Original Article

Quantitative comparison of incisal tooth wear in patients receiving one-phase or two-phase treatment for skeletal Class III malocclusion with anterior crossbite

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ABSTRACT

Objectives: The present study aimed to compare the amount of incisal tooth wear in the maxillary central incisors of patients with skeletal Class III malocclusion and anterior crossbite receiving one-phase or two-phase treatment. The hypothesis was that tooth wear would differ according to treatment modalities.

Materials and Methods: Maxillary dental casts obtained before (T1) and after (T2) orthodontic treatment were divided into three groups. Group I consisted of casts from 21 patients (7 males, 14 females; mean age 9.8 years) who received two-phase treatment (maxillary protraction followed by fixed appliance therapy). Group II comprised casts from 37 patients who underwent orthodontic camouflage treatment for crossbite, subdivided according to age. Group IIa consisted of casts from 15 adolescents (8 males, 7 females; mean age 13.5 years), and group IIb consisted of casts from 22 adults (13 males, 9 females; mean age 24.5 years). Maxillary dental casts obtained at T1 and T2 were scanned. For each pair of digital images, T2 was superimposed on T1 using the best-fit method. Tooth wear was quantified and compared among groups.

Results: Significantly less tooth wear was observed in group I compared to groups IIa and IIb, but no difference was found between groups IIa and IIb. Spearman correlation analysis revealed no significant correlation between tooth wear and age, treatment duration, or craniofacial morphology.

Conclusions: Despite the long duration of early treatment, it caused less wear of the maxillary central incisors than did orthodontic camouflage treatment. (*Angle Orthod.* 2018;88:151–156.)

KEY WORDS: Tooth wear; Three-dimensional; Class III; Orthodontic treatment; Maxillary protraction

INTRODUCTION

Tooth wear is a normal physiologic process that occurs with aging, but it can cause dentin hypersensitivity, pulp involvement, and compromised esthetics as consequences of the loss of hard tissue.[1] Many authors have studied the associations between tooth wear and age,[2,3] gender,[2,4–7] bite force,[8] parafunctions,[3,7] facial height,[8] mouth breathing,[9] salivary factors,[10] and malocclusion.[6,7,11,12] Tooth wear may occur during orthodontic treatment as a result of occlusal interference and abrasion by orthodontic appliances. A few studies have investigated tooth wear occurring during[13] and after orthodontic treatment.[3,14] However, no report has described tooth wear occurring during the treatment of anterior crossbite, although the incisors play important roles in occlusal function and dental esthetics.

Orthopedic/orthodontic treatment of a young patient with skeletal Class III malocclusion represents a

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Table 1. Descriptive Statistics for Age at the Beginning of Treatment, Treatment Duration, and Cephalometric Characteristics[a]

Groups	Gender (No. of Subjects, Teeth)	Age, y	Treatment Duration, mo: Maxillary Protraction Mean (SD)	Treatment Duration, mo: Fixed Appliance Mean (SD)	ANB, °	FMA, °
Group I	Male (7, 14)	10.3 (1.6)	7.0 (4.9)	25.6 (7.9)	−2.3 (2.1)	27.5 (4.4)
	Female (14, 24)	9.6 (1.7)	9.4 (3.0)	25.4 (7.3)	−1.8 (1.4)	28.9 (5.1)
	Total (21, 38)	9.8 (1.6)	8.6 (3.8)	25.5 (7.3)	−2.0 (1.7)	28.2 (4.8)
Group IIa	Male (8, 16)	13.5 (2.7)		29.5 (11.6)	−1.2 (1.3)	29.3 (3.5)
	Female (7, 13)	13.5 (2.4)		34.3 (12.8)	−1.5 (1.0)	27.6 (2.7)
	Total (15, 29)	13.5 (2.5)		31.7 (12.0)	−1.4 (1.1)	28.5 (3.1)
Group IIb	Male (12, 21)	26.0 (8.6)		22.6 (9.9)	−2.6 (1.9)	22.3 (4.5)
	Female (8, 16)	23.0 (7.2)		26.0 (4.5)	−3.5 (1.2)	22.2 (7.8)
	Total (20, 37)	24.8 (8.0)		24.0 (8.2)	−2.9 (1.6)	22.7 (6.2)

[a] SD indicates standard deviation.

challenge in orthodontics because of the uncertainty of long-term stability.[15] Prepubertal patients diagnosed early with Class III problems can be treated orthopedically with a protraction facemask or chin cup to normalize the underlying skeletal discrepancy, then with fixed orthodontic appliances (two-phase orthodontic treatment). After the adolescent growth spurt, however, the therapeutic possibilities are limited to camouflage treatment (one-phase orthodontic treatment) or surgical jaw repositioning. Most strategies for the camouflage of Class III malocclusion involve proclination of the maxillary incisors and retroclination of the mandibular incisors to improve dental occlusion.[16] Traumatic occlusion generated during this process may cause jiggling movement, periodontal disease, root resorption, and also tooth wear.[17,18] However, no quantitative study has compared incisal tooth wear in patients with Class III malocclusion treated by one-phase and two-phase orthodontic treatment.

Cha et al.[19] and Park et al.[13] have shown that the volume of tooth wear in orthodontic patients can be measured by the superimposition of three-dimensional (3D) digital models. Park et al.[13] introduced a 3D digital superimposition method for the quantitative evaluation of canine wear during orthodontic treatment; this study was the first to calculate tooth wear volumetrically using 3D reverse-engineering technology. In the present study, incisal tooth wear occurring during early and late (camouflage) interventions for skeletal Class III malocclusion with anterior crossbite was evaluated quantitatively. The hypothesis was that wear of the maxillary central incisor would be related to treatment modality in these patients.

MATERIALS AND METHODS

The sample consisted of pretreatment (T1) and posttreatment (T2) maxillary dental casts from 56 patients who received orthodontic treatment to correct anterior crossbite at the Department of Orthodontics, Gangneung-Wonju National University Dental Hospital, Gangneung, South Korea. Inclusion criteria were (1) one or two maxillary central incisors in an anterior crossbite occlusion, (2) skeletal Class III occlusion (ANB $< 1°$), (3) use of metal brackets, (4) no incisal adjustment during orthodontic treatment, and (5) stone dental casts free of obvious distortion and accurately showing the incisal surfaces of the maxillary central incisors. The ethics committee of Gangneung-Wonju National University approved the study protocol (IRB 2014-14).

Three groups were formed according to treatment type and patient age. Group I consisted of casts from 21 subjects (7 males, 14 females; mean age 9.8 years) who had undergone two-phase treatment (bonded rapid maxillary expansion and facemask [RME/FM], followed by fixed appliance therapy) to correct anterior crossbite. Group IIa consisted of casts from 15 adolescents (8 males, 7 females; mean age 13.5 years) who had received camouflage treatment (9 with and 6 without extraction) around the same time as the phase II treatment of group I. Group IIb consisted of casts from 20 adults (12 males, 8 females; mean age 24.8 years) who underwent camouflage treatment (7 with and 13 without extraction). In total, 104 maxillary central incisors from 56 patients were evaluated at T1 and T2. The distributions of age, ANB angle, and Frankfurt horizontal plane to mandibular plane angle (FMA) in each group are shown in Table 1.

3D Assessment of Tooth Wear

The casts, made of alginate (Aroma Fine Plus; GC Co, Tokyo, Japan) and hard stone (New Plastone II White; GC Co), were scanned using a laser surface scanning system (KOD300, accuracy 50 μm; Orapix Co, Ltd, Seoul, South Korea). The maxillary central incisors were scanned with a point spacing of 150 μm. The images were then imported into a 3D scan data-processing program (Rapidform XOR3®; INUS Technology Inc, Seoul, South Korea). Images of maxillary

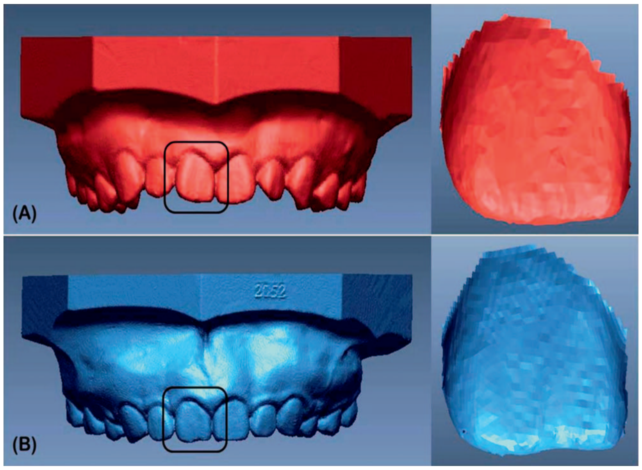

Figure 1. Construction of a single-tooth three-dimensional (3D) digital model. Pretreatment (A) and posttreatment (B) reconstructed 3D digital maxillary models (left) and extracted 3D digital maxillary central incisor models (right).

central incisors were extracted from the 3D digital models (Figure 1).

To evaluate tooth wear, 3D images of the maxillary central incisors at T1 and T2 were superimposed using two registration areas (labial and lingual middle third) with Rapidform XOR3®. This function, designated "3D surface-to-surface matching" (best fit method), employs a least–mean-square algorithm. The middle thirds of the incisors' labial and lingual surfaces were used as references because these areas are considered to be rarely affected by attritional wear and gingival conditions (Figure 2A). With reference to a color bar, the region and degree of tooth wear were identified clearly (Figure 2B). As solid models were required to calculate the volume of tooth wear, four boundary planes were constructed on each T1 maxillary central incisor model (Figure 3A). The mesial and distal planes were created parallel to the long axis of the crown and 0.5 mm from the mesial and distal contact points. The lingual plane was constructed perpendicular to the mesial and distal planes using the same vector as was used for the long axis. The gingival plane was perpendicular to the mesial, distal, and lingual planes and cut off the incisal third of the tooth. Volumetric differences between the T1 and T2 models were then calculated for each pair (T1 and T2) of incisors (Figure 3B).

To evaluate the method error, 20 pairs of maxillary central incisors were selected randomly, and superimposition and volume calculations were repeated at 2-week intervals by the same investigator. The systematic error was evaluated with a paired *t*-test at a significance level of $P < .05$. No significant difference between the two sets of measurements was detected. For all measurements, the method error was tested using Dahlberg's formula (method error $=\sqrt{\sum d^2/2n}$, where d is the difference between two measurements

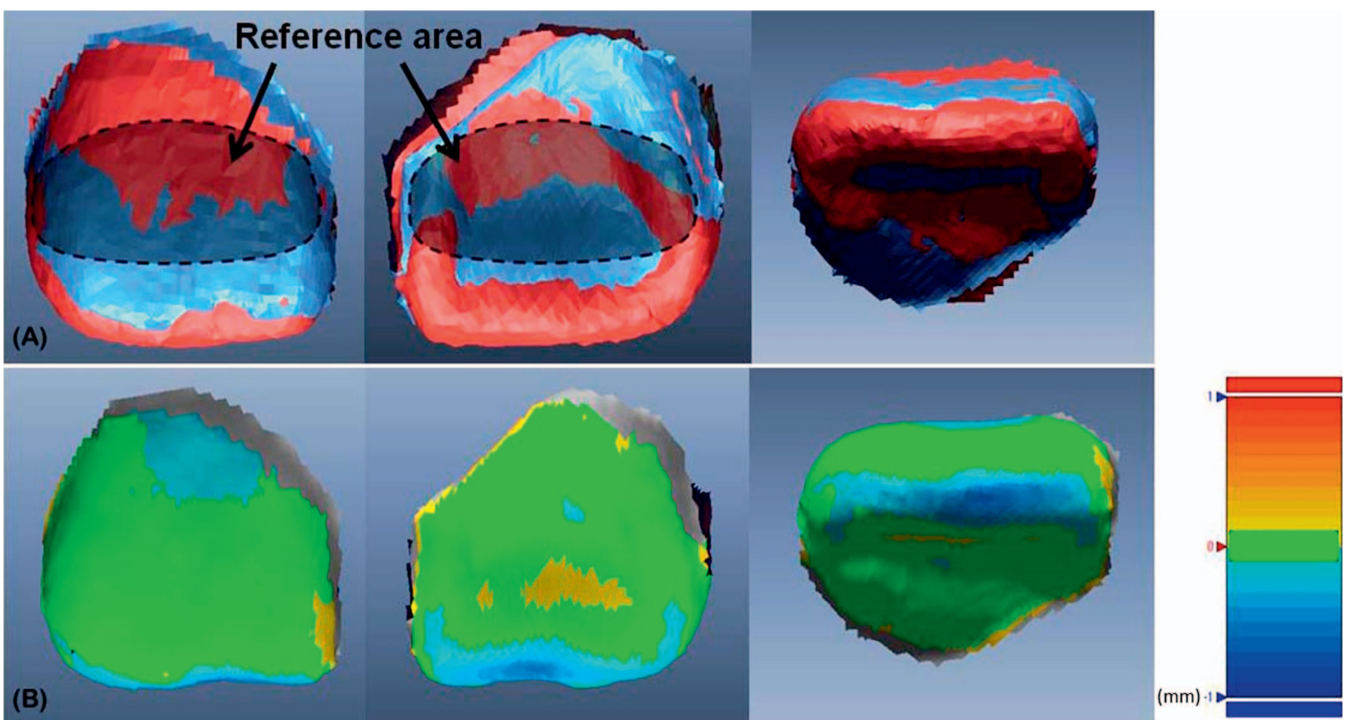

Figure 2. Superimposition of pretreatment (red) and posttreatment (blue) maxillary central incisor models. (A) Superimposition with the best-fit method using the middle third of the labial and lingual surfaces as reference areas. (B) Examination with reference to a color bar.

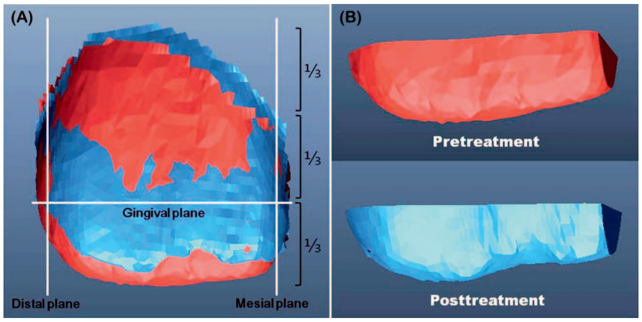

Figure 3. Quantification of the volume of tooth wear. (A) Superimposed pretreatment (red) and posttreatment (blue) maxillary central incisor models and boundary planes (mesial, distal, and gingival) for the creation of solid models. (B) Solid three-dimensional geometries surrounded by the boundary planes. The volume of tooth wear was determined by calculating the difference between the pretreatment and posttreatment models.

taken on an incisor pair and *n* is the number of subjects), yielding a method error of 0.18 mm^3.

Statistical Analysis

Because the data were not distributed normally, nonparametric analysis was used. Gender-based differences within groups were examined using the Mann-Whitney *U*-test. The Kruskal-Wallis test was used to identify significant differences among groups. These differences were further analyzed using the Mann-Whitney *U*-test with Bonferroni correction to reduce the possibility that any significance was due to chance. Associations between tooth wear and variables such as age at the beginning of treatment, treatment duration, or craniofacial morphology were assessed by Spearman's correlation analysis. The level of significance was set at $P < .05$ ($P < .016$ for the Bonferroni-corrected Mann-Whitney *U*-test).

RESULTS

No gender-based difference in tooth wear was found in any group (Table 2). Thus, data from subjects of both genders in each group were combined.

Descriptive statistics and comparisons of tooth wear in the three groups are shown in Table 3. The mean tooth wear values were 1.05 $\pm$ 0.75 mm^3 in group I (RME/FM followed by fixed appliances), 3.59 $\pm$ 2.15 mm^3 in group IIa (camouflage treatment in adolescents), and 3.97 $\pm$ 2.57 mm^3 in group IIb (camouflage treatment in adults). The Kruskal-Wallis test revealed significant differences among the three groups, and the Mann-Whitney *U*-test showed significantly less tooth wear in group I than in groups IIa and IIb (both $P <$ .01). No significant difference was observed between adolescents (group IIa) and adults (group IIb) who received camouflage treatment.

Spearman's correlation analysis revealed no significant correlation between tooth wear and age, treatment duration, or craniofacial morphology in groups I or II (Table 4).

DISCUSSION

This report is the first to describe the quantitative analysis of tooth wear as a function of orthodontic treatment modality. Several reports[20,21] have described tooth wear caused by orthodontic treatment, which should be of concern to orthodontists. The quantitative analysis of such wear yields important additional information compared to conventional tooth wear indices (TWIs). Previous studies have employed many different TWIs that are simple to use but present problems related to standardization and quantification. In addition, they are not suitable for the identification of minor tooth wear occurring during orthodontic treatment. In the present study, a 3D superimposition method was used that has the potential to become a powerful tool for the quantitative assessment of tooth wear.

3D superimposition is used widely to evaluate orthodontic tooth movement,[22–24] but few studies[13] have investigated tooth wear caused by orthodontic treatment using this method. In the present study, the method previously developed for canines, in which the mesial and distal boundary planes were designated 1.5 mm from the corresponding contact points, was modified[13] These planes were designated 0.5 mm from the contact points in the present study to include the largest possible portions of the incisal edges. In future research, individual boundary planes should be defined based on tooth shape.

Two-phase treatment of skeletal Class III malocclusion resulted in less maxillary central incisor wear than

Table 2. Mean, Standard Deviation, and *P* Values for Sex Differences in Each of the Three Groups[a]

Variables	Group I			Group IIa			Group IIb		
	Males (n = 14) Mean (SD)	Females (n = 24) Mean (SD)	Mann-Whitney *U*-Test	Males (n = 16) Mean (SD)	Females (n = 13) Mean (SD)	Mann-Whitney *U*-Test	Males (n = 21) Mean (SD)	Females (n = 16) Mean (SD)	Mann-Whitney *U*-Test
Tooth wear, mm^3	1.45 (0.82)	0.93 (0.66)	NS	3.86 (2.18)	3.25 (2.15)	NS	4.12 (2.60)	3.77 (2.60)	NS

[a] NS indicates not significant; SD, standard deviation.

Table 3. Comparison of the Mean Values of Tooth Wear in Three Groups by Kruskal-Wallis Test and Mann-Whitney *U*-Test[a]

	Group I (n = 38)	Group IIa (n = 29)	Group IIb (n = 37)	Mann-Whitney *U*-Test		
Variables	Mean (SD)	Mean (SD)	Mean (SD)	I-IIa	I-IIb	IIa-IIb
Tooth wear, mm^3	1.05 (0.75)	3.59 (2.15)	3.97 (2.57)	**	**	

[a] SD indicates standard deviation.
** $P < .01$.

did camouflage treatment, despite the greater total treatment duration of the former (Table 3). This finding may be explained by the posterior bite block effect of the bonded RME, which minimized traumatic occlusion during crossbite correction in the first phase of treatment. One advantage of two-phase over one-phase treatment is the ability to initiate fixed orthodontic therapy after anterior crossbite correction. Warren et al.[25] observed severe wear in subjects with Class III malocclusion and edge-to-edge incisor relationships and suggested that this wear was likely associated with frequent contact between the maxillary and the mandibular incisors. Similarly, it is possible that incisal tooth wear was accelerated during the edge-to-edge occlusion that occurred transitionally during the course of crossbite correction in camouflage treatment in the present study. The results suggest that clinicians should consider proper use of posterior bite blocks in the treatment of anterior crossbite. In addition, overcorrection of the reverse overjet is recommended in growing patients with Class III malocclusion, not only to prevent possible relapse, but also to avoid tooth wear due to occlusal interference.

Given the observation period between FM/RME and fixed appliance therapy (17.8 $\pm$ 17.0 months), more natural tooth wear likely occurs during the treatment period in patients undergoing two-phase treatment compared with those undergoing one-phase treatment. Pintado et al.[26] investigated natural tooth wear in 18 young adults for 2 years using a profiling system on epoxy replicas. They reported mean losses of 0.173 mm^3 for canines, 0.047 mm^3 for second premolars, and 0.063 mm^3 for first molars. It seems tooth wear that occurred during orthodontic treatment is more than natural tooth wear. As no quantitative data on central incisor wear have yet been published, the current findings cannot be compared with natural tooth wear values. Thus, further quantitative research on natural tooth wear is needed.

Table 4. Spearman's Correlation Analysis Between the Amount of Tooth Wear and Other Variables

	Tooth Wear, mm^3			
	Group I		Group II	
Variables	Correlation (*r*)	*P*	Correlation (*r*)	*P*
Age	.239	.149	.114	.362
Treatment duration	.010	.950	−.078	.534
ANB angle	−.074	.657	−.093	.459
FMA	−.316	.053	.082	.512

Among subjects undergoing camouflage treatment in the current sample, adults showed more tooth wear than did adolescents, but this difference was not significant (Table 3). Studies[27,28] have demonstrated an increase in the microhardness of enamel with age, due to the reduction of enamel porosity with posteruptive maturation. In the present study, it needs to be noted that more incisal tooth wear was observed in adults than in adolescents and subjects who underwent two-phase treatment, despite the greater post-eruptive age of the adult teeth. These results could be explained by the fact that adults have slower turnover rates of alveolar bone and greater bite force than do adolescents.[29,30]

Many previous studies have reported associations between tooth wear and age,[2,3] gender,[2,4–7] and craniofacial morphology.[8] In contrast, no significant gender difference (Table 2) and no significant correlations between tooth wear during orthodontic treatment and age, ANB angle, FMA, or treatment duration were observed in the present study (Table 4). The results were consistent with previous results[13] that showed no significant correlation between canine wear during orthodontic treatment and age, gender, treatment duration, or craniofacial morphology. The amount of tooth wear during orthodontic treatment may depend on the orthodontic treatment methods and therefore may not follow the natural tooth wear pattern. Such sensitive changes cannot be measured accurately by traditional methods such as TWIs. Further research using more sophisticated methods, such as the 3D volumetric assessment introduced in this study, are recommended to clarify the association between tooth wear and age, gender, and craniofacial morphology.

CONCLUSIONS

- The results of the present study support the hypothesis that incisal wear of the maxillary central incisor is related to treatment modality in patients with skeletal Class III malocclusion and anterior crossbite.
- Although early treatment is lengthy, it resulted in less wear of the incisors than did orthodontic camouflage treatment.

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