeth ≤ 2 times per day had a higher SPS on the lingual surface of tooth #24 than the group brushing ≥ 3 times per day ($p = 0.005$) (Fig. 4A).

3.2. ΔR_{20} according to general characteristics of participants

The results of the analysis of ΔR_{20} values according to general characteristics are presented in Table 2. There were no significant differences in ΔR_{20} values according to sex, age, systemic diseases, or medication ($p > 0.05$). The group brushing their teeth ≤2 times per day had significantly higher ΔR_{20} values on the lingual surface of tooth #24 than the group brushing their teeth ≥3 times per day ($p = 0.012$) (Fig. 4B). The group taking daily medications and those who brushed their teeth ≤2 times per day tended to have higher ΔR_{20} values on the lingual surface of tooth #12 than their counterparts ($p = 0.062$ and p = 0.084, respectively).

3.3. SPS according to manual dexterity of participants

Table 3 presents results of analyzing SPS according to manual dexterity. The low manual dexterity group had significantly higher SPS on the lingual surfaces of teeth #12, #24, and #32 than the normal group ($p < 0.05$) (Fig. 5A).

3.4. ΔR_{20} according to manual dexterity of participants

Table 4 presents results of the analysis of ΔR_{20} values according to manual dexterity. The low manual dexterity group had significantly higher ΔR_{20} values on the lingual surfaces of teeth #12, #24, #32, and #44 than the high manual dexterity group ($p < 0.05$) (Fig. 5A).

4. Discussion

Analyzing the factors that predict poor oral hygiene can play an important role in maintaining and promoting the oral health of independent older adults. Even though there has been widespread interest in factors that have negative effects on dental biofilm removal ability, very little has been published regarding the effects of changes in manual dexterity—the ability to perform fine movement—on independent older adults without hand disabilities. We hypothesized that reduced manual dexterity would have a negative impact on the

Table 2
Analysis of $\triangle R_{20}$ by general characteristics of participants.

Variables /teeth		#12		#16		#24		#32		#36		#44	
		Buccal	Lingual	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual
Sex													
Male	11	9.09 ± 19.58	8.63 ± 23.82	6.18 ± 15.71	10.27 ± 19.21	23.18 ± 58.53	17.54 ± 33.25	3.45 ± 8.99	9.00 ± 19.85	20.45 ± 51.95	25.72 ± 33.43	14.00 ± 31.78	26.45 ± 38.01
Female	33	9.42 ± 28.84	11.78 ± 20.94	5.81 ± 13.00	14.75 ± 25.13	4.90 ± 10.95	14.51 ± 36.69	4.45 ± 10.78	9.87 ± 31.46	5.39 ± 16.11	13.18 ± 22.66	20.21 ± 92.20	19.87 ± 30.40
t (p)		−0.036 (0.972)	−0.418 (0.678)	0.076 (0.940)	−0.540 (0.592)	1.029 (0.327)	0.242 (0.810)	−0.277 (0.783)	−0.087 (0.931)	0.946 (0.365)	1.159 (0.267)	−0.218 (0.829)	0.583 (0.563)
Age													
65–69	14	5.28 ± 12.71	5.14 ± 9.83	5.28 ± 16.75	15.50 ± 26.80	2.92 ± 6.09	13.71 ± 27.22	3.00 ± 7.87	2.92 ± 5.28	5.28 ± 17.26	12.21 ± 23.93	8.71 ± 22.57	19.92 ± 29.74
70–79	23	7.78 ± 17.42	15.60 ± 27.27	7.56 ± 13.45	13.60 ± 23.67	12.13 ± 40.50	19.95 ± 44.11	5.95 ± 12.66	16.08 ± 38.85	11.82 ± 37.83	19.78 ± 29.84	25.69 ± 109.48	25.73 ± 36.21
≥80	7	22.57 ± 57.97	7.57 ± 13.68	1.71 ± 2.98	10.00 ± 19.38	13.85 ± 23.75	3.00 ± 5.50	0.85 ± 2.26	2.00 ± 2.88	8.14 ± 15.41	13.14 ± 14.65	15.42 ± 39.94	10.85 ± 21.59
F (p)		1.070 (0.352)	1.149 (0.327)	0.511 (0.604)	0.121 (0.886)	0.460 (0.635)	0.620 (0.543)	0.795 (0.459)	1.216 (0.307)	0.212 (0.810)	0.422 (0.659)	0.190 (0.828)	0.589 (0.559)
Systemic diseases													
Yes	34	10.55 ± 29.69	12.91 ± 23.73	6.29 ± 14.57	15.11 ± 26.48	11.41 ± 34.66	17.73 ± 39.40	3.05 ± 8.77	11.61 ± 32.48	9.47 ± 31.79	14.79 ± 23.65	23.82 ± 91.85	22.02 ± 33.56
No	10	5.20 ± 11.27	4.50 ± 8.56	4.60 ± 9.70	8.60 ± 8.07	2.90 ± 8.49	6.90 ± 15.17	8.10 ± 14.13	3.00 ± 5.01	8.10 ± 20.55	21.50 ± 33.49	1.10 ± 2.80	19.80 ± 28.24
t (p)		−0.555 (0.582)	−1.720 (0.093)	−0.344 (0.732)	−1.251 (0.218)	−0.764 (0.449)	−0.845 (0.403)	1.069 (0.308)	−0.829 (0.412)	−0.128 (0.899)	0.591 (0.566)	−0.776 (0.442)	−0.191 (0.850)
Taking daily medications													
Yes	35	8.88 ± 27.69	12.88 ± 23.43	6.11 ± 14.39	14.45 ± 26.27	11.08 ± 34.20	17.42 ± 38.86	2.97 ± 8.66	11.42 ± 32.02	4.28 ± 13.09	12.51 ± 21.28	23.17 ± 90.57	19.85 ± 32.97
No	9	11.11 ± 23.27	3.66 ± 8.10	5.11 ± 10.15	10.44 ± 7.81	3.22 ± 8.94	6.88 ± 16.09	9.00 ± 14.67	2.77 ± 5.26	28.11 ± 58.38	31.11 ± 37.11	1.11 ± 2.97	28.00 ± 29.50
t (p)		0.221 (0.826)	−1.923 (0.062)	−0.196 (0.846)	−0.450 (0.655)	−0.678 (0.501)	−0.791 (0.434)	1.180 (0.267)	−0.801 (0.428)	1.216 (0.258)	1.443 (0.181)	−0.724 (0.473)	0.674 (0.504)
Tooth brushing frequency (daily)													
≤2	20	11.90 ± 35.62	17.65 ± 28.59	2.80 ± 6.94	19.15 ± 30.65	15.00 ± 43.71	31.65 ± 48.16	2.45 ± 7.40	17.20 ± 40.12	5.95 ± 14.96	15.15 ± 25.62	11.60 ± 28.18	26.15 ± 39.66
≥3	24	7.20 ± 16.29	5.45 ± 10.72	8.50 ± 16.95	9.04 ± 14.88	4.87 ± 12.21	1.62 ± 3.73	5.66 ± 12.12	3.37 ± 11.32	11.83 ± 37.06	17.29 ± 26.69	24.54 ± 107.45	17.66 ± 24.42
t (p)		0.578 (0.567)	1.804 (0.084)	−1.503 (0.143)	1.348 (0.189)	1.087 (0.283)	**2.781 (0.012)**	−1.035 (0.307)	1.492 (0.150)	−0.657 (0.515)	−0.270 (0.789)	−0.523 (0.604)	0.870 (0.390)

Significant values are in bold font: $p < 0.05$ by *t*-test.

Table 3
Simple Plaque Scores by manual dexterity.

Manual dexterity[a]		#12		#16		#24		#32		#36		#44	
		Buccal	Lingual	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual	Buccal	Lingual
Normal	26	0.09 ± 0.30	0.09 ± 0.30	0.54 ± 1.21	1.00 ± 1.54	0.18 ± 0.40	0.18 ± 0.60	0.09 ± 0.30	0.09 ± 0.30	0.18 ± 0.60	1.27 ± 2.19	0.18 ± 0.60	1.09 ± 1.44
Low	18	0.21 ± 0.64	0.75 ± 1.32	0.27 ± 0.62	1.15 ± 1.88	0.54 ± 1.45	1.24 ± 2.04	0.27 ± 0.71	0.97 ± 1.74	0.57 ± 1.39	1.30 ± 1.91	0.42 ± 1.06	2.03 ± 2.29
t (p)		−0.594 (0.556)	**−2.691 (0.010)**	0.972 (0.337)	−0.240 (0.812)	−0.810 (0.422)	**−2.651 (0.011)**	−0.81 (0.422)	**−2.778 (0.009)**	−0.905 (0.371)	−0.044 (0.965)	−0.716 (0.478)	−1.588 (0.124)

Significant values are in bold font: $p < 0.05$ by *t*-test.
[a] Categorized according to Mathiowetz's study [22], which suggested the cut-off values according to sex and age.

effective dental biofilm removal in independent older adults without hand disabilities.

This study reconfirmed that frequency of tooth brushing is associated with the accumulation of dental biofilm. Furthermore, as a result of analyzing the relationship between manual dexterity and dental biofilm accumulation, we observed that the low manual dexterity group had more dental biofilm on the lingual surfaces of teeth #12, #24, and #32 than the normal group ($p < 0.05$), and the difference between the two groups was 733%, 588% and 977%, respectively (results not shown). In addition, the low manual dexterity group exhibited more red fluorescence, indicating more mature dental biofilm, on the lingual surfaces of teeth #12, #24, #32, and #44 ($p < 0.05$) than the normal group, and the difference between the two groups was 818%, 1363%, 2726% and 185%, respectively (results not shown). Therefore, the low manual dexterity group had more dental biofilm—and more mature dental biofilm—on the lingual surfaces of their teeth than the normal group. These results indicate that oral hygiene care for this group, mostly tooth brushing, was ineffective in removing dental biofilm due to the lack of manual dexterity. As efficient use of the hands is very important in almost every part of our daily lives, manual dexterity has been regarded as a crucial factor for resolving various problems in our lives [27]. However, there have been few studies reporting on the relationship between manual dexterity and oral health. Moreover, those studies that did research this topic focused on dependent older adults or people who had already had a disease causing impaired manual dexterity such as rheumatoid arthritis [14,28], with none of the studies investigating independent older adults. As the present study used a new device, QLF-D, to assess dental biofilm accumulation and targeted healthy older adults, it is difficult to directly compare the results of the present study with those of the previous studies. However, the present study's results are in line with the results of a previous study that reported that hand function, including manual dexterity, plays a central role in the oral hygiene of older adults living in nursing facilities [15]. In addition, these results support the results of a previous study showing that declined manual dexterity affects the time one spends on brushing their teeth [14]. In other words, the results of this study indicate that manual dexterity can decline even in independent older adults who have not been diagnosed with any hand disabilities, affecting the accumulation of pathogenic dental biofilm.

Tooth brushing is the most basic and effective method for removing dental biofilm [29]. Tooth brushing removes dental biofilm mechanically through the fine vibratory motion of filaments, however, the act of correctly brushing teeth requires a variety of motor skills [30]. It is more difficult to place brush filaments on the lingual surface than on the facial surface [30]; therefore, a more stable technique is required to completely remove dental biofilm accumulated on the lingual area [31]. Accordingly, we interpreted that older adults with low manual dexterity would not have performed the fine tooth brushing motions in a correct manner—particularly on the lingual surfaces—due to decreased fine motor skills in the hands compared to those of the normal group. Although a study by Inada et al. [31] reported there was more dental biofilm on the surfaces of teeth on the right side than on the left side of the mouth after tooth brushing, this study did not reveal any differences in the accumulation and maturation of dental biofilm between teeth on the right and left sides.

Despite great improvements in the oral health of populations globally, older adults still have poor oral health status; this is supported by the high prevalence of periodontal disease in this population [32,33], indicating they lack the ability to perform tooth brushing sufficiently. Tooth brushing remains the most basic means of controlling dental biofilm. Since there is currently no chemotherapy that can completely prevent the formation of dental biofilm [34], dental professionals should proactively intervene to help older adults brush their teeth properly. As described in previous studies [9,10], the QLF-D technique we used is capable of quantitatively assessing mature dental biofilm and is better accepted by participants than traditional means of

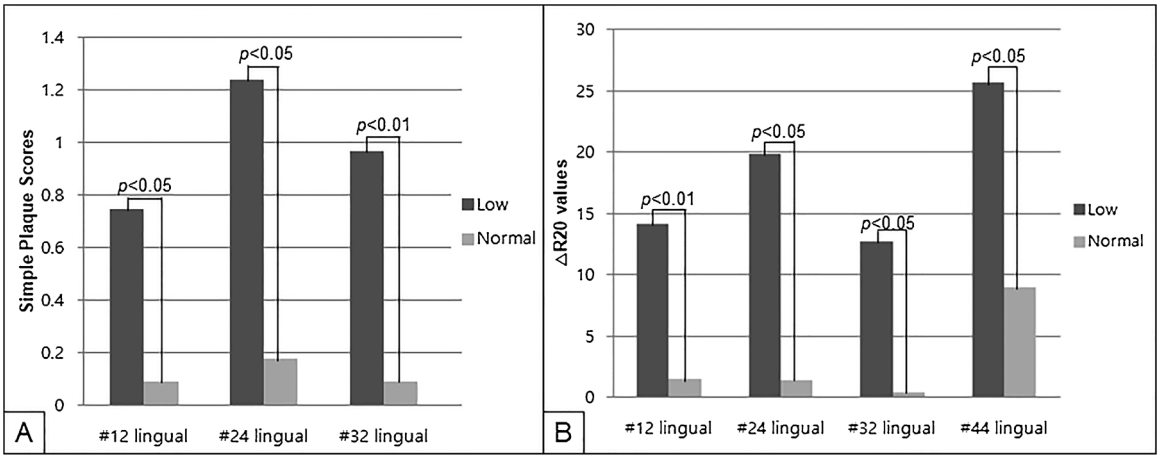

Fig. 5. Simple Plaque Score and $\triangle R_{20}$ value of teeth #12, #24, #32 and #44 according to manual dexterity.

dental biofilm assessment. Another advantage of QLF-D is that participants can be provided specific numbers representing the level of oral hygiene, including SPS and ΔR_{20} values, which may help them better understand their oral hygiene status. Thus, dental biofilm assessment using QLF-D can provide considerable valuable information during clinical intervention for the improvement of oral hygiene status in older adults. Based on the results of this study that reduced manual dexterity is a factor negatively affecting the removal of dental biofilm, we suggest that assessment of manual dexterity should precede clinical biofilm assessment and tooth brushing instruction in older adults. In addition, a previous study has shown that right-handed individuals have better manual dexterity than left-handed individuals [35]. As manual dexterity has been associated with oral hygiene status, one's dominant hand should be considered when giving tooth brushing instructions. Moreover, electric toothbrushes or auxiliary oral hygiene devices should be recommended for older adults, depending on their manual dexterity. Furthermore, intervention programs to improve manual dexterity may contribute to improved oral health by increasing the ability to manage dental biofilm, which calls for interdisciplinary collaboration between dental professionals and physicians.

Although this is the first study to investigate the relationship between manual dexterity and the accumulation of dental biofilm assessed using QLF-D in independent older adults, there may be limitations to generalizing this study's results. First, all participants were Incheon residents, with a relatively small sample size. Calculation of the optimal sample size to achieve adequate statistical power revealed that 21 participants were required for each group. However, 23 participants were excluded from the study due to reasons including exclusion criteria, missing data, and so on and the final number of the participants in the low manual dexterity group was 18. For this reason, the study's statistical power may be slightly lower than expected. Second, even though we excluded those who exhibited factors facilitating dental biofilm accumulation, this study did not comprehensively reflect all factors affecting oral hygiene. Finally, since this study was designed as a cross-sectional study, the causal relationship between the factors analyzed could not be proved in the study. Therefore, more studies should be conducted, including longitudinal research and standardized testing, to prove the causal and temporal relationships between manual dexterity and dental biofilm accumulation. Moreover, further studies should include a more representative sample and a greater number of participants, as well as conducting a comprehensive investigation into factors affecting dental biofilm accumulation. Despite such limitations, the strength of this study is that it showed reduced manual dexterity affects the accumulation of mature dental biofilm in independent older adults without hand disabilities. More importantly, the study used QLF-D, which is more reliable, valid, and convenient for use in older adults than traditional methods of dental biofilm assessment, to quantitatively assess the mature dental biofilm accumulated on the buccal surface and lingual surface of each index tooth. This study found that the low manual dexterity group had significantly more dental biofilm and more mature dental biofilm particularly on the lingual surfaces of teeth than the normal group among older adults without hand disabilities. This finding indicates that reduced manual dexterity can be a predictor of poor oral hygiene, even in independent older adults, although the statistical effect size is small. Therefore, we suggest that manual dexterity of older adults without hand disabilities be assessed in advance of clinical dental biofilm assessment and tooth brushing instruction. In addition, intervention programs to improve manual dexterity may contribute to improving not only activities of daily living but the oral hygiene status of older adults.

Table 4
Analysis of $\triangle R_{20}$ by manual dexterity.

Manual dexterity[a]		#12		#16		#24		#32		#36		#44	
		buccal	lingual	buccal	lingual	buccal	lingual	buccal	lingual	buccal	lingual	buccal	lingual
Normal	26	15.36 ± 46.06	1.54 ± 2.42	8.63 ± 19.46	12.54 ± 15.10	6.18 ± 14.31	1.36 ± 4.20	2.45 ± 7.81	0.45 ± 0.82	1.72 ± 5.10	11.45 ± 23.76	9.63 ± 31.96	9.00 ± 10.86
Low	18	7.33 ± 16.49	14.15 ± 24.00	5.00 ± 11.15	14.00 ± 26.0	10.57 ± 34.75	19.90 ± 40.00	4.78 ± 11.01	12.72 ± 32.77	11.63 ± 33.58	17.93 ± 26.75	21.66 ± 92.04	25.69 ± 35.75
t (p)		0.864 (0.392)	**−2.972 (0.005)**	0.768 (0.447)	−0.175 (0.862)	−0.405 (0.687)	**−2.620 (0.013)**	−0.648 (0.520)	**−2.149 (0.039)**	−0.967 (0.339)	−0.714 (0.479)	−0.422 (0.675)	**−2.374 (0.022)**

Significant values are in bold font: $p < 0.05$ by *t*-test.
[a] Categorized according to Mathiowetz's study [22], which suggested the cut-off values according to sex and age.

Declarations of interest

None.

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