

# Impact of restorative treatment of tooth wear upon masticatory performance

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## ABSTRACT

**Objective:** The restorative treatment of generalized tooth wear involves an increase in vertical dimension of occlusion and a comprehensive alteration of occlusal morphology. The aim of this study was to assess the impact of a direct adhesive restorative treatment on masticatory performance parameters.

**Materials and methods:** A sample of 23 fully dentate adult generalized tooth wear patients (17 male, 6 female, age  $41.7 \pm 8.3$  years) undergoing direct composite restorative treatment was selected. Before and one month after restorative treatment with resin bonded composite restorations, masticatory performance was evaluated using 1) a comminution test, 2) a maximum voluntary bite force recording and 3) the sum score of five items related to eating and chewing from the Oral Health Impact Profile (OHIP-49) questionnaire. Statistical analysis was performed using a paired *t*-test, and analysis per OHIP item was done by a McNemar test ( $p < 0.05$ ).

**Results:** There was no statistically significant difference in median particle size (X50) calculated before and after treatment ( $4.19 \pm 0.97$  and  $4.03 \pm 0.76$ , respectively,  $p = 0.327$ ). Maximum voluntary bite force decreased significantly after treatment (baseline  $389 \pm 90$  N, one month recall  $323 \pm 173$  N,  $p = 0.028$ ). The sum score of the five OHIP items significantly decreased after treatment (baseline  $10.6 \pm 4.8$ , one month recall  $6.6 \pm 2.5$ ,  $p = 0.001$ ), with the item regarding unsatisfactory diet showing the largest significance ( $p = 0.029$ ).

**Conclusions:** This study indicates that the restorative treatment of generalized tooth wear using direct resin bonded composite has no significant short-term effect on masticatory performance as measured with a comminution test, although the self-reported ability to eat and chew, as measured by the sum score of all pertaining OHIP items, did significantly improve.

**Clinical significance:** On individual level, food comminution could be influenced by restorative treatment with increase of vertical dimension of occlusion, but at group level no significant effect is observed. Nevertheless, tooth wear patients do perceive improved ability to eat and chew foods, which is clinically relevant.

## 1. Introduction

Tooth wear is a common dental phenomenon with prevalence and magnitude that increases with age [1]. The development of tooth wear is related to mechanical factors (e.g., chewing or grinding), extrinsic chemical factors, (e.g., consumption of acidic foodstuffs) and intrinsic chemical factors (e.g., vomiting or reflux episodes) [2–5]. The etiology is almost always multi-factorial [6].

While tooth wear naturally occurs within stomatognathic physiology, it could sometimes progress to become severe or pathological. Recently, the terms ‘severe tooth wear’ and ‘pathological wear’ were redefined in a European consensus meeting on tooth wear [7]. Severe wear is substantial loss of tooth structure, with dentin exposure and significant loss ( $\geq 1/3$ ) of the clinical crown, whereas pathological wear is tooth wear which is atypical for a patients age, causing complaints

such as pain or discomfort, functional problems (e.g. masticatory dysfunction), or deterioration of esthetic appearance, which in case of progression may give rise to undesirable complications of increasing complexity. It has been stated that tooth wear management strategies should not be governed merely by tooth wear severity but rather by risk assessment and analysis of tooth wear pathological aspects within a particular patient (e.g. severity of wear in the context of age, progression rate, presence of complaints and possible complications due to tooth wear) [7].

Patients with pathological or severe tooth wear, either by chemical or mechanical cause, may need restorative care to compensate for the loss of tooth tissue, possibly comprising full rehabilitation at an increased vertical dimension of occlusion (VDO). Several techniques using direct or indirect composite restorations, ceramics or hybrid materials have been described to build-up worn teeth and to reconstruct

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the occlusion [8–13]. Only mid-term results for direct composites are available in the literature, and different success rates have been reported [3,8,14,15]. The technique was reported to result in a significant improvement of the Oral Health Related Quality of Life and orofacial appearance [16].

To our knowledge, no studies have assessed the influence of restoration of the worn dentition upon masticatory performance. Prior research assessing the influence of increase in VDO on masticatory muscle activity and bite force reported an increase of bite force with a vertical increase up to a specific range [17,18], which includes the range of VDO increase applied in restorative treatment of severe tooth wear. The increase in VDO through tooth wear restoration may therefore lead to an increase in bite force and in turn in an increase of masticatory performance, as bite force is considered one of the main factors related to masticatory efficiency [19]. Moreover, postcanine occlusal contact area has been significantly correlated to masticatory performance [20]. Restorative treatment of the worn dentition also inevitably changes the occlusal morphology and this may lead to change in occlusal contact area. This may be either a decrease or an increase, and may affect masticatory performance.

The aim of this study was to assess the effect of restorative treatment of generalized tooth wear using a direct adhesive minimally invasive approach, on masticatory performance. The hypothesis was that masticatory function, both objectively measured and subjectively perceived, would improve significantly after restoration.

## 2. Materials and methods

This study is a part of a larger clinical trial called the Radboud Tooth Wear Project, for which ethical approval was obtained (ABR code: NL31371.091.10). This study was carried out in accordance with the Declaration of Helsinki for research involving humans.

### 2.1. Patients

Tooth wear patients were referred by general dental practitioners to the Radboud Tooth Wear Project at the Department of Dentistry of the Radboud University Medical Center, Nijmegen. Patients who had a clear request for restorative intervention due to problems such as difficulties with chewing, discomfort or aesthetics were eligible for this study. The inclusion took place between September 2013 and June 2015 using the following criteria: 1) Patient age at least 18 years; 2) Generalized moderate to severe tooth wear (Tooth Wear Index (TWI) score  $\geq 2$ ) with treatment demand [21]; 3) Full dental arches, except for one diastema due to one missing tooth in the posterior allowed. Exclusion criteria were: 1) Limited mouth opening ( $< 3.5$  cm); 2) Temporomandibular disorders; 3) Periodontitis (Dutch Periodontal Screening Index, DPSI  $\geq 3$ ); 4) Deep carious lesions or endodontic problems; 5) Systemic or local conditions that would contra-indicate dental procedures.

### 2.2. Study protocol

At baseline, intraoral 3D-scans of the dentition were made, age, gender, TWI-scores, number of occlusal units and maximum voluntary bite force were registered for each patient, and masticatory performance was measured using a comminution test with artificial test food. Self-reported masticatory function was documented using the Oral Health Impact Profile Questionnaire (OHIP-49). Thereafter, full dental arch restorative treatment of the worn dentition of each patient was performed. At a recall appointment one month after completion of the treatment, intraoral 3D-scans of the restored dentitions were made, maximum voluntary bite force, masticatory performance and self-reported masticatory function were documented again for each patient.

The measurements of the main outcome measures were done by one trained examiner (BS), except for the measurements of masticatory

performance and bite force that were collected by two examiners (BS and BL).

### 2.3. Restorative treatment of tooth wear

After written informed consent, patients were restoratively treated including a full rehabilitation of all teeth in an increased VDO using direct composite restorations.

The following composite materials were used: Clearfil AP-X (Kuraray, Osaka, Japan) and IPS Empress Direct (Ivoclar Vivadent, Schaan, Liechtenstein). Clearfil AP-X was used in the molar and premolar areas, and at the palatal side of the anterior teeth. IPS Empress Direct was applied as veneering material at the buccal surfaces of the upper and lower anterior teeth, because of the aesthetic features of this material. For all restorations a three step etch-and-rinse adhesive system Clearfil SA Primer and Photobond (Kuraray) was used.

The restorative treatment protocol was to provide all teeth with free-hand composite build-up restorations using the DSO-technique ('Direct Shaping by Occlusion') [2,12]. A detailed description of the protocol has been published previously by Opdam et al. [12]. In this protocol, first the new vertical dimension of occlusion (VDO) was determined, based on the anticipated reconstruction of the anatomical form of the teeth, carefully considering the necessary interocclusal space posteriorly and anteriorly. To be able to convert the desired VDO to the intra-oral situation, two polyvinyl silicone bite stops (Star VPS, Danville Materials, USA) were made at both sides in the premolar area on mounted casts in increased VDO. Reconstructions were generally made in centric relation (CR), but in case of end-to-end anterior relation maximal occlusion (MO) was preferable. The scheme for restoring teeth in increased VDO started with the lower anterior teeth followed by the upper anterior teeth, using the bite stops as occlusal supports in the premolar region. The next step in the restoration scheme was to restore the first premolars in the upper jaw. A proper occlusal anatomical form was created without the use of a mould or matrix. Finally, the remaining posterior teeth were built up accordingly using the DSO-technique. At the end of the restorative treatment, a fully supported occlusal contact, including canine-guidance was obtained.

The treatment required between three and five sessions (lasting 3 h each) with an interval of one or two weeks in between sessions.

The restorative treatments were performed by six dentists, where each dentist treated at least two patients. These dentists were all trained in performing the same tooth wear treatment protocol as described above. Also throughout the course of the study, meetings were organized in order to keep focus upon the same protocol across all operators.

### 2.4. Measurement methods

#### 2.4.1. TWI-score

The Tooth Wear Index (TWI) [21] was used in order to quantify tooth wear severity. TWI scores can vary between 0 (no loss of enamel surface characteristics) and 4 (complete enamel loss, pulp exposure, or secondary dentin exposure). The mean TWI score of all postcanine teeth per patient was calculated. In a previous study involving TWI measurements in a larger sample of our tooth wear patients, the intraobserver reliability of TWI was assessed with a weighted Cohen's kappa of 0.6 [22].

#### 2.4.2. Occlusal units

The number of occluding posterior teeth was registered during intra-oral clinical inspection in order to determine the number of occlusal units per patient. An occluding molar pair was counted as two occlusal units, whereas an occluding bicuspid was counted as one occlusal unit.

#### 2.4.3. VDO increase

In order to determine the increase in VDO after treatment, the intra-oral 3D scans made before and after treatment, were analyzed using Meshlab (<http://meshlab.sourceforge.net/>). The increase of VDO was measured at the location of the first molars by analyzing the intra-oral 3D-scans of the dentition in maximum occlusion of before and after treatment. On both scans, the distance between the lowest point on the buccal sulcus of the upper and lower first molars was measured. The difference between the distances measured before and after treatment was regarded as the applied increase in VDO.

#### 2.4.4. Maximum voluntary bite force measurement

Maximum voluntary bite force was measured using a bite force transducer [23]. Both sides of the transducer tips were covered with a 6.5 mm thick rubber layer in order to protect teeth. The measuring bite fork was 18 mm thick, and it was covered with a disposable plastic protective shield when used in the mouth. The bite force measuring device was calibrated with loads varying from 0 to 1050 N by means of compression test machine at our department.

Bite force was measured at two locations: between the first molars on the right and between the first molars on the left side [22]. Patients were encouraged to bite on the transducer as hard as possible for a few seconds. The measurements on each side were performed three times in a row. The mean bite force of all six measurements was used for statistical analysis.

#### 2.4.5. Masticatory performance

The masticatory performance of all patients was determined by a masticatory performance test consisting of comminution of artificial test food, accordingly to the protocol of Sterenborg et al. [22]. The test food was made of a dental impression material, Optosil Comfort (Bayer Dental, Leverkusen, Germany) and the participants chewed on a portion of 17 cubes with an edge size of 5.6 mm (3 cm<sup>3</sup>). The number of chewing cycles was fixed and the examiner counted out loud the number of chewing cycles, 20 in total. Chewed particles were collected in a labeled coffee filter, which were made anonymous by allocation of a number. All patients rinsed their mouth with approximately 100 ml water to collect remaining particles. The air-dried samples were disinfected with absolute alcohol on the same filter. For further analysis, the particles were detached from the filter paper with a powder brush and were dried in an oven for 1 h at 80 °C. The sample was then separated using a series of 12 sieves, with mesh sizes 5.6 mm, 5.0 mm, 4.5 mm, 4 mm, 3.15 mm, 2.8 mm, 2 mm, 1.6 mm, 1.4 mm, 1 mm, 0.71 mm, 0.5 mm and a bottom plate stacked on a mechanical shaker and vibrated for 5 min. Once the particles were separated, the content of each sieve was weighed to the nearest 0.001 g. Every patient performed the test three times, with an interval of 5 min between the tests. Based on each test outcome, the median particle size (X50) was calculated. The average X50 of three tests per patient was used for statistical analysis.

The median particle size (X50) is the size of a theoretical sieve through which 50% of the weight can pass [24]. The masticatory performance is defined as the median particle size related to a fixed number of chewing cycles [25]. A small median particle size after a fixed number of chewing cycles indicates that the food has been well fragmented, and therefore, the masticatory performance is considered high [26].

In a previous study, we determined the reliability of X50 in a larger sample of tooth wear patients. The reliability of the mean X50 score, as calculated by the Pearson correlation coefficient, was high (0.966) [22].

#### 2.4.6. Self-reported masticatory function

In order to evaluate self-reported masticatory function, five items of the Dutch OHIP-49 questionnaire were used [27]. These items measure respectively the perceived difficulties in chewing, discomfort to eat specific food items, avoidance of specific food items, unsatisfactory diet

**Table 1**

OHIP items related to eating and chewing that were assessed in the study, including their item numbers out of the original OHIP-49 questionnaire.

OHIP items related to eating and chewing
Have you had difficulty chewing any foods because of problems with your teeth, mouth or dentures?
Have you found it uncomfortable to eat any foods because of problems with your teeth, mouth or dentures?
Have you had to avoid eating some foods because of problems with your teeth, mouth or dentures?
Has your diet been unsatisfactory because of problems with your teeth, mouth or dentures?
Have you had to interrupt meals because of problems with your teeth, mouth or dentures?

and meal interruptions (Table 1). Patients scored each item on a five-point Likert scale (0-never, 1-hardly ever, 2-occasionally, 3-fairly often, 4-very often).

#### 2.5. Statistical analysis

The median particle size (X50), bite force and OHIP scores were calculated at baseline and one month after completion of restorative treatment. Possible differences in median particle (X50) and bite force before and one month after treatment were tested using a paired *t*-test. Possible difference in sum score of all five OHIP items related to eating foods and mastication was also tested using a paired *t*-test. Possible differences in OHIP scores per each of the five separate OHIP items were tested with McNemar test considering the ordinal type of scores per item. For this purpose and to avoid underpowered estimates, scores 2–4 (occasionally, fairly often and very often) were merged into one and the same ordinal score 2, because scores 3 and 4 were not reported by patients after treatment.

For statistical analyses, software SPSS v. 22.0 and a significance threshold of 0.05 were applied.

### 3. Results

The total number of patients that consented for participation and completed the study was 23 (17 male and 6 female; age  $41.7 \pm 8.3$  years) with a mean postcanine TWI-score of  $2.2 \pm 0.5$ . The average number of occlusal units per patient was  $11.6 \pm 0.9$  (Table 2). The VDO increase after treatment was  $2.0 \pm 0.99$  mm.

At the recall one month after treatment the median particle size X50 did not change significantly compared to baseline ( $p = 0.327$ ) (Fig. 1, Table 3). Bite force decreased significantly from 388.52 N to 323.16 N after treatment ( $p = 0.028$ ) (Fig. 2, Table 3). The sum score of the five OHIP-items related to eating and chewing decreased significantly ( $p < 0.001$ ) (Table 3) with average 4 points (i.e., 0.8 points on the Likert scale per item). The McNemar analysis per OHIP item showed improvement for all five outcomes. For the item related to unsatisfactory diet this effect was statistically significant ( $p = 0.029$ ), the other *p*-values ranged between 0.053 and 0.072.

### 4. Discussion

The aim of this study was to assess the effect upon masticatory

**Table 2**

Descriptive statistics at baseline ( $n = 23$ ).

	Min	Max	Mean	Std. Deviation
Age (y)	30.4	59.4	41.7	8.42
TWI average postcanine	1.3	3.3	2.2	0.51
Occlusal units	9.0	12.0	11.6	0.90

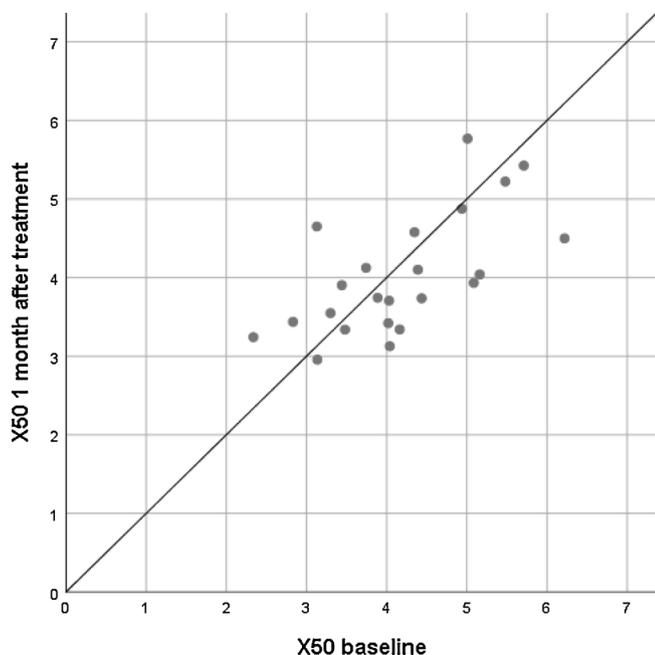


Fig. 1. Scatter plot presenting individual X50 value at the one month recall plotted against X50 values at baseline. For reference an Y = X line is shown.

performance of restorative treatment of generalized tooth wear using an adhesive direct minimally invasive approach. To that end a comminution test was used, as well as self-report items of the OHIP questionnaire, and additionally, the applied increase of VDO and maximum voluntary bite force was documented. The hypothesis that restorative treatment of tooth wear would improve masticatory performance was partially rejected; the comminution test showed no difference after treatment, although perceived masticatory function, as measured by the sum score of all pertaining OHIP items, did significantly improve.

No significant difference in the degree of breakdown of food was observed one month after completion of restorative treatment compared to baseline. Obviously that could be due to a lack of power. The 95% confidence interval for the change in X50 is [-0.48...0.17] (Table 3). This implies that it is for 95% certain that the change of X50 is in this interval. That excludes a large effect on X50, but leaves room for a modest change in X50.

Our finding of a decrease in bite force after an increase in VDO in the range performed in our study is in not line with previous experimental findings [17,18]. The present result could be related to awareness of patients regarding the recent build-up restorations in their dentition and consequently a protective behavior, including exerting a lesser maximum voluntary bite force. The decrease in maximum bite force was not accompanied by a decrease in masticatory performance, as might be expected from previous observation [19]. It may be speculated that several, opposing, factors were acting upon the masticatory performance. For instance, an increase in occlusal contact area [20] could have occurred after restorative treatment compared to baseline. Especially in patients with attrition due to mechanical factors such as bruxism, it is plausible that the worn occluding tooth surfaces

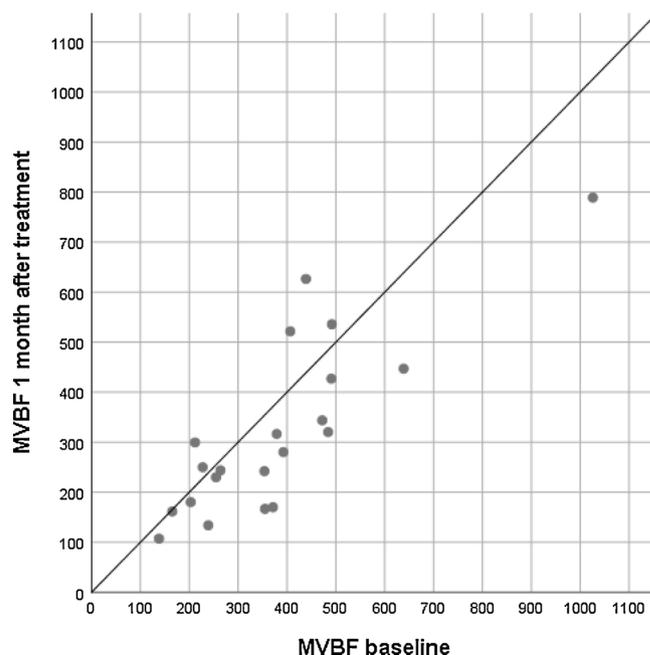


Fig. 2. Scatter plot presenting individual maximum voluntary bite force (MVFB) at the one month recall plotted against baseline MVFB values. For reference an Y = X line is shown.

are transformed to larger areas of occluding surfaces created through well-fitting cusps and fossae, and this may have had a positive effect on masticatory performance, balancing out the negative effect of the bite force reduction. In our study, we did not measure occlusal contact area, nor did we control for variation in other influencing factors, but measured the overall effect of restorative treatment of the worn dentition upon the comminution of food.

Although the objective comminution test failed to show significant differences from pre- to post treatment, the self-reported ability to eat and chew improved significantly according to the OHIP questionnaire. Overall, after treatment, average scores of 0.2–0.8 were registered on each of the analyzed OHIP items, indicating that after restoration of the worn dentition patients experienced masticatory problems hardly ever to never (resp. Likert scores 0 and 1). The difference in outcomes regarding self-assessed improvement in mastication and unchanged objective masticatory performance is in line with previous findings of little to no correlation between the changes in objective and subjective masticatory function [28].

This study indicates that restorative approach toward tooth wear does not affect comminution of food, but it does improve mastication perceived by patients, which is statistically significant and clinically relevant. Patients perceived eating and chewing as improved, possibly due to satisfaction with treatment, esthetical dental and facial appearance and improvement in oral health-related quality of life that we previously observed after restorative treatment of tooth wear [16,29]. This perceived improvement could also have been related to a decrease in sensitivity or pain of the worn teeth after restorative treatment.

To our knowledge, there are no previously published studies that

Table 3

Mean values for the masticatory efficiency (X50), bite force (Newton) and self-reported masticatory function using the sum score of the five specific OHIP items at baseline and at recall one month after treatment, and result of statistical testing of the differences.

Outcome variable	Baseline Mean ± SD	Recall 1 month Mean ± SD	p-value	Mean difference [95% CI]
X50	4.19 ± 0.97	4.03 ± 0.76	0.327	-0.16 [-0.48...0.17]
Bite force [N]	389 ± 90	323 ± 173	<b>0.028*</b>	-58 [-108...-7]
OHIP sum score	10.6 ± 4.8	6.6 ± 2.5	<b>0.001*</b>	-4 [-6.1...-1.9]

\* p-values < 0.05 are significant.

explore the effect of restoration of the worn dentition upon masticatory performance in tooth wear patients. An experimental increase of VDO up to 6 mm, a distance which includes the range of VDO increase performed in our study, reported no significant change in masticatory efficiency [30]. Although that study used an anatomically shaped removable splint in healthy subjects, in comparison to our study using adhesive restorations in patients, the findings are similar. Furthermore, in another recent study we found that the degree of tooth wear is not associated with the ability to comminute food in a group of tooth wear patients [22]. This suggests that neither tooth wear nor its restorative treatment have significant influence on the ability to break down food.

In this study, a comminution Optosil test was used in order to document masticatory performance. This type of testing is widely used in studies on mastication with dentate subjects [19]. Another approach to examine objectively masticatory efficiency would be to use a food mixing ability test. Theoretically, the restoration of occlusal morphology with cusps, fossae and incisal edges out of the generally flatter surfaces of non-restored worn teeth, would help to increase food bolus mixing. However, it was found that in persons with good masticatory function, such as healthy young fully dentate subjects, the discriminative capacity of a mixing ability test was inferior to that of a comminution test [31]. As the sample of participants in our study consisted of fully dentate young to middle-aged tooth wear patients in relatively good health, choosing comminution testing seems appropriate.

In our study, multiple dentists were involved into restoring the dentitions of tooth wear patients. This could have introduced some variation into the morphology of the created restorations as composite build-ups were done direct and free-hand. However, such variation is inevitable in dental practice, also within a single operating dentist, and likely much smaller than variation due to differences in individual dental morphology and occlusion between patients. In order to minimize variation due to multiple operators, dentists were repeatedly trained in performing the standardized treatment protocol. In our study, also two examiners (BS and BL) were involved in recording masticatory performance and maximal voluntary bite force. Upon performance of these measurements according to the same standardized protocol, as described in Materials and Methods, examiner bias is not likely to have occurred as outcomes are dependant mainly upon the patients performance.

All post-treatment measurements in our study were done at the one-month recall after completion of restoration of the worn dentition. This gave the opportunity for patients to initially explore and adapt to their new restorations in their natural environment. The masticatory performance test showed stable average X50 scores within tooth wear patients before and after restorative treatment. These scores are intermediate between X50 values found in previous studies in healthy fully dentate subjects and edentulous persons (average 4.1 in our sample versus respectively 3.4 and 4.8 in previous research) [31]. It is not clear whether masticatory performance changes in the long term, as patients may adapt further towards functioning into their new occlusion. Further research by performing measurements in the longer term (e.g., 6 or 12 months) is encouraged.

In conclusion, this study indicates that the restorative treatment of generalized tooth wear using direct resin bonded composite has no short-term significant effect on the masticatory performance measured with a comminution test, although self-reported ability to eat and chew, as measured by the sum score of all pertaining OHIP items, improved significantly.

#### Author declaration

We wish to confirm that there are no known conflicts of interest associated with this publication and there has been no significant financial support for this work that could have influenced its outcome.

We confirm that the manuscript has been read and approved by all

named authors and that there are no other persons who satisfied the criteria for authorship but are not listed. We further confirm that the order of authors listed in the manuscript has been approved by all of us.

We confirm that we have given due consideration to the protection of intellectual property associated with this work and that there are no impediments to publication, including the timing of publication, with respect to intellectual property. In so doing we confirm that we have followed the regulations of our institutions concerning intellectual property.

We further confirm that any aspect of the work covered in this manuscript that has involved human patients has been conducted with the ethical approval of all relevant bodies and that such approvals are acknowledged within the manuscript.

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