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Wear behavior of a microhybrid composite *vs.* a nanocomposite in the treatment of severe tooth wear patients: A 5-year clinical study

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ABSTRACT

Objective. This study aimed to compare the wear behavior of a microhybrid composite *vs.* a nanocomposite in patients suffering from severe tooth wear.

Methods. A convenience sample of 16 severe tooth wear patients from the Radboud Tooth Wear Project was included. Eight of them were treated with a microhybrid composite (Clearfil APX, Kuraray) and the other eight with a nanocomposite (Filtek Supreme XTE, 3M). The Direct Shaping by Occlusion (DSO) technique was used for all patients. Clinical records were collected after 1 month (baseline) as well as 1, 3 and 5 years post-treatment. The maximum height loss at specific areas per tooth was measured with Geomagic Qualify software. Intra-observer reliability was tested with paired t-tests, while multilevel logistic regression analyses were used to compare odds ratios (OR) of "large amount of wear".

Results. Intra-observer reliability tests confirmed that two repeated measurements agreed well ($p > 0.136$). For anterior mandibular teeth, Filtek Supreme showed significantly less wear than Clearfil APX; in maxillary anterior teeth, Clearfil APX showed significantly less wear ($OR_{material} = 0.28$, $OR_{jaw\ position} = 0.079$, $p < 0.001$). For premolar and molar teeth, Filtek Supreme showed less wear in bearing cusps, whereas Clearfil APX showed less wear in non-bearing cusps (premolar: $OR_{material} = 0.42$, $OR_{bearing\ condition} = 0.18$, $p = 0.001$; molar: $OR_{material} = 0.50$, $OR_{bearing\ condition} = 0.14$, $p < 0.001$).

Significance. Nanocomposite restorations showed significantly less wear at bearing cusps, whereas microhybrid composite restorations showed less wear at non-bearing cusps and anterior maxillary teeth.

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1. Introduction

Tooth wear is a condition of increasing prevalence, which can severely reduce the quality of life [1,2]. Severe tooth wear is defined as tooth wear with substantial loss of tooth structure, defined as more than one third of the clinical crown [3]. Severe tooth wear can lead to tooth sensitivity, aesthetic demands and loss of the vertical occlusion dimension. Commonly used restorative materials for the treatment of severe tooth wear patients are direct or indirect composite restorations [4–7], lithium disilicate glass-ceramics [8] and polymer infiltrated ceramic network (PICN) [9]. A 3.5-year survival study has shown that direct composite restorations have a great potential for restoration of functional and esthetical properties [5]. Treatments using direct composite restorations are relatively cheap and contribute to acceptable levels of oral health-related quality of life with minimally invasive techniques [10].

Microhybrid composites and nanocomposites are two types of commonly used all-purpose direct composite resin materials. Microhybrid composites consist of both microscale and nanoscale (∼20 nm) glass fillers, while nanocomposites are made of either individual (5–20 nm) or clustered (0.6–1.4 μm) nanoscale glass fillers [11]. Several studies showed that glass filler parameters have effects on mechanical properties, while increased filler content and decreased filler size can improve the material strength and wear resistance [12–14]. In line with those studies, nanocomposites showed better wear resistance compared to microhybrid composites *in vitro* [14,15]. Nevertheless, a microhybrid composite showed a significant decrease in the surface roughness compared to nanocomposites after toothbrush abrasion *in vitro* [16]. However, only few studies have been reported on wear behavior of nanocomposites and microhybrid composites *in vivo*, likely due to the challenges related to quantitative analysis of tooth wear in clinical studies.

Traditionally, tooth wear is evaluated qualitatively using scoring systems [17]. In recent years, there has been an increasing interest in quantitative analysis based on digital 3D scans since this method is more objective and precise than scoring systems [18–20]. However, the main challenge faced by researchers is that the alignment procedures of 3D scans have not yet been standardized, which can influence the accuracy of quantitative measurements [20,21].

Failure of conventional large posterior composite restorations is predominantly attributed to fracture and caries [22]. However, treatment of severe tooth wear patients requires large cusp-replacing composite restorations. In a prospective clinical study on the treatment of severe tooth wear patients with direct composite restorations, no clinically unacceptable restorations due to wear were observed. However, formation of significant wear facets on most of the placed composite restorations was only reported in qualitative manner observed after 3.5 years of clinical service [5]. Quantitative data on the wear resistance of these restorations prescribed for high-risk patients with severe tooth wear are still lacking. Therefore, the objective of this study was to quantitatively evaluate the wear behavior (height loss) of two different types of direct composite restorations (*i.e.* a microhybrid composite and a nanocomposite) prescribed in patients with severe tooth wear.

2. Materials and methods

2.1. Participants

Participants with tooth wear were referred by their general dental practitioners to the Radboud Tooth Wear Project at the Department of Dentistry of the Radboud University Medical Center in Nijmegen (The Netherlands). This study is a substudy of a larger clinical trial (ethical approval was obtained, CMO Arnhem-Nijmegen file No. NL30346.091.10). Participants who agreed to participate in the trial were asked to sign an informed consent document before entering the study. Inclusion criteria of the Radboud Tooth Wear Project were: (1) patient's age ≥18 years; (2) generalized moderate to severe tooth wear with patient demand for treatment (TWI ≥ 2, *Smith and Knight tooth wear index* [23]); (3) full dental arches, a single diastema due to one missing posterior tooth was allowed; (4) estimated need for an increase in vertical dimension of occlusion (VDO) <3 mm in the first molar region. Patients with specific individual risk factors, such as bruxism or patients with GORD (Gastro-Oesophageal Reflux Disease), were also included. Exclusion criteria were: (1) limited mouth opening; (2) (History of) temporomandibular dysfunction; (3) advanced periodontitis, deep caries lesions, or multiple large restorations including teeth with endodontic problems; (4) local or systemic conditions contra-indicating dental treatment.

Additional inclusion criteria were used to create the convenience sample in this study. Both buccal and palatal veneer restorations had to be prescribed and the 3D intra-oral scans directly after treatment and of the recalls at 1 year, 3 years and 5 years needed to be available. Of the 20 patients restored with a nanocomposite (Filtek Supreme XTE, 3M, Seefeld, Germany) included in the project, 8 patients were eligible. Of the 37 patients restored with a microhybrid composite (Clearfil AP-X, Kuraray, Osaka, Japan), 23 were eligible. From this group, 8 patients were randomly selected using a simple random sampling method. We numbered each patient and randomly chose 8 numbers from the database to create similar group sizes.

2.2. Restorative treatment with direct composite restorations

All patients were in need of a full rehabilitation and to obtain enough interdental space for the restorations, an increased vertical dimension of occlusion (VDO) was necessary. Minimally invasive additive techniques were applied using direct composite restorations. Restorations were placed without preparation of teeth, when possible. Rubberdam or cotton rolls and suction devices were used for moisture control. Appropriate matrix systems and wedges were used to build up the teeth. For bonding, a 3-step etch-and-rinse adhesive was applied according to manufacturer's instructions, using 37% phosphoric acid (DMG, Hamburg, Germany), Clearfil SA Primer, and Clearfil Photobond (Kuraray). A microhybrid (Clearfil AP-X, Kuraray) or a nanocomposite (Filtek Supreme XTE, 3M) was used for the composite restorations. Restorations were placed according to the DSO-technique (Direct Shaping by Occlusion, where the patients occlude on soft composite prior to polymerization) [24] and light cured using a Bluephase 16i unit (Ivoclar Vivadent, Liechtenstein; maximum output 1.600 mW/cm^2). In the group in which a microhybrid composite (Clearfil AP-X) was used, buccal direct veneer restorations on anterior teeth were placed using a nano-hybrid composite (IPS Empress Direct, Ivoclar Vivadent, Schaan, Liechtenstein), due to aesthetic demands. In the group in which a nanocomposite (Filtek Supreme XTE) was used, the same composite was used for posterior, anterior and buccal veneer restorations. For optimal bonding in teeth with pre-existing composite restorations, the adhesive surface of the tooth was air-abraded using CoJet sand (30 μm, 3M) and a silane coupling agent (Clearfil Porcelain Activator, Kuraray) was used, additional to the bonding procedure based on the application of Clearfil SA Primer and Clearfil Photobond (Kuraray).

2.3. *Recall*

Patients visited the clinic for final adjustments 1 month after finishing the restorative procedure (considered as a baseline, T_0). The restorations were finished by fine-grit diamonds and rubber points with aluminum oxide polishing paste. Aluminum oxide discs or abrasive finishing strips were used for interproximal surface finishing. Recall appointments were scheduled after 1 year (T_1), 3 years (T_3) and 5 years (T_5). During each recall appointment, the dentition was documented using clinical examination, photographs and an intraoral 3D scan (LAVA COS/True Def, 3M). The scanning procedure was conducted in accordance with the manufacturer's instructions. Scans were made with the patient in a sitting position, Optragate (Ivoclar Vivadent) was used, teeth were rinsed, air-dried and lightly dusted with titanium dioxide (3M). The scans were digitally stored in the web-based platform (Casemanager, 3M).

2.4. *Height loss measurements*

To quantify the amount of wear over a specific period, the recall scans of T_1, T_3, and T_5 were compared with the scans of T_0. This procedure is presented in more detail in Fig. 1. Quantitative analysis of changes between sequential intra-oral scans was performed in Geomagic Qualify (3D Systems, Morrisville, North Carolina, USA). Of each scan all teeth were manually isolated and saved separately (step a). Two scans of interest (e.g. tooth #17, scans of T_0 and T_3) were aligned using 'Best Fit Alignment' on the whole tooth surface, with the Deviation Elimination on level 1 (step b). Subsequently, on the combined image, locations showing wear facets were deselected and a new 'Best Fit Alignment' was performed (step c), referred to as a modified reference-based alignment. The quality of the best fit was checked by the 3D comparison (with a spectrum) and 'cross-sections' (perpendicular to the surface in buccal-palatal/lingual direction) (step d). '3D Compare' was used to visualize differences between the scans, where the oldest scan was selected as 'reference' and the newest scan as 'test'. For all subtractions, the same spectrum was used. The area with the largest amount of wear (darkest blue point) was selected manually and quantified using 'Create annotations' with a deviation radius of 0.2 mm. In case of a void or large wear facet, resulting in a gray area in the heatmap subtraction image, a cross-section on the location where the largest loss of material was expected '2D Dimensions' was used on a cross-section to quantify the areas with the largest amount of wear (step e).

For the anterior teeth, material height loss was measured at the incisal edge and for maxillary anterior teeth on the palatal area as well; for premolar teeth, the occlusal surface on both buccal and palatal cusps was measured; for molar teeth, the occlusal surfaces on mesio-buccal, disto-buccal, mesio-lingual and disto-lingual cusps were measured. The maximum height loss per location was expressed in millimeter (mm).

2.5. *Intra-observer reliability*

Intra-observer reliability was tested by re-measuring recall data after 1 year, 3 years and 5 years post-treatment. Four patients were included in the intra-observer reliability test, where two patients were treated using microhybrid composite and the other two patients were treated using the nanocomposite. The number of measurement was $N_{1\ year} = 268$, $N_{3\ years} = 256$, $N_{5\ years} = 254$, respectively.

2.6. *Data preparation and statistical analysis*

Positive height loss measurements (ranging between 0 and +10 μm) corresponding to clinically irrelevant height increase in the dataset were set to 0. Per tooth, multiple measurements were performed (total measurements: 2964). Teeth presenting fractures at specific recalls and restorations which were repaired or replaced in the period of observation were excluded from the analysis.

The intra-observer reliability was analyzed with a paired t-test and presented by Bland–Altman plots and scatter plots. Subsequently, the correlation between both measurements, the duplicate measurement error (DME), the mean difference (diff), 95% CI and p values were calculated.

The distribution of wear (height loss) data was inspected using density curves. To be able to analyze the skewly distributed data, we transformed our measurement data to a binary dataset based on the comparison of the height loss measurements with the height loss average (anterior teeth, premolar teeth, and molar teeth) of all recall data. In case the height loss measurement showed less height loss than the average height loss per type of tooth, this scenario was defined as 'small amount of wear' and when the height loss was more than the average this scenario was defined as 'large amount of wear', respectively, yielding a binary dataset containing '0' or '1' values. Considering the clustering of teeth from one patient, multilevel logistic regression analysis was used for the main analyses to compare odds ratios (OR) of "large amount of wear" (R version 3.6.2). Generally, OR values <1 correspond to better wear resistance, whereas OR values >1 correspond to reduced wear resistance. To enhance the understanding of the relation between wear and materials, the jaw and bearing/non-bearing condition and also interactions (material with jaw, material with bearing/non-bearing condition) were considered as independent variable.

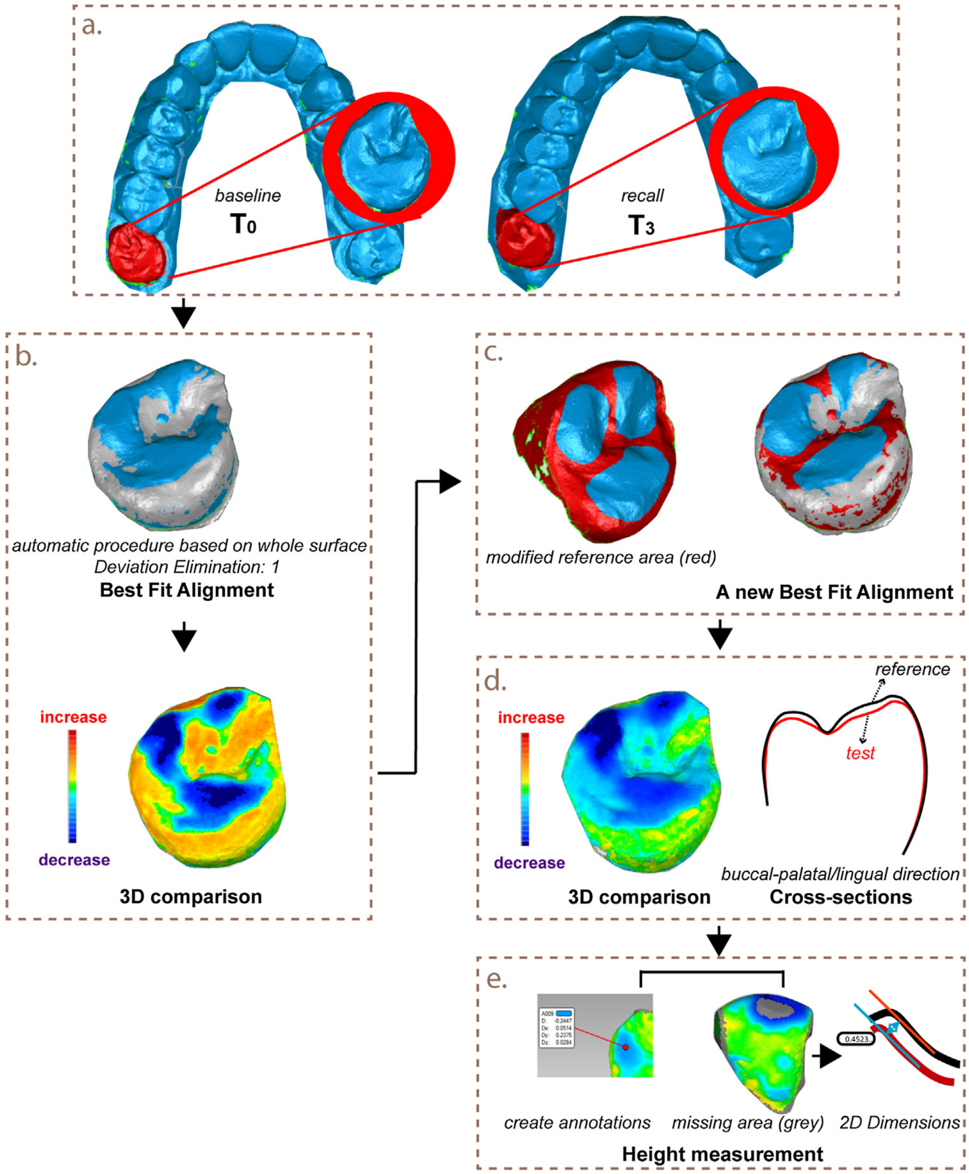

Fig. 1 – Quantification procedure of the amount of wear over a specific period between baseline and recall.

3. Results

3.1. *Intra-observer reliability*

The summary statistics for intra-observer reliability tests are shown in Table 1. The two repeated measurements from one observer at each recall moment were in agreement to each other: the correlation results showed good reliability; duplicate measurement error (DME) was very small and no structural differences were seen ($p > 0.136$). In addition, the results of intra-observer test are also depicted by Bland–Altman plots and scatter plots (Fig. 2).

3.2. *Overview of height loss data*

To display the height loss distributed of restorations in anterior teeth, premolar teeth, and molar teeth after 1, 3 and 5 years, density curves are presented (Fig. 3). Under each density curve, the total area is equal to 100%. In general, these density curves all display a right-skewed distribution. A similar trend could be found in different types of teeth. The majority of anterior teeth, premolar teeth and molar teeth showed height loss below 0.25 mm while height loss exceeding 0.5 mm was minimal at 1 year recall. With increasing recall time, after 3 years and 5 years, more height loss was observed (peaks shifting to the right), corresponding to increased wear. In addition, there are also some height loss differences in different types of teeth. At all recall moments, the curve peak position and the wideness of the curve confirmed that height loss proceeded in the order height loss $_{molar}$ > height loss $_{premolar}$ > height loss $_{anterior}$. The quantitative data of actual height loss in the different scenarios were also shown in Table 2.

Table 1 – Intra-observation reliability test.

Comparison	Correlation	DME	Diff.	95% CI	p
1 year	0.613	0.064	−0.003	[−0.014...0.008]	0.583
3 years	0.861	0.07	−0.004	[−0.017...0.008]	0.511
5 years	0.794	0.101	−0.014	[−0.032...0.004]	0.136

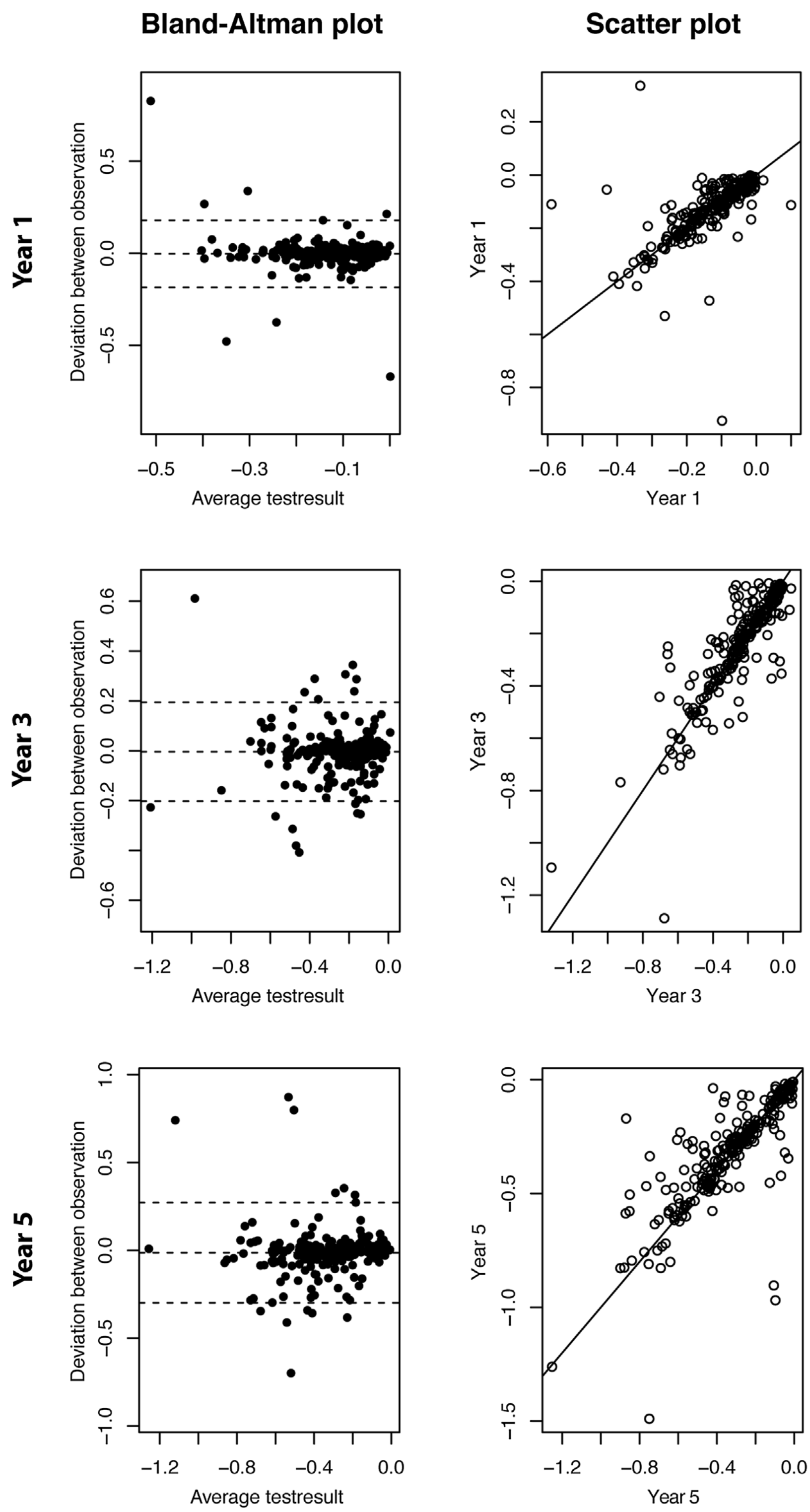

Fig. 2 – Bland–Altman plots (left) and scatter plots (right) presenting the intra-observer reliability of the wear measurements of the recall at year 1 (up), year 3 (middle), and year 5 (low).

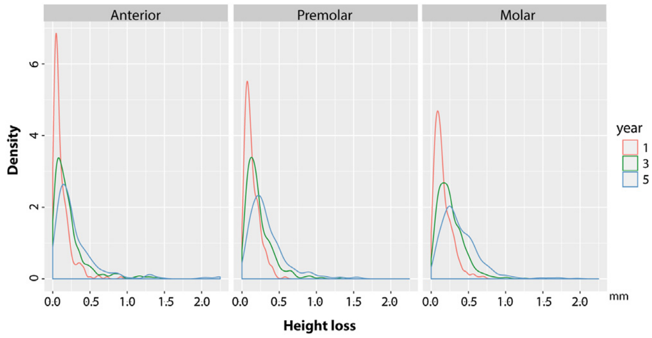

Fig. 3 – Density curves of the height loss in anterior teeth, premolar teeth, and molar teeth after 1 year (red), 3 years (green), and 5 years (blue) (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article).

3.3. *Analysis of height loss in different types of teeth*

Table 3 shows the results of the multilevel logistic regression in anterior teeth. We found an interaction between material and jaw ($p < 0.001$). That implies that effect of material on the amount of wear differs per jaw. Similarly, the effect of jaw on the amount of wear differs per material. This complicates the interpretation of the regression table, in the end, ORs of specific effects from individual or combination factors are shown in Table 3. In the mandibular anterior, Filtek Supreme XTE decreased the odds of a large amount of wear by 0.28 times (OR = 0.28, Cl [0.066...1.13]), while in the maxillary anterior, Supreme XTE increased the odds of a large amount of wear more than triple (OR = 0.28 × 10.8 = 3.02, Cl [0.75...12.24]). To give a full example of how to combine the results, Table 4 shows all ORs of all combinations between the material and the jaw position.

For premolar teeth, the chance of "a large amount of wear" also depends on two interacted factors the material and the bearing condition ($p = 0.001$) (Table 5). For the bearing cusps, Filtek Supreme XTE decreased the odds of a large amount of wear (OR = 0.42, CI [0.13...1.41]); for the non-bearing cusps, Filtek Supreme XTE increased the odds of a large amount of wear more than one time (OR = 0.42 × 3.19 = 1.34, CI [0.40...4.67]), which means that in bearing cusps, Filtek Supreme XTE showed better wear resistance, while in non-bearing cusps, Clearfil APX performed better. Moreover, restorations on the maxillary teeth have a significantly higher chance to develop a large amount of wear (OR = 1.71, $p = 0.002$).

Molar teeth showed a similar trend as premolar teeth, where maxillary restorations have a higher chance to develop large amounts of wear (OR = 1.28, $p = 0.048$) (Table 6). We found a strong interaction between material and bearing condition ($p < 0.001$). Comparable to the premolar teeth, on the bearing cusps restorations restored with Filtek Supreme showed better wear resistance (OR = 0.50, CI [0.18...1.38]), whereas on the non-bearing cusps restorations made of Clearfil APX wore less severely (OR = 0.50 × 2.73 = 1.37, CI [0.50...3.83]).

4. Discussion

The present study reports the outcome of a five-year follow-up study of wear (height loss) measurements in patients presenting severe tooth wear. These patients were treated with two types of direct composite restorations. In this clinical study, wear measurements of 16 patients, and a total of 2964 measurements were included. The outcome was expressed as height loss of the restorations. To our knowledge, this is the first time that (1) *in vivo* wear behavior (in terms of height loss) of a unique and challenging high-risk group of severe tooth wear patients is studied quantitatively, and (2) *in vivo* wear behavior (height loss) of two types of composite restorations (*i.e.* a microhybrid composite *vs.* a nanocomposite) is directly compared.

In this study, an intraoral scanner was used to make digital 3D scans. By comparing the scans at different recall moments in time, it was possible to quantify the amount of wear. However, this procedure is complex and depends on many variables. O'Toole et al. have investigated the accuracy of commonly used alignment techniques and found 'reference alignment' produced low alignment errors [21]. Nevertheless, our hypothesis is that in case of severe (occlusal) tooth or restoration wear, only using the buccal and palatal/lingual side of the tooth as the 'reference' would make the best fit unreliable. Therefore, we decided to use a 'modified reference alignment' procedure, in which a third dimension (occlusal surface) was used to obtain the best fit between the two scans.

Table 2 – Quantitative data of actual height loss in the different scenarios.

(mm)		Clearfil APX						Filtek Supreme XTE					
		Year 1		Year 3		Year 5		Year 1		Year 3		Year 5	
		Average	SD	Average	SD	Average	SD	Average	SD	Average	SD	Average	SD
Anterior	Maxillary	−0.068	0.064	−0.128	0.121	−0.185	0.156	−0.115	0.153	−0.218	0.234	−0.308	0.354
	Mandibular	−0.08	0.084	−0.166	0.184	−0.253	0.265	−0.09	0.106	−0.176	0.267	−0.279	0.408
Premolar	Maxillary	−0.139	0.092	−0.229	0.129	−0.335	0.164	−0.126	0.086	−0.228	0.171	−0.327	0.242
	Mandibular	−0.112	0.077	−0.189	0.139	−0.319	0.247	−0.109	0.095	−0.217	0.262	−0.344	0.334
	Bearing cusps	−0.167	0.081	−0.274	0.132	−0.41	0.205	−0.132	0.105	−0.269	0.265	−0.393	0.308
	Non-bearing cusps	−0.124	0.107	−0.18	0.147	−0.263	0.195	−0.113	0.085	−0.177	0.146	−0.285	0.269
Molar	Maxillary	−0.138	0.1	−0.241	0.13	−0.358	0.167	−0.159	0.129	−0.261	0.201	−0.386	0.297
	Mandibular	−0.143	0.099	−0.241	0.161	−0.36	0.215	−0.13	0.105	−0.246	0.188	−0.409	0.352
	Bearing cusps	−0.212	0.116	−0.321	0.155	−0.464	0.185	−0.176	0.147	−0.312	0.222	−0.49	0.348
	Non-bearing cusps	−0.119	0.089	−0.209	0.135	−0.289	0.167	−0.129	0.105	−0.198	0.139	−0.318	0.281

Table 3 – Multilevel logistic regression analysis on the effect of the material and jaw position on the odds ratio (OR) of having a 'large amount of wear' in anterior teeth (N = 823).

Anterior teeth	OR	p	95% Confidence interval
Intercept	1.79	0.251	[0.66...4.92]
Filtek Supreme XTE *vs.* Clearfil APX, in mandibular	0.28	0.074	[0.066...1.13]
Maxillary *vs.* mandibular, with Clearfil APX	0.079	<0.001	[0.043...0.14]
Interaction: additional effect Filtek Supreme XTE in maxillary	10.8	<0.001	[5.13...23.23]

Table 4 – Odds ratios (ORs) of all combination between material and jaw in anterior teeth.

OR	Filtek Supreme XTE	Clearfil APX
Maxillary	$0.28 \times 0.079 \times 10.8 = 0.24$	0.079
Mandibular	0.28	1 (reference)

The areas on the occlusal surface with significant amount of wear were deselected from alignment to optimize the fit.

Due to the complexity of the measurement technique, it is highly challenging to provide an answer on the accuracy and precision of this 3D measurement technique. Our procedure resulted in some positive values (0.7%) in the dataset, ranging between 0 and +10 μ, which are neglectable measurement errors. Most importantly, the intra-observer reliability of the measurement can give an indication of the precision. The correlation results showed moderate to good reliability (correlations of 0.61–0.86). The duplicate measurement error (DME) and the standard deviation for the difference showed a very small random error in the two measurements, and no structural differences were found. Altogether, we propose that the modified reference alignment procedure presented herein allows to quantify the height loss of wear facets.

We showed the results for separate types of teeth and composites. In addition, we investigated the effects of jaw position and bearing condition on wear behavior. By combining all results of different types of teeth, it can be concluded that Clearfil APX exhibits reduced wear in non-bearing cusps and anterior maxillary teeth. This result can be understood from the fact that the loading in the anterior area is highly comparable to the non-bearing cusps in the premolar and molar areas. In contrast, Clearfil APX showed inferior wear performance in the anterior mandibular teeth, whereas it was expected that Clearfil APX was superior as in the anterior maxillary. However, this phenomenon can be explained by the usage of IPS Empress (in the anterior mandibular teeth of Clearfil APX group), which is a nano-hybrid composite and has better aesthetic ability than Clearfil APX. In this case, the comparison of wear performance between Clearfil APX and Filtek Supreme XTE was not always possible due to the study design. Based on our observations, we speculate that microhybrid Clearfil APX restorations showed more wear resistance in non-bearing cusps and anterior area, whereas nanocomposite Filtek Supreme XTE restorations showed more wear resistance in bearing cusps.

A possible explanation for this phenomenon might be related to the complex interplay between filler size and surface roughness of the composites on the one hand, and loading conditions on the other hand. On bearing cusps, nanocomposites showed significantly increased wear resistance as compared to microhybrid composites. This observation is in line with previous *in vitro* studies, which suggested that nanocomposites exhibit superior wear resistance when compared to microhybrid composites [14,15]. This phenomenon might be related to the reduced filler size and surface roughness of nanocomposites, since rough materials typically display poor wear performance [25–27]. On the bearing cusps, high mechanical forces (attrition) may be strong enough to de-bond large filler particles from the matrix of microhybrid composites, resulting in a rougher surface compared to nanocomposites containing smaller (nanoscale) fillers [16]. Consequently, these microhybrid composites are less wear-resistant under the challenging clinical conditions associated

Table 5 – Multilevel logistic regression analysis on the effect of material, jaw position and bearing condition on the odds ratio (OR) of having a 'large amount of wear' in premolar teeth (N = 747).

Premolar teeth	OR	p	95% Confidence interval
Intercept	0.99	0.990	[0.42...2.37]
Filtek Supreme XTE *vs.* Clearfil APX, on bearing	0.42	0.139	[0.13...1.41]
Maxillary *vs.* mandibular	1.71	0.002	[1.21...2.43]
Non-bearing *vs.* bearing, with Clearfil APX	0.18	<0.001	[0.11...0.30]
Interaction: additional effect Filtek Supreme XTE on non-bearing	3.19	0.001	[1.57...6.54]

Table 6 – Multilevel logistic regression analysis on the effect of material, jaw position and bearing condition on the Odds ratio (OR) of having a 'large amount of wear' in molar teeth (N = 1376).

Molar teeth	OR	p	95% Confidence interval
Intercept	1.53	0.225	[0.74...3.15]
Filtek Supreme XTE *vs.* Clearfil APX, on bearing	0.50	0.152	[0.18...1.38]
Maxillary *vs.* mandibular	1.28	0.048	[1.00...1.64]
Non-bearing *vs.* bearing, with Clearfil APX	0.14	<0.001	[0.10...0.20]
Interaction: additional effect Filtek Supreme XTE on non-bearing	2.73	<0.001	[1.66...4.51]

with this high-risk group of patients suffering from severe tooth wear.

In the non-bearing cusps or anterior area, the abrasion force is typically low. For microhybrid composites, only small fillers are removed from the surface layer due to limited bonding to the matrix, but larger filler particles will remain embedded in the matrix. This effect results in superior wear resistance compared to nanocomposites, since composites comprising larger filler particles with a stronger bonding to the matrix reduce wear induced by mild bearing condition (*e.g.* caused by toothbrushes) due to their smoother surface [16].

In this clinical study, we studied severe tooth wear for two types of (direct) composite materials. We can conclude that the type of teeth and bearing condition also affect the final wear behavior. However, tooth wear is a multifactorial process, which may lead to various grades of wear of dental hard tissues [28]. After treatment of direct composite restorations, there are still many clinical factors from patients which can affect the wear behavior, such as lifestyle factors, parafunctional habits, and bruxism. Therefore, it is hypothesized that these patient-related factors strongly influence the severity or risk-level on tooth wear as well [29], which will be studied in our future work.

5. Conclusion

This study has shown that in a period of 5 years, significant wear was observed in severe tooth wear patients treated with direct composite restorations. Restorations containing nanoscale glass fillers induced less wear when positioned in bearing cusps, whereas composite restorations reinforced with microscale glass fillers showed less wear on the non-bearing cusps and anterior maxillary area.

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