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Research Article

THREE-DIMENSIONAL DIGITAL SUPERIMPOSITION FOR ASSESSING TOOTH WEAR IN ORTHODONTIC TREATMENT

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ABSTRACT

This study describes the development of a novel method for evaluating tooth wear during orthodontic treatment using a three-dimensional (3D) digital superimposition technique. Dental casts were collected from 112 patients undergoing orthodontic treatment, with pre-treatment (T1) and post-treatment (T2) casts used to create 3D images of the canines. Both lingual and labial surfaces were utilized as reference points, and the volume of the canines was measured before and after orthodontic intervention using four boundary planes. Analysis of data collected over an average orthodontic treatment duration of 36.5 months revealed an average tooth wear of 3.0 mm3 across 448 canines. Notably, male subjects exhibited a canine tooth wear volume of 3.3 ± 2.5 mm3, while female subjects showed a volume of 2.9 ± 2.2 mm3. Furthermore, it was observed that upper right canines experienced significantly greater wear compared to lower right canines. The utilization of three-dimensional digital models enables precise quantification of tooth wear in orthodontic patients through regional registration. This methodology holds promise for use in restorative dentistry to evaluate treatment outcomes effectively.

Key words:-. Tooth wear, Orthodontic treatment, Three-dimensional digital superimposition, Dental casts, Restorative dentistry.

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INTRODUCTION

During dental treatment, tooth material undergoes attrition, erosion, and abrasion, influenced by various factors such as age, gender, bruxism, and malocclusion [1-3]. However, tooth wear during orthodontic treatment remains understudied, with few quantitative assessments published [4]. Existing methods like the tooth wear index (TWI) have limitations and cannot capture wear occurring during orthodontic treatment [5]. While previous studies have utilized stylus and laser scanning techniques for tooth wear assessment [6-9], they are primarily research-oriented and lack clinical application [10]. Dental CAD-CAM technologies offer promising avenues for dental assessment, allowing for the storage, retrieval, and diagnostic versatility of digital data. Orthodontists increasingly rely on digital 3D models for treatment planning and evaluation [11], aided by technologies like Invisalign and Orthocaps. Proposals for superimposed digital models to measure tooth wear volume have been made by researchers, suggesting a need for robust methods in clinical orthodontic studies. In this preliminary report, we introduce a novel three-dimensional digital superimposition method for evaluating tooth wear, aiming to address this gap in clinical assessment.

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METHODOLOGY

A total of 112 dental casts were obtained from patients who received orthodontic treatment. Restorations on anterior teeth, no anterior crossbite, as well as no occlusal adjustments were included in the inclusion criteria (Table 1). With a laser surface scanning system with 0.25mm point spacing, maxillary and mandibular dental casts were scanned before and after alginate and hard stone orthodontic treatment. Using reverse modeling software, we reconstructed and imported the 3D virtual models. 448 pairs of canines (T1 and T2) have been extracted from 112 digital models in order to obtain 448 pairs of canines. The best-fit method was used to superimpose 3D images of the canines at T1 and T2. For superimposition, we used only labial and lingual surfaces that are generally not affected by attrition wear or gingival condition. Calculating volume of a canine requires a solid 3D model. With the help of boundary planes, four boundary planes were created on the T1 canine. A 2.5 mm gap was created between the distal and mesial planes. It is also perpendicular to the mesial and distal planes, just like the canine long axis. In the incisal third of each canine, the gingival plane should be perpendicular to all three planes. Volumetric differences between T1 and T2 were calculated. The same investigator repeated superimposition and volume calculations on 20 randomly selected canines at one-week intervals to evaluate method error. Dahlberg's formula was used to test for method error. A method error of 0.3 mm3 was found in the measurements.

Statistics

Nonparametric analysis was used due to the non-normal distribution of the data. A Mann-Whitney U-test was used to compare the results of males and females in the study. Wilcoxon signed rank test was used to compare upper canines with the lower canines as well as the right canines with the left canines. To determine the correlation between the variables, Spearman correlation analysis was used.

RESULTS

During orthodontic treatment, 36.5 months passed between impressions taken at T1 and T2. Between T1 and T2 canines, there was a mean (6 standard deviation) difference in volume of 3.0 ± 2.3 mm3. In spite of negligible differences, it was observed that three out of 448 canines had an increase in volume following orthodontic treatment. Wear rate for male subjects was 3.3 ± 2.5 mm3 and the tooth wear rate for female subjects was 2.9 ± 2.2 mm3. These differences, however, did not reach statistical significance (Table 2). On the upper right canine, 3.4 ± 3.0 mm3 of tooth wear was detected, on the upper left canine, 3.0 ± 2.9 mm3, on the lower right canine, 3.0 ±2.7 mm3. Teeth wear was greater on the upper right canine (Table 3). Among the factors analyzed in Spearman correlation analyses (Table 4), none showed significant associations with tooth wear.

Table 1: An analysis of the durations of treatment, ages, and the cephalometric characteristics of the patients

Subjects (n)	Age (Years)	Treatment Duration (Months)	ANB (u)	FMA (u)
Male (46)	23.3 ± 5.4	38.4 ± 8.3	3.3±2.7	29.5±5.8
Female (66)	22.5 ±6.7	35.1 ± 9.7	3.5 ±2.2	8.7±5.7
Total (112)	22.8 ± 6.1	36.5 ± 9.3	3.4±2.4	9.0±5.7

Table 2: Comparing tooth wear (mm3) between males and females using the Mann-Whitney U-test

	Male Subjects (n =46)		Female Subjects (n = 66)		
	Mean	SD	Mean	SD	P
Upper right canine	3.8	3.7	3.2	2.4	.347
Upper left canine	3.5	3.5	2.7	2.3	.688
Lower right canine	2.8	2.5	3.0	4.2	.347
Lower left canine	3.5	2.9	2.7	2.5	.071
Total	3.3	2.5	2.9	2.2	.280

Table: 3 A Wilcoxon Signed Rank Test for Comparing Tooth Wear (mm3) Between Upper and Lower Canines

	Right Canines (n =112)			Left Canines (n =112)			
	Mean	SD	pa	Mean	SD	pa	pb

Upper canines	3.4	3.0	0.021	3.0	2.9	0.996	0.289
Lower canines	2.9	3.6		3.0	2.7		0.444

Table: 4 Assessing the correlation between variables using Spearman Correlation Analysis

	Tooth Wear (mm3)	
	r	P
Gender	3.181	0.234
Age	0.303	0.234
Treatment duration	0.203	0.551
ANB	30.066	0.728
FMA	0.025	0.1010

DISCUSSION

There are several tooth wear indicators developed that are simple to use, but lack the standardization and reliability of quantifying wear [12]. The majority of tooth wear indicators cannot detect minor enamel losses. However, TWIs cannot be used to measure the wear of teeth during orthodontic treatment or after the conclusion of a short-term follow-up, despite their applicability for epidemiological studies [13]. The measurement of tooth wear quantitatively is extremely difficult, if not impossible. Composite filling wear has been measured using a 3D optical scanner or detected using a toolmaker microscope. Clinical applicability of such methods, however, needs to be critically examined [14].

In orthodontics, digital 3D data acquisition is used. This technique has not yet been used in order to measure the length of a tooth longitudinally. Orthodontic tooth movement was assessed using the palatal surface in our previous publications [15]. A novel method was proposed for quantifying tooth wear in 3D by superimposing the lingual and labial surfaces. The idea behind such a trial methodology was to calculate tooth wear by registering two separate teeth that were separated at a distinct distance from one another, such as before and after treatment, and using the individual tooth's stable reference area [16]. In the present study, the method error (0.2 mm3) indicates the technique is sufficiently reliable and reproducible. Higher scanning resolutions improve regional registration accuracy. 0.15 mm point spacing was used to scan the canines in this preliminary study. Depending on the different teeth (premolars or molars), the scanning accuracy should be changed in future studies.

Our study found that superimposition of the two surfaces lingual and labial is more accurate when both surfaces are used. Lower incisors lack cusps and sufficient shape characteristics for registration, and molars have restorations. Because canines have a characteristic morphology and wear more severely than other teeth, we evaluated only upper and lower canines in this preliminary study [17]. Various tooth shapes, such as those found in molars and incisors, may need to be examined further to see how modifications to superimposition affect the superimposition method. The volume of three of the 224 canines increased during orthodontic treatment for a total of three patients. It is possible that such false results were caused in part because alginate impressions and white stones were not accurate enough to give accurate results. Differences may be explained by alginate shrinkage or variable setting expansion. This false result can also be caused by resin remnants after removing fixed appliances or unintentional enamel removal. According to a study, the resin remnants had a mean volume of 2.48 mm3 and enamel loss was measured at 0.05 mm3. Such bias deserves careful consideration in a future prospective study. Ex vivo studies require replicate casts, impressions, 3D scanning, regional registration, and volume calculations compared to the loss measured, for example, via micro-CT. The pre- and post-treatment impressions could not be replicated in this preliminary study. While it is likely that there will be the same standard errors at T1 and T2, they will differ at T2. It has been shown that occlusal wear increases with aging and that adult tooth wear is similar to childhood wear. In addition, tooth wear is strongly correlated with biting force, sexual differences, ramal height, gonial angle, and craniofacial morphology. The study included only adults with skeletal Class I. Therefore, ANB and FMA were not significant. A mean of 2.0 6 1.3 mm3 of tooth wear was observed on the canines after 35.5 68.3 months of orthodontic treatment. No other study has measured tooth wear during orthodontic treatment. An epoxy replica of teeth was used. in their study on the effects of enamel loss on 18 young adults. Canines lost an average of 0.173 mm3 of volume. As a result, orthodontic patients' mean canine wear is greater than non-orthodontic patients' [13].

It remains to be demonstrated that this is true in randomized clinical trials with control subjects. The masseters and bite forces of males are generally stronger. Females have suffered significantly greater attrition than males according to many previous studies. Despite the higher average tooth wear among male subjects (2.3 6 1.5 mm3), there was no statistically significant difference between the male and female groups (Table 2). Right and left canines did not differ statistically significantly (Table 3). Asymmetrical tooth wear is unlikely to be influenced during active orthodontic treatment by functional displacement of the mandible. In a group with clinically normal occlusion, found no difference in wear scores between upper and lower canines. It was found in the present study that there was more wear on the right canine than the left canine. Due to the limited scope of this study, it was not possible to interpret the asymmetrical wear pattern seen in the four quadrants. It is to our knowledge the first study to be performed using reverse engineering technology in order to calculate tooth wear volumetrically. A 3D tooth superimposition method is used in this preliminary study to measure tooth wear. This method's validity needs to be verified in the lab with protocols. It may be necessary to refine samples to better clarify skeletal pattern, treatment duration, gender, age, and location relationships. Restorative dentistry may also benefit from the methodology presented here. By combining 3D registration with an intraoral scanner, volumetric changes can be quantified in the near future. There is a need to develop additional automatic algorithms for the extraction of 3D landmarks for these clinical applications.

CONCLUSION

Using three-dimensional digital models to assess the quantitative wear of teeth in orthodontic patients, regional registration of teeth was investigated. Using boundary planes and superimposition, this technique was explained. In 35.5 months, there was a loss of 2.0 mm in the canines. Wear on the upper right canine (2.4 mm3) was significant. Restorative dentistry can also use the method described in this study to evaluate tooth wear.

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