Change of plaque removal ability by worn toothbrush

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I. INTRODUCTION

Plaque control has long been the cornerstone of periodontal treatment. Supragingival plaque has been shown to be associated with disease progression in many longitudinal studies that compared inflammation of the periodontal tissues with the disease progression.[1] In a recent comprehensive review, it was reported that the presence of supragingival plaque is not a good predictor of disease progression, but the absence of supragingival plaque has a very high negative predictive value.[1] This means that teeth without plaque have healthy periodontal tissues, which is the major rationale for daily oral hygiene.

Although many methods of oral hygiene are available, the toothbrush is the most frequently used dental aid, and for many people, it represents the only method of plaque removal. It has been shown that in industrialized countries, 80% to 90% of the populations brush their teeth at least once or twice a day.[2]

It has been further shown that if the goal is plaque control, the tooth brushing practices by most people is unsatisfactory. An average daily brushing of approximately 2 minutes' duration will remove only 50% of the plaque present on the teeth.[3,4]

Plaque is missed in a predictable pattern when brushing the teeth. In general, after brushing, the facial surfaces have less plaque than the lingual surfaces, the mandibular teeth have slightly more plaque than the maxillary teeth, the molars have far more remaining plaque than either the premolars or incisors, and the proximal surfaces retain the highest level of plaque.[5,6] An interesting motion study has shown that most toothbrushes do an adequate job of removing plaque from the flat surfaces of the teeth, but manipulation onto the gingival margin and approximal surfaces requires an adjustment to the brusher's technique. The authors concluded that most people do an inadequate job of brushing the gingival and interproximal areas, regardless of the type or design of the toothbrush.[7]

It is well known that toothbrush bristles wear dur-

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ing use, and that the majority of dental professionals use bent and splaying bristles as the main indicator of toothbrush wear. Dental professionals and toothbrush manufactures generally recommend a toothbrush be replaced every three months. This advice is based on the assumption that a worn toothbrush is less effective than a new one. The American Dental Association (ADA) also makes this recommendation, stating that worn brushes are not effective at removing plaque bacteria and broken bristles many injure the gums.[8] However, not all patients take this advice, and evidence suggests that the average interval at which a toothbrush is replaced ranges from 2.5 to six months.[9-11] The general public has been shown to base their decision on when to replace their toothbrush on the degree of splaying and bending of the brisles.[9,11] The rate of toothbrush wear is believed to be influenced by a number of factors, including the duration of use, the brushing force and the brushing technique. Since many patients use a toothbrush for significantly longer than the recommended three months, it is important to know whether the excessive wear is of clinical relevance.

Although Bergström (1973) reported that the amount of toothbrush wear correlated with the length use,[10] other investigators have reported that this is not always the case, and that toothbrush wear varies widely amongst individuals because of the differences in the way in which the toothbrushes are used. [9,11-12] There are few studies that have investigated the effect of toothbrush age and wear on the capacity to remove plaque, and the results of those studies vary with none of them showing differences in the proximal area from the total tooth surfaces.[14-18] Daly et al. (1996) reported that the plaque scores actually improved during the initial stages of toothbrush ware.[13] Sforza et al. (2000) confirmed the findings of Daly et al. when they found that increased toothbrush wear was not associated with a worsening of the plaque scores.[14] In contrast, Glaze and Wade (1986) concluded that plaque removal decreased with increasing toothbrush wear and recommended that toothbrushes be replaced frequently to ensure the optimal plaque control.[16] Recently, Conforti et al. (2003) provided data to support the hypothesis that a worn toothbrush is less efficient with respect to plaque removal than a new brush.[18]

The aim of this 3-month cohort study was to determine if the wear of a toothbrush had 1) any effect on the clinical variables of dental plaque and 2) any relationship with the personal dental behaviors in a periodontally healthy population.

II. MATERIALS AND METHODS

1. Subjects

Fifty-two volunteers (38 male, 14 female, aged 23-30 years) were recruited from senior dental students at Seoul National University, who were selected according to the following criteria:

1) Presence of all 6 Ramfjord teeth (16, 21, 24, 36, 41 and 44) and pocket depths $\leq$3mm on all surfaces.
2) No crowns, fixed or removable prostheses or orthodontic appliances.
3) No restorations involving the surfaces of the teeth to be scored.
4) Healthy with no medical conditions requiring antibiotic cover for scaling and polishing.

2. Plaque scoring

The level of plaque was recorded using the patient hygiene performance index.[19] In order to assess the plaque score, the plaque on the subjects' teeth was highlighted using a 10% erythrosine solu-

tion (RED-COTE®, Butler, USA), which was used as a mouth rinse for 1 min and the 6 Ramfjord teeth were scored. The tooth surfaces, both facial and lingual, were divided into the following 5 sections (Figure 1):

1) mesial third
2) distal third
3) middle third
gingival third
middle third
coronal third; a score of 1 or 0 was assigned to each subdivision according to the presence or absence of plaque; all questionable areas were scored zero.

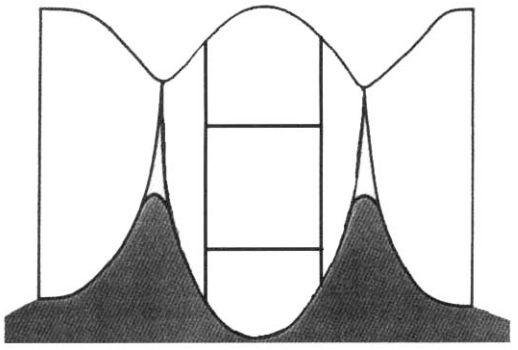

Figure 1. Sections of the tooth surface for plaque scoring according to the patient hygiene performance index.

3. Toothbrush

The type of toothbrush used in this study was an Oral-B Advantage® (Oral-B Laboratories, Belmont, CA, USA), which had soft bristles. The subjects were instructed to use the same toothbrush and toothpaste (e-fresh, Bukwang Pharm Co., Ltd, Seoul).

4. Brushing surface area

The brushes were assessed by measuring the increase in the brushing surface area. Standardized digital photographs of the toothbrush heads were obtained, the outlines of the brushing surface areas were marked, and the areas were estimated (Figure 2) using image analysis software (TDI Scope Eye®, Techsan Co., Ltd., Seoul).

5. Experimental design

On the first visit, the selected subjects were given a questionnaire regarding their dental behaviors (alcohol consumption, smoking, and the frequency, duration and the methods of daily tooth brushing, the replacement interval of the toothbrushes). All the plaque and calculus was removed professionally in order to obtain a plaque score of 0 for each subject. Each subject was issued with a new toothbrush and the same toothpaste. They were instructed to use only them during the course of the study, and refrain from using any interdental cleaning devices and mouthwashes. In addition, they asked to brush their teeth as they would normally.

After 1 week (baseline), 2 and 3 months, the level of plaque was disclosed and scored. The used toothbrushes were collected at the end of the 3-month period. The brushing surface of each toothbrush was then photographed.

6. Data analysis

The null hypothesis, which stated that a new toothbrush is no more effective at reducing the plaque scores than a 3-month-old toothbrush, was used. The plaque scores were recorded for the proximal, middle, whole-sites (proximal plus middle) portions on the 6 test teeth in each patient.

The power of this study was 0.9. The plaque scores at the baseline, 2 months and 3 months were compared using a paired t-test. Pearson's correlation

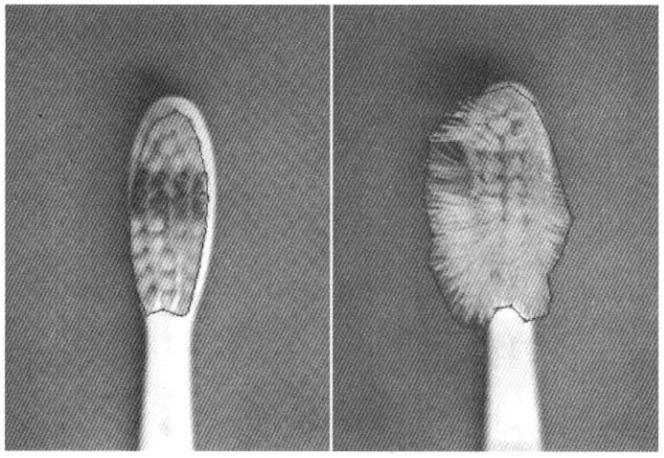

Figure 2. Brushing surface area (outline). A new toothbrush (left) and a 3-month-old toothbrush (right).

analysis was performed to determine the relationship between the plaque scores, the toothbrush wear and the dental behaviors. The confidence level was set at 95% for all analyses ($p<0.05$).

III. RESULTS

Of the 52 subjects in the study, 46 were found to have a complete set of data that was suitable for analysis.

1. Plaque scores

The results of the plaque scores are shown in Table 1 and Figure 3.

At the baseline (week 1), the mean (±SD) plaque score for the whole-sites was 11.72 (±6.60), and which increased to 13.35 (±7.08) at 2 months and to 13.41 (±6.36) at 3 months, but this was not statistically significant (p=0.061, 0.065). The increase for the middle was also not statistically significant (p=0.068, 0.583). However, there was a significant difference was found between these scores for the proximal sites at the baseline and 3 months (p=0.017).

2. Brushing surface area

The 3-month-old toothbrushes showed a wide variation in the amount of bristle wear (Figure 4).

Compared with the brushing surface areas of the new toothbrushes used by each subject, their 3-month-old brushes had higher brushing surface areas ranging from 0% to 174.2%. Overall, the mean increase (±SD) in the brushing surface area of the

Table 1. Mean plaque scores (±SD) (n=46)

	1 week	2 months	3 months
Whole-sites	11.72 ± 6.60	13.35 ± 7.08	13.41 ± 6.36
Proximal	8.74 ± 4.80*	9.67 ± 4.81	10.30 ± 4.27*
Middle	2.98 ± 2.45	3.67 ± 2.92	3.20 ± 2.66

* Statistically significant difference between the groups, $p<0.05$

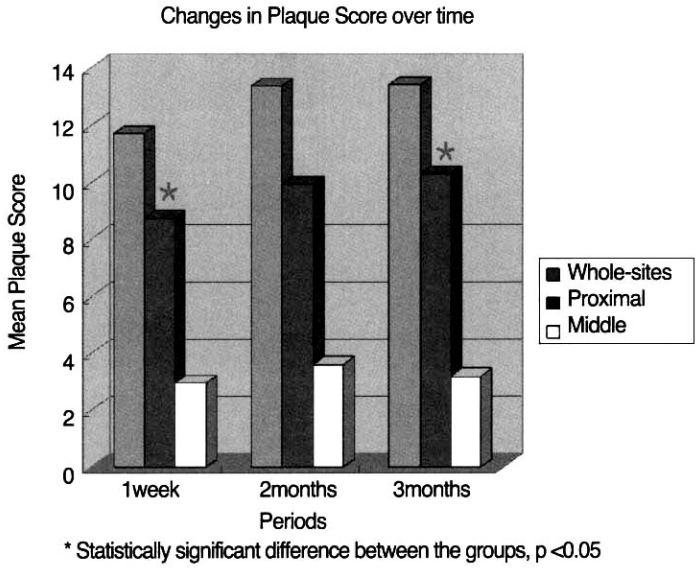

Figure 3. Changes in the plaque score over time.

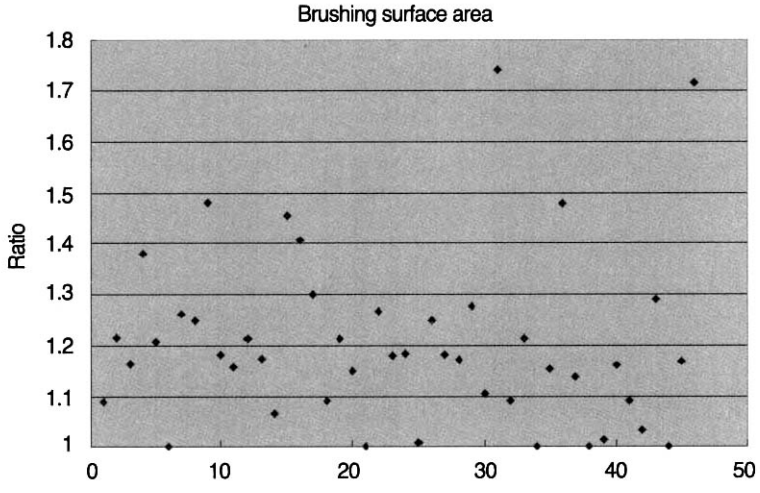

Figure 4. The ratio of the brushing surface areas of the 3-month-old toothbrush compared with the new toothbrushes (n=46).

used brushes was 21% (±16%).

3. Correlation

The effect of toothbrush wear on plaque removal was examined by correlation analysis. Although the wear was increased by 21%, the correlations between the brushing surface areas and the plaque scores for the whole-sites and the proximal sites at 3 months were weak (r=0.211, 0.183) (Figure 5).

There were no correlations between the amount of toothbrush wear and the dental behaviors (replacement range of the toothbrush, frequency, duration and methods of daily tooth brushing, r=-

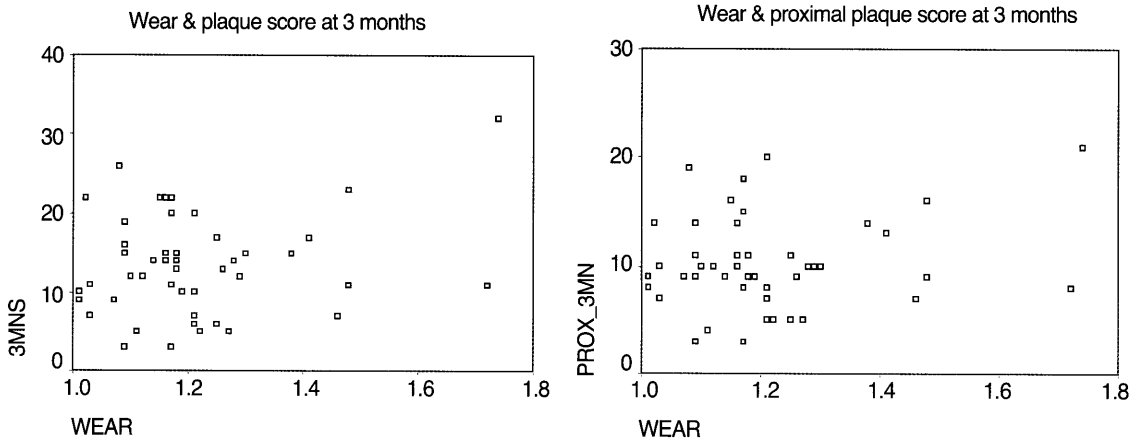

Figure 5. The plaque scores for the whole-sites (left) and the proximal sites (right) of the 3-month-old toothbrushes as a function of the brushing surface areas (n=46).

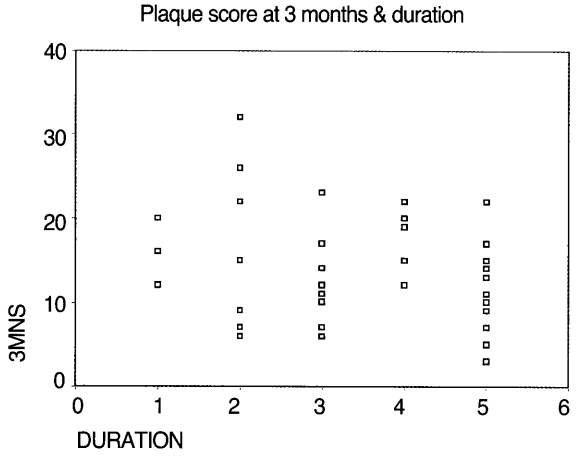

Figure 6. The plaque scores for the whole-sites of the 3-month-old toothbrushes as a function of the duration of daily toothbrushing (n=46).

0.193, -0.009, 0.017, 0.094). However, there was statistically significant correlation between the plaque levels at 3 months and the duration of tooth brushing (r=-0.343, p=0.02) (Figure 6).

IV. DISCUSSION

This study found that 3-month-old toothbrushes were less effective in removing plaque from the interproximal areas than new toothbrushes, although regarding the all the sites, there were similar plaque levels at the baseline and 3 months later. Increased plaque accumulation is associated with gingivitis[20], which may lead to periodontitis if not sufficiently removed.[21] Alveolar bone loss increases with the decreasing efficacy of oral hygiene.[22] It is widely accepted that thorough plaque control can prevent the development and recurrence of periodontitis.[23] In particular, the interproximal areas are strategically important sites where periodontal disease is initiated

and progresses. No previous studies[12-18] examined whether or not new toothbrushes are more efficient in interproximal cleaning than worn ones.

This study found that although the wear was increased by 21%, there was a weak correlation between the brushing surface areas and the plaque scores, and there were no correlations between the toothbrush wear and the tooth brushing behaviors such as the replacement range of toothbrushes, frequency, duration and methods of daily tooth brushing. The amount of wear in the 3-month-old toothbrushes varied widely. The variation in the amount of wear sustained by the toothbrushes during use is most likely the result of the different tooth brushing forces along with the different brushing techniques among the individuals. Patients who brush with the highest force tend to produce most toothbrush wear.[24] As well as the extent of wear, which was measured by the brushing surface area of each toothbrush, variations were also noted in the type of wear. Such variations could have been influenced not only by the brushing force and technique but also by the individual variations in the arch shape and size, the tooth size and inclination, the cusp and incisal edge form, and the sharpness and interdental embrasure sizes. Habits such as 'chewing' the brush head whilst brushing can contribute to the differing appearances of the worn toothbrushes.[15]

This study assessed the amount of toothbrush wear by measuring the increase in the brushing surface area for each toothbrush. Glaze and Wade (1986) first described this technique. However, the brushing surface area in their study was calculated by multiplying the greatest length by the greatest breadth of the brushing surface.[16] Since the brushing surfaces of worn toothbrushes generally have an irregular outline, multiplying the greatest length by the greatest breadth produces only an approximation of the total brushing surface area. This study developed a method of taking standardized digital photographs and using image analysis software, which permitted an accurate calculation of the brushing surface area regardless of how irregular the brushing surface became.

One factor that might have contributed to the improvement in the plaque scores for the middle areas at 3 months compared with those at 2 months despite the progressive toothbrush wear is the Hawthorne effect (improved performance resulting from being studied) or the anticipation of an oral examination as a part of study participation.[25] Therefore, a worn toothbrush might not be an impediment to effective tooth cleaning. The subjects performed all brushing at home with no stipulation on the duration of brushing. Therefore, with the expectation of an oral examination, the patients might have brushed for longer than their normal duration prior to their visit to the clinic.

Studies examining the effectiveness of manual toothbrushes in plaque removal are limited by the fact that any findings obtained are related to the particular type of toothbrush used (e.g. brand, model, head size and shape, bristle filament diameter and height, number and inclination of bristle tufts, number of bristle rows, etc.) as well as to the type of study population.[15] The selection of dental students in this study may have a positive effect on the oral hygiene performance. It is possible that students may have discussed the plaque scores, which had been checked by an examiner. Therefore, they would have been motivated to achieve lower scores at the next examination in order to be competitive with their fellow students. Listgarten[26] previously discussed the limitations of using dental students in clinical trials

V. CONCLUSION

In conclusion, although the capacity to remove

plaque at the whole sites was not related to toothbrush wear, there was a significant increase in the plaque levels at the proximal area. There was no relationship between toothbrush wear and the behaviors investigated . Therefore, in order to substantiate these results, an investigation using non-dental subjects, the use of a variety of toothbrushes and an evaluation over a longer period of time would be ideal.

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-국문초록-

칫솔 마모에 따른 치태제거능력에 관한 연구

이학철, 양병근, 이철우, 이용무, 류인철, 정종평, 한수부

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연구 목적: 3개월 간의 잇솔질에 따른 칫솔의 마모의 정도와 양상을 관찰하고, 이를 이용한 잇솔질 시의 치태제거능력의 변화를 평가하여 일반적으로 권장되고 있는 3개월 주기의 칫솔 교체 주기의 근거를 실제 임상적으로 확인해보고자 하였다.

연구방법: 치주적으로 건강한 치과 대학생 52명을 대상으로 설문지를 통해 잇솔질 습관을 조사하고, 치석제거술을 시행하고 실험기간 동안 동일한 칫솔과 치약을 사용하게 하였다. 1주일 후와 2달과 3달째에 구강 내를 erythrosine으로 염색한 후 6개의 Ramfjord 치아의 plaque score를 측정하고, 3달 동안 사용한 칫솔을 수거하여 brushing surface area의 면적으로 마모도를 평가하였다.

결과: 6명이 탈락하였고 전체 부위의 plaque score는 1주 때와 비교하여 2,3 개월의 값이 통계학적으로 유의한 차이가 없었으나, 치간 부위의 plaque score는 3개월 값이 1주와 비교하여 통계학적으로 유의성 있는 증가를 보였다. 칫솔의 마모도는 평균 21% 증가하였지만, 3개월의 plaque score와 상관관계는 약하였다. 교체 주기, 잇솔질 횟수, 시간 등의 잇솔질 습관과 마모도의 연관성도 없었지만, 잇솔질 시간과 3개월째의 plaque score의 상관관계는 유의성 있는 결과를 보였다.

결론: 3개월 동안 사용한 칫솔의 치간 부위 치태제거 능력은 감소하였으며, 이의 임상적 영향에 대한 장기간의 연구가 필요하겠다.

주요어 : 칫솔, 칫솔 마모, 치태 조절, 구강 위생