Treatment of Severe Tooth Wear

A minimally invasive approach

The printing of this thesis is financially supported by KNMT

Printed by Gildeprint Enschede

Cover design and layout by ©how Creative

Published by Jorien Hamburger

ISBN 978-90-9028731-7

Treatment of Severe Tooth Wear

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Proefschrift

ter verkrijging van de graad van doctor
aan de Radboud Universiteit Nijmegen
op gezag van de rector magnificus prof. dr. Th.L.M. Engelen,
volgens besluit van het college van decanen
in het openbaar te verdedigen op vrijdag 9 januari 2015
om 12.30 uur precies

door

Jorien Trienke Hamburger

geboren op 3 juli 1981
te Ooststellingwerf

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Chapter 1

General introduction

General Introduction

According to the Oxford English Dictionary, the definition of wear is 'to suffer gradual destruction, loss or decay from attrition or use'.[1] Wear often occurs when two surfaces interact, resulting in the loss of one surface with or without the loss of another. Tooth wear is a common phenomenon that exists in almost every mouth. In contrast to caries and periodontitis, wear is a physiological process that may be seen to characterize the aging dentition.[2] Tooth wear can be identified as a result of erosion, attrition, abrasion, and (possibly) abfraction.[3, 4]

Recently, erosion appears to be the most commonly identified cause of tooth wear. Erosion can be described as the 'chemical dissolution of tooth substance without the presence of plaque'.[5] The acids responsible for erosion are not products of the intraoral flora, but stem from dietary, occupational or intrinsic sources. Frequent contact between acids and a tooth's surface can cause dental erosion. The stomach is the source of intrinsic acid, which may enter the mouth through regurgitation or gastro-oesophageal reflux where it may damage the dentition in patients of all ages. Erosion is often seen to be most severe on palatal tooth surfaces, and active erosion may cause exposed dentinal tubules to remain open, resulting in tooth sensitivity.[5-7]

Attrition results from tooth-to-tooth contact without the presence of food and is typically characterized by wear facets that are matched by corresponding facets on teeth in the opposing arch. The presence of shiny facets, is a good indicator for active attrition.[5, 7] There are two parafunctional activities that are associated with attrition: tooth grinding and tooth clenching. Tooth grinding is the process where teeth rub together repeatedly in a predefined way and with great force, and often damages large amounts of incisal and occlusal tooth tissue. Tooth clenching is when the teeth are pressed in occlusion without, or with minimal movement, applying great forces on small areas. Tooth substance loss is less likely to be severe in tooth clenching, although palatal imprints of lower incisors have been linked with clenching.[8]

Abrasion occurs when there is friction between a tooth and an exogenous agent. Although a multitude of foreign bodies (including brushing with toothpaste) can cause abrasion, the most common and often overlooked factor is food.[5] Wear of teeth by friction from the food bolus on occlusal surfaces, incisal surfaces, or both, is known as 'masticatory abrasion" or "demastication". Abrasion can also occur as a result of overzealous tooth brushing (especially in cervical areas).[5] The influence of occlusal forces has also been linked to cervical tooth wear (see below).

Abfraction has been defined as the microstructural loss of cervical tooth substance in areas where there is consistent concentrations of stress.[9, 10] Abfraction most commonly occurs at the cement enamel junction area of teeth, where flexure sometimes leads to the breakage of the extremely thin layer of enamels rods, as well as micro fractures in the cement and dentin. Lesions appear as a result of occlusal loading forces forming a crescent along the cervical line, where the brittle and fragile enamel layer exists.[5] It seems that also the presence of acids (erosion) is an important factor in the formation of cervical lesions.[8] There is no conclusive evidence linking cervical tooth wear to abrasion or occlusal forces, therefore, the term NCCL (non-carious-cervical-lesion) is used when referring to cervical tooth wear defects, leaving all etiological options open.

Emerging data suggest that tooth wear is common in all age groups[11] also severe levels of wear is being observed in different age groups.[12] Unacceptable levels of wear are categorized as pathological tooth wear and there is some evidence that prevalence of dental erosion is growing. What can be assumed from recent studies is that physiological wear is most likely age-related, but severe tooth wear may occur at any age.[7, 11]

While anthropologists accept attrition, abrasion, and erosion as distinctly separate mechanisms, dentists are moving away from these static concepts, and acknowledging dynamic change of the dentition especially in relation to progression of life.[7] It is difficult to determine the underlying cause of wear by just appearance because often the cause of wear is multifactorial. In the United Kingdom, although they acknowledge the importance of erosion, abrasion, and attrition, the term tooth wear is most commonly used to describe the result of all processes.[11] Nevertheless, there are circumstances in which one cause, most commonly erosion, is considered more dominant than the others.[11]

Little is known about patients who suffer from severe tooth wear. Up to this point, there has been too little research into the causes or treatment of severe tooth wear. General practitioners encounter only a handful of these patients each year, and thus it is difficult to gain experience in treating these individuals. Moreover, most GDP's refer these patients to specially trained dentists in private clinics or at universities.

Dentists ideally want to intervene early in the process of tooth wear in order to prevent more tooth substance loss and loss of vertical dimension. Restorative treatment is not always the best option for a number of reasons. The influence of time is not clear and a patient may experience periods of progressive wear intermittent with periods of relative stability. Moreover, restorative treatment has a limited longevity. It may be assumed that a treatment, especially in a young patient, will have to be repeated, probably more than once, in the lifetime of the patient. Unless a dentist has a clear understanding of the cause and progression of the wear process in an individual patient, it is not possible to give a specific and effective advice to prevent wear progression. In these cases, proper informed consent must be preceded by an explanation of these uncertainties. This may also mean a patient will need to be monitored before receiving restorative treatment.

Treatment

There are a number of different questions that need to be addressed before a patient with severe tooth wear is treated restoratively. Firstly, a decision must be made regarding what material to use, whether it is strong enough, and whether the patient will find it esthetically pleasing. Once a material has been chosen, a dentist must decide whether to increase the occlusal vertical dimension in a patient's mouth to gain enough space for the restoration, and whether this increase needs to be tested before the definitive treatment starts.

In 2012, Mehta et al. wrote four overview papers which thoroughly explicate different techniques and materials in the treatment of severe tooth wear.[13-16] Treatment options can be divided into categories; treatment with removable prostheses, indirect treatment methods, direct treatment methods and treatment according to the concept of Dahl. These options will be describe in full later in the thesis, but for the sake of clarity a brief description of each is provided below.

- Removable partial dentures are a traditional treatment and sometime a temporary treatment option. Patients do not always prefer this treatment option because it is not long-term and is not fixed in the mouth.[17-24]
- Indirect restoration is used to describe any fixed treatment using materials manufactured outside the mouth such as crowns, bridges, and porcelain veneers. Most case studies have shown that these treatments are considered to be of the highest quality.[25-27] Nevertheless, the high cost and invasive nature of the treatment, coupled with the high risk of porcelain chipping and wear of the antagonist are some of its disadvantages.[8, 25]
- Direct (composite) restorations are used to build up the worn dentition directly in situ. From case reports it seems that different treatment protocols and several types of composite can be successful and may show high patient satisfaction.[28-31]
- The Dahl concept is a treatment based on intrusion of the lower anterior teeth and eruption of premolars and molars. This occurs usually after six to nine months and can be effectuated with the use of composite resin[32] or with a removable device providing partial bite increase.

Orthodontics can be helpful in the treatment of patients with severe tooth wear, for example to create an increase in occlusal vertical dimension.[33, 34]

These classifications of treatments highlight the fact that there is rarely a straightforward scenario, and often when treating severe tooth wear there is a combination of various options and processes.

Of these possible treatments, we aim to focus on the minimal invasive, adhesive treatment options in this thesis. Reasons for this choice are the low biological price because no preparations have to be made and the low costs for the patient. Restorations are easily repairable after failure as well.

Objectives

The objective of this thesis is to explore the different options for treatment of patients with severe tooth wear. In the absence of high quality clinical studies, this is an exploration of the possibilities of different treatment modalities and strategies.

Specific aims of this thesis are:

- To explore the differences in management strategies between specialized dentists in the UK, Germany, and the Netherlands when treating patients with severe tooth wear. (Chapter 2.)
- To investigate the influence of layer thickness of samples of different types of composite and porcelain that are directly bonded to a tooth surface on a fracture strength of a tooth restorative complex. (Chapter 3 and 4.)
- To evaluate the performance of direct composite restorations that are placed in patients with severe tooth wear and a decreased occlusal vertical dimension. (Chapter 5.)

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Chapter 2

An explorative survey of restorative management approaches of severe tooth wear

Under review

Abstract

Purpose

Aim of this study was to explore differences in management strategies in the treatment of patients with severe tooth wear, to evaluate whether it could be explained by differences in treatment goals and / or wear aetiology.

Materials and methods

A questionnaire was sent to specialized dentists in the UK, Germany and the Netherlands. The questionnaire was distributed digitally to 117 dentists, and contained questions about indication, examinations used, treatment approaches and materials used, etc..

Results

Total response rate was 54,7%. Dentists were grouped according to their main choice of direct and indirect treatment options. Overall, 26 out of 57 dentists who completed the questionnaire, reported using indirect techniques, whereas 32 reported using mainly indirect techniques. Attrition, abrasion and a combination of factors were seen by direct and indirect treating dentists, in similar frequencies. Indirect treating dentists tended to replace restorations more often. Indirect treating dentists tested increase in occlusal vertical dimension more often than direct treating dentists. None of the listed problems associated with the treatment were reported to occur regularly or often. Bulk fracture was reported to occur both in the first 12 months and later.

Conclusion

A wide range of treatment choices for severe tooth wear was found among specialized dentists. Division into direct and indirect treating dentists appeared to be related to the country of practice. This variation could not be explained by differences in treatment goals. Problems with techniques are reported to occur only rarely, for either approach.

Introduction

Tooth wear is a common clinical finding in patients of all ages.[1] There is some evidence that the prevalence of this condition is increasing.[2, 3] The aetiology of tooth wear may be found in erosion, attrition or abrasion or a combination of these processes.[4, 5] Severe tooth wear can result in significant damage to teeth, leading to teeth with shortened crowns, a reduction of the vertical dimension of occlusion (VDO) or to compensatory vertical growth of the alveolar bone.[6] As a consequence, restorative treatment of severe tooth wear is a challenge for the dentist.

Erosion and bruxism are the aetiological factors most often encountered in severe tooth wear, and it is likely that restorations placed in worn teeth are subject to the same phenomena. The available evidence in respect of the longevity of restorations originates from studies in which severe tooth wear was usually an exclusion criterion. The results of these studies cannot, therefore, be extrapolated to restorations in severe wear cases. The available scientific publications on restorative treatment in severe wear patients is very limited: one randomized clinical trial (RCT)[6], four clinical studies[7-10] and 24 case reports[11-34]. The treatment approaches described in these reports can be divided into four categories: treatment with removable prostheses, indirect treatment methods, direct treatment methods, and treatment according to the Dahl concept.[35]

Treating severe tooth wear by means of a removable partial denture is a traditional treatment option, which has been described in several case reports.[14, 17, 20, 22, 24, 26, 28, 34] In 1986 a treatment of a patient with an overlay denture was reported, which was successful after two years in clinical service.[34] The only problem mentioned was the wear of the denture. To resolve this problem, occlusal metal surfaces were fitted to the denture. A 1987 report describes a case treated with an overlay denture with a VDO increase of 2 mm.[22] This technique has the advantages of relatively low cost, 20 low biological price and satisfactory results.[28] Removable overlay dentures are, however, usually presented as a temporary solution.

Only case reports have been published on full fixed prosthetic treatment options such as full reconstruction with glass-ceramic, gold and porcelain fused to metal (PM) crowns.[16, 21, 32] Most studies do not report on long term results. One paper described a 10-year follow-up of a single case and demonstrated that a moderate increase in VDO is well tolerated and that this increase may be stable over a number of years.[16] Most papers conclude that patients are very satisfied with the treatment outcome, but meticulous treatment planning is considered very important. Disadvantages of this approach to treatment are the high cost, the invasive nature of the treatment, and the high risk of porcelain (chipping) failures.[23]

Recently, more studies on using direct techniques in restoring severe tooth wear have been reported on. The only available RCT in this field compared the performance of direct and indirect composite restorations in 16 patients[6], and a very high failure rate after three years was reported: 50%, including 22% fractures and 28% lost restorations. No differences were found between the direct and indirect techniques. In contrast, two case series on the use of direct composite restorations showed low failure rates of 4% after 3 years[30] or 1,9% annual failure rate[8]. Restorations failed mainly due to fracture and patient satisfaction in both studies was high. Although speculative, the difference in results between these studies and the study by Bartlett et al.[6] may be explained by the type of composite used, microfilled in the RCT and hybrid in the case series, but also differences in technique and patient profiles may have played a role. Case reports have been published[11, 12, 29, 31, 33] in which the dominant wear aetiology was erosion, with overall good results and high patient satisfaction[11, 12, 29, 31, 33].

The Dahl concept, where an increase in VDO is created by restorations or an appliance placed only in the anterior region, is a treatment aimed at localized wear only. In a clinical study using indirect composite restorations the overall failure rate after 2 years was 13%.[7] In a study where direct composite restorations were used, a success rate of 89.4% was observed after 30 months. It was concluded that hybrid composites performed better than microfilled composites.[9] In a recent study, after 2.5

years, only 6% of the hybrid composite restorations had failed due to bulk fracture.[35]

In summary, it appears that direct composite restorations may be used successfully in cases of severe tooth wear, but evidence is limited and contradictory. Hybrid composites may have a better performance than microfilled composites, and both the direct and indirect approach seem to work. No evidence could be found to support the use of ceramic, gold or PFM restorations for treating patients with severe tooth wear. Although it can be expected that severe erosion cases and severe bruxism cases present different treatment prognoses for the restorations, there is no evidence supporting this theory.

In the absence of sufficient scientific evidence, clinicians have to rely on their own common sense and experience for treatment decisions in severe wear cases. We hypothesized that this may be associated with considerable variation in treatment choice, even among specialized dentists. It was the aim of our study to explore this variation and to evaluate whether it could be explained by difference in treatment goals and / or wear aetiology.

Materials and methods

A questionnaire was developed through a collaboration involving the Radboud University Nijmegen Medical Centre, Munich University and King's College London Dental Institute. The completed questionnaire was sent to 117 practitioners in The Netherlands, Germany and the UK known to be accepting referrals for the management of patients with severe tooth wear. Specialized dentists were approached, since the prevalence of severe tooth wear and the complicated nature of the restoration procedures implies that general practitioners treat only few of these patients, resulting in limited expertise. Severe tooth wear cases are therefore frequently referred to specialized dentists. In the UK all those invited to participate in the study (n= 52) were recognised by the General Dental Council as specialists in prosthodontics and restorative dentistry.

In Germany the practitioners approached (n=36) all worked in university centres in the field of prosthodontics and restorative dentistry. And in the Netherlands all the practitioners identified for the purpose of the study (n= 30) worked in centres for Special Dental Care.

The questionnaire was distributed digitally together with a covering letter explaining the purpose and importance of the study. Follow-up reminders were sent to all 117 practitioners after four to six weeks. The entire questionnaire can be viewed in an online appendix to this paper.

The first part of the questionnaire consisted of questions regarding background information of the respondent, including the nature and extent of their clinical practice, the amount of time spent on treating patients with severe tooth wear, and the type of patients referred for treatment. The second part included questions about the pre-treatment phase. Questions explored treatment principles, the reason patients sought treatment, type / aetiology of the observed wear, as well as information gathered prior to commencing treatment. In the third part of the questionnaire the restorative procedures were addressed, starting with treatment goals, e.g., restoration of anatomical form or posterior occlusal support, achieving canine or group guidance, followed by the frequency of using specific treatment techniques. Removal of restorations of good quality in combination with extensive restorative therapy was addressed. Furthermore, the dentists were asked about the use of a splint to test the increase in VDO.

The questionnaire continued with details about either direct or indirect treatment techniques. Materials and methods used, and differences in choices between anterior, premolar and molar teeth were evaluated. Information about failures was gathered: including type of failure and timing of failures (early, that is within first 12 months, or later). The final part of the questionnaire contained questions about the post treatment phase: the prescription of a night guard, and if so, which type, and information about the recall regime.

For the analysis, respondents were divided into two groups according to their treatment preference: either direct or indirect (exclusively or predominantly). Those dentists who only answered questions on one of the two techniques, were assumed to exclusively use that technique. For dentists who answered questions on both techniques, the answers to the question assessing frequency of use of the different techniques, indicating a predominant choice for either direct or indirect techniques, were used for group assignment. Differences in responses between groups were analyzed using Chi-square tests.

Results

The questionnaire was sent to 117 dentists of whom 64 responded – in the Netherlands 21 (out of 35 sent), from the UK 24 (52), and from Germany 19 (30), with a a total response rate of 54,7% - 60,0% in the Netherlands, 46,15% in the UK and 63,3% in Germany. Of the 64 dentists that responded, seven did not complete the questionnaire (6 from Germany, 1 from the Netherlands) resulting in a total of 57 “active respondents”. Gender distribution of respondents was 77% male and 23% female. Twenty dentists reported working also in a general dental practice for an average of 17.7 hours per week. Nineteen dentists reported working in a specialized practice on an average of 11.6 hours per week and most of the respondents (47 dentists) reported working in a hospital or university on an average weekly basis of 33.8 hours.

Seventeen dentists could be categorized by exclusive use of one technique, six direct and 11 indirect approaches only. After considering the technique frequency question, the other 40 dentists were categorized for predominant technique used: 25 direct and 15 indirect. The dentists’ preference in the three countries was quite different: Germany all indirect (13), UK 10 indirect and 14 direct, and the Netherlands 3 indirect and 17 direct.

The most common indication for treating severe tooth wear was aesthetic function (66% of the dentists report this always or mostly), irrespective of treatment technique. Other indications: pain (18%), impaired masticatory function (19%) or symptomless concerns (patients concerned about the condition of their dentition: 47%) were reported less frequently. Most dentists (69%) rejected the thesis that the treatment of severe wear is guided by the same principles, whatever the aetiology. With respect to aetiology, the following factors were reported: a combination of factors (58%), erosion (44%), attrition (32%), abrasion (18%) and specific occupational habits (9%). Direct treating dentists reported erosion (52% vs. 35%, p=0.007) and specific occupational habits (5% vs. 0%, p=0.004) more often than indirect treating dentists. Other factors were seen by direct and indirect treating dentists in the same frequency. Direct and indirect treating dentists reported gathering similar diagnostic information (table 2.1). Some differences, however, could be observed between dentists from different countries, with dentists in Germany using supplementary radiographs and extra-oral assessments less frequently.

Table 2.1

Additional diagnostic information collected in the pre-treatment phase.
A: Response rate divided by country B: Response rate divided by treatment strategy

	A			B	
	Germany	**UK**	**The Netherlands**	**Direct**	**Indirect**
History of gastrointestinal reflux	92%	92%	85%	87%	92%
History of eating/ vomiting disorders	92%	100%	75%	84%	96%
Study casts	100%	96%	90%	90%	100%
Face bow registration	100%	79%	70%	71%	92%
Photographic records	77%	71%	80%	77%	73%
Supplementary radiographs	38%	75%	90%	81%	62%
Dietary analysis	62%	88%	80%	87%	69%
Specific extra-oral assessments	23%	38%	70%	52%	77%

Treatment goals for direct treating dentists more often included achieving canine-/anterior guidance than for indirect treating dentists (74% vs. 37%, p=0.007).

Table 2.2

Reported frequencies of using specific treatment techniques.

	Always	Mostly	Regularly	Sometimes	Never	Total
Direct technique; bonded composites	6	20	15	11	1	53
Semi-direct technique; laboratory made matrix for composites	0	1	18	21	11	51
Indirect technique; onlays palatal veneers, crowns	0	4	9	26	11	50
A combination of direct and indirect	2	8	0	7	6	23
Removable prostheses	0	3	17	25	5	50
Direct and/or indirect rest. AND removable prostheses	1	6	17	23	4	51
Orthodontic treatment prior to the restoration	1	1	14	23	11	50

The reported frequencies of using specific techniques are shown in table 2.2. Indirect treating dentists tended to replace serviceable restorations more often than indirect treating dentists (table 2.3). Roughly half of the indirect treating dentists reported replacing every type of restoration. Existing indirect restorations were left in place more often than other restoration types by direct treating dentists.

Indirect treating dentists reported testing the increase in OVD more often than direct treating dentists (p=0.001).

Indirect treating dentists mostly choose all-ceramic crowns in anterior teeth, followed by PM crowns, and ceramic facings. PM crowns and all-ceramic crowns were used most often in the premolar region, while gold or PM crowns were used in the molar region.

Table 2.3

Replacing good-quality pre-existing restorations of:

Response rate divided by treatment strategy. The percentage represents the answers ‘always’ and ‘mostly’.

	Direct	Indirect
Amalgam	27%	46%
Composite	20%	42%
Alternative tooth-colored restorations	11%	46%
Gold castings incl. bridges	7%	58%
Porcelain fused to metal, incl. bridges	7%	44%
All-ceramic restorations incl. bridges	7%	46%

A night guard was prescribed either always (37%) or in selected cases (61%) with no significant difference between the two treatment groups. A full arch rigid splint was the usual choice (74%), followed by a soft splint (24%) and most infrequently a partial splint (4%). None of the dentists reported prescribing a partial coverage soft night guard on a regular basis. Recall policy was similar for the treatment groups. Roughly 50% referred patients back to their own dentist, while the rest recalled their patients, usually every six months.

Side effects, or failures of the treatment, either direct or indirect, were seen only infrequently. None of the listed problems were reported regularly or often. Pain, getting used to the new OVD, problems with eating, talking and aesthetics were reported to occur in the first 12 months after treatment. Bulk fracture was reported to occur both in the first 12 months and later. Other problems listed (severe wear, marginal deterioration, wear of opposing teeth, proximal wear, staining and secondary caries) were reported to occur only in the long term.

Discussion

The purpose of this study was to gain insight into variation in treatment strategies for severe tooth wear as used by specialized dentists in the perspective of the different approaches proposed in the literature. From the literature review presented, it was apparent that there is a lack of evidence for the restorative treatment of severe tooth wear. The treatment options covered by clinical studies, mainly case reports or series, range from complete direct composite restorations to complete fixed indirect restorations.

The methodology of the survey suffered two principal limitations. First, not all practitioners in The Netherlands, Germany and the UK who accepted referrals for the management of patients with severe tooth wear could be identified to participate in the study -such practitioners not being listed on an accessible database, or belonging to any one national, European or international organisation. Secondly, the response to the questionnaire was disappointing. Notwithstanding these limitations, the findings presented in this unique attempt to survey the treatment planning views and behaviours of specialists and specialist treatment centre practitioners actively involved in the management of severe tooth wear are considered important, if for no other reason, to highlight the wide variation in thinking and treatment preferences both within and between the countries considered. This, in turn, highlights the need to strengthen the evidence-base on the efficacy of the alternative approaches to the management of severe tooth wear, leading to more consensus on the most effective treatment options.

The dental care systems, and also the settings in which this care is provided vary widely among the included countries. In the Netherlands, severe tooth wear restoration is reimbursed by the public health insurance. Centres for special dentistry exist all over the country where people with specific special dental problems are treated, at limited costs for the patients. Dentists working in such centres may or may not be specialized. In Germany, many tooth wear patients are referred to university clinics, to dentists who are often registered prosthodontists. In the UK, these patients are also treated by prosthodontic specialists. These differences among countries make it very difficult to make direct comparisons. On the other hand, the way dentistry is organized among countries may be a factor in the way patients are treated.

Treatment choices reported by the dentists covered the entire spectrum observed in the literature. Only about one third of the respondents exclusively used direct or indirect techniques, showing that most consider both approaches clinically relevant. On the basis of preferred method, the group was split approximately evenly. The answers regarding specific treatment details showed much more variation for indirect treating dentists than direct treating dentists. This may be explained by the fact that there are many more indirect treatment options than direct ones.

Overall, treatment indications and goals were similar across the treatment groups, so there is no clear indication for treatment choice being guided by those factors. The most common indication given for restorative treatment of patients with severe tooth wear was aesthetics. Given the severity of the condition, it is remarkable that pain and reduced chewing function were not mentioned more often. Evidently aesthetics is an important factor for patients, and may determine patients' care-seeking behaviour.

Erosion was more often cited as an observed aetiological factor by direct treating dentists. Especially for dentists in different groups but from the same country, it would be hard to envisage a true difference in wear aetiology underlying this phenomenon. Maybe direct treating dentists are more aware of the signs of dental erosion than their indirect treating counterparts. Conversely, dentists diagnosing erosion could be more likely to choose direct treatment options, because the mechanical loading of the restorations is expected to be less than in cases of bruxism. Composite restorations are known to have a lower strength than full metal crowns. On the other hand dental erosion is a recent concept that is more known among those working in the field of cariology, using composite materials much more frequently than restorative and prosthetic dentistry. The highest number of dental erosion related papers in the past 10 years appeared in the journal Caries Research.

The tendency for the practitioners preferring direct approaches to the management of severe tooth wear to seek to develop canine or anterior guidance might be explained by the difficulty of developing alternative forms of occlusal guidance when adopting a direct approach. Furthermore, adjusting, in particular, canine guidance at the time of completing, or reviewing a case of severe tooth wear, treated by means of a direct approach, is more readily achieved than the adjustment of other forms of occlusal guidance.

The distinction between direct and indirect treatments can be considered mainly in terms of minimally invasive (MI) approaches. MI dentistry is a concept that is closely linked with adhesive dentistry and composite resin restorations. For most indirect treatment options considered in this study (sound) tooth material has to be sacrificed, whereas this is not the case when direct restorations are provided. The difference in invasive approaches between the treatment groups in this study is highlighted by the response to the questions about replacing good quality restorations during the treatment. Indirect treating dentists reported replacing them much more often than direct treating dentists. Probably this stems from the belief that a stable and caries free tooth is the best basis for a crown, which is considered to be a long-term, or even a ‘permanent’ restoration.

Irrespective of country or treatment preference, respondents reported that side effects and failures occur only seldom. For a treatment that has traditionally been regarded as complex and challenging, this is surprising. On the other hand, the single randomized controlled trial on restorative treatment of severe wear showed a very high failure rate.[6] The low failure rate as reported by the clinicians may suggest that indeed no problems occurred. It also reflects the retrospective and possibly biased experience of the operator rather than the actual clinical situation. Therefore, this finding should be interpreted very cautiously. However, it seems obvious that if dentists don't experience or are not aware of problems with the treatment technique they use, they are not stimulated to change to another technique.

A long term randomised controlled trial on alternative approaches to the treatment of severe tooth wear is needed. Practically, the likelihood of such a study being undertaken seems fairly remote, considering the costs in terms of money and time. Under such circumstances specialists in different aspect of dentistry should be encouraged, through networking, to collect, share and publish clinical outcomes of their own preferred techniques, on the basis that such evidence, despite its limitations, is better than no evidence. It is hoped that treatment choices will then converge slowly towards a few effective and cost-effective solutions. Otherwise, the existing situation of widely varying treatment approaches will be perpetuated.

Conclusion

A wide variation of treatment choices for severe tooth wear was found among specialized dentists. The division into direct and indirect treating dentists appeared to be related to the country of practice. The variation could not be explained by differences in treatment goals, but may be associated with the perceived aetiology, as direct treating dentists report erosion more often. Restorative failures and complications are reported to occur only rarely, for either approach.

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Chapter 3

Effect of thickness of bonded composite resin on compressive strength

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Jounal of the Mechanical Behavior of Biomedical Materials

2014;37C:42-7

Abstract

Objective

The aim of this study was to investigate the compressive strength of composites with different physical properties bonded as a restoration to dentin in layers of varying thickness.

Methods

Four types of direct composite materials: a midway-filled (Tetric EvoCeram); a compact-filled (Clearfil AP-X); a nano-filled (Filtek Supreme); and a micro-filled material (Heliomolar), were bonded in 0.5–3.0 mm thick layers onto bovine dentin. Each material group contained 25 samples, which were loaded until fracture.

Results

The nano-filled and the compact filled material showed a significant association between layer thickness and compressive strength. The midway-filled composite was the most consistent material showing similar failure load over the complete thickness range.

Conclusion

A clear influence of layer thickness on compressive strength was found in some composite resin materials. When restorations are placed that are heavily loaded, such as in patients with severe wear due to bruxism it may be advisable to choose a material that is adequately strong in all thicknesses.

Introduction

A number of patients that suffer from severe tooth wear need restorative treatment to maintain a functioning dentition during their lifetime. In order to have sufficient space to restore the occlusal surfaces of posterior teeth and palatal surfaces of anterior teeth, the vertical dimension of occlusion often needs to be increased. This involves a new occlusion that has to be constructed by the dentist, which is a complicated treatment that can be achieved in several ways.[1-3] Severe tooth wear may be caused by erosion, bruxism or a combination of these factors.[4] Therefore, as bruxism may be present and the support of natural tooth substance to occlusal forces is absent in restorations made in increased vertical dimension, these restorations are likely to be subjected to heavy loading resulting in an increased risk of fracture and wear. From the limited number of clinical studies on treatment of tooth wear it indeed appears that fractures are the most common type of failures.[2, 3]

Therefore, a restorative material to be used in these heavily loaded restorations should have a sufficiently high strength and wear resistance. Clinical studies performed in a general practice environment, have shown that composite resin performs well in normal and large sized restorations in all kinds of patients.[1, 5-8] Apparently, current dental composites have adequate mechanical properties for use in all areas of the mouth. However concern still exists when direct composites are placed in high stress situations, especially in patients with bruxing or other parafunctional habits[9], although a recent review paper recommends these materials for severe tooth wear[10]. A clinical study found that bruxism as a patient risk factor increased the failure rates of posterior composite resin restorations.[8] In one study reporting on the use of micro-filled composites to restore tooth wear in increased vertical dimension a high failure rate was found, which may indicate that the material was not strong enough although from the paper reasons for failure are not clear.[11] Recent developments in dental composites include nano-composites with smooth surfaces and higher fracture strength than micro-filled materials, but clinical results for these materials are scarce[12, 13] and limited to case reports where the special category of patients with severe tooth wear and bruxism is concerned[14].

The minimally invasive restorative treatment of severe wear patients includes direct or indirect uplays on the occlusal surface that are commonly bonded to the tooth without previous preparation. The thickness of a restoration mainly depends on the interocclusal space, and it may vary within the restoration due to the required anatomy but also because teeth are not worn down in a flat surface and may be subject to further eruption limiting the available space. This may result in localized thin layers of resin composite in some teeth, possibly compromising the strength of the restoration. Thickness of the restoration can be influenced either by increase of vertical dimension of occlusion (VDO), or by creating space by grinding. The latter invasive option is undesirable, as these patients have already suffered inordinate loss of tooth substance.

It is assumed that the fracture strength of a bonded layer of composite depends both on physical properties of the material and its thickness. Studies on the relation between layer thickness and strength of the material are scarce. A recent study comparing direct composites, indirect composites and ceramic materials showed a clear influence of layer thickness on compressive strength of the materials and showed that direct hybrid composites produced better than indirect materials.[15]

In a recent in-vitro study ultra-thin (0.6 mm) occlusal uplay-restorations, CAD/CAM manufactured from composite and ceramic, were cemented onto teeth and subjected to loading until fracture occurred.[16] In this study too authors concluded that restorative material thickness influenced the fatigue resistance of composite and ceramic. The effect of material composition is less clear. Filler volume of a composite was shown to have an important influence on physical properties of composite resin restorations.[13, 16] Other researchers found the influence of the type of material on the mechanical properties to be significant, but low.[12]

As no data on the influence of different types of composite on compressive strength are available, the aim of this study was to investigate the compressive strength of direct composites of different composition and physical properties, applied in layers of varying thickness to dentin.

Materials and methods

For this study, four materials were chosen: a compact-filled resin composite, Clearfil AP-X (Kuraray, Osaka, Japan); a midway-filled resin composite, Tetric EvoCeram (Ivoclar Vivadent, Schaan, Lichtenstein); a nano-filled resin composite Filtek Supreme (3M, St. Paul MN, USA); and a micro-filled resin composite, Heliomolar (Ivoclar Vivadent, Schaan, Lichtenstein).

Results for APX and Tetric EvoCeram have been used previously.[15] These materials vary in physical properties as shown in table 3.1. The division of dental composites is chosen according to their morphological and mechanical characteristics.[17] Using each material, 25 disc shaped samples were made and bonded in a standardized way to bovine dentin and of a varying (between restorations) but uniform (within a restoration) layer thickness. All samples were subjected to compressive loading until failure.

Table 3.1

Specifications and properties of the materials used.

Composite	Type	Manufacturer	Filler particle size (µm)	Content (w/v)	FS (Mpa)	FM (Gpa)	E (Gpa)
Clearfil AP-X	Compact filled	Kuraray	0.2–17	86/70	204	15.3	15.3
Filtek Supreme XTE	Nano filled	3M ESPE	0.6–10	87.5/59.5	108.6	6.1	6.1
Tetric EvoCeram	Midway filled	Ivoclar-Vivadent	~550 nm	76/55	120	10	10
Heliomolar	Micro filled	Ivoclar Vivadent	<1	66.7/46	100	4.1	4.1

FS: flexural strength. FM: flexural modulus. E: E-modulus.

Specimen preparation

Bovine incisor teeth were grinded down from the buccal surface until dentin was exposed. Subsequently, these teeth were embedded with the dentin surface exposed in PMMA using a standardized mould. The dentin surface was etched with phosphoric acid for 15 s, then rinsed and gently dried. A three-step etch and rinse adhesive (Clearfil SAPrimer/ Clearfil PhotoBond, Kuraray, Osaka, Japan) was applied for bonding to the dentin in all experimental groups. Firstly, Clearfil SA primer was applied and dried with a gently air stream. Subsequently, Clearfil PhotoBond was mixed and applied to the surface. The solvent in the adhesive was evaporated using a gentle air stream and the adhesive was cured for 15 s. Next, a Teflon spacer of 3.0 mm height, with an open circle of 5.0 mm in diameter in the middle, was placed onto the dentin. The hole was subsequently filled with composite resin and covered with a glass microscope slide to press away excess material. The composite was light-cured for 40 s using a KaVo PolyLux II curing device with minimum output 500 mW/cm^2. After curing the Teflon mould was removed and used to make the samples of the other materials. To achieve variable composite layer thickness for the samples, the mould was then ground down parallel to the dentin surface using 22 grit sandpaper in several stages until a 0.5 mm thick mould remained. At the different stages of grinding down the mould, it was used for making new samples of each composite as described before. Finally, this resulted in composite-samples of various thicknesses between 0.5-3.0 mm for each composite (n=25).

The thickness of the bonded composite layers were measured three times by measuring the total height of the entire sample with a digital measuring device (Sony, Magnescale LY-101) both before and after making the sample. The mean value of these 3 measurements, after subtraction of the samples height before restoration, was recorded as composite layer thickness. This automatically included the adhesive bonding layer.

Samples were placed in a universal testing device (MTS, 858 Mini Bionix®II) using a 6.15 mm diameter ball-shaped stylus at crosshead speed of

0.5 mm/s. Each sample was uniaxially loaded until failure occurred. The failure load was recorded in Newton. Load at failure was determined as the value at the failure point where a sharp drop in the load occurred after the main part of deformation and energy absorption. From the failure point on, the specimen has virtually lost its strength and elasticity and will tear open (www.instron.com). The failed samples visually showed large fractures or the restoration was partially or completely broken off.

Linear regression analysis was applied to quantify the relation between thickness of the material and compressive strength. T-tests were used to compare the predicted compressive strengths of two materials at various thicknesses.

Results

The compact-filled material (figure 3.1) shows a significant relation between layer thickness and compressive strength ($p<0.001$). The relation between layer thickness and compressive strength in the nano-filled material is also significant ($p=0.001$). However, the midway-filled composite ($p=0.624$) and the micro-filled composite ($p=0.405$) show no significant effect of layer thickness on failure load.

Apart from differences in slope of regression lines in figure 3.1, a difference in variability of the results can also be seen. The micro-filled material shows a wider range of measurements, that is less predictable results than other materials.

Table 3.2

Results of regression analysis

Material	**Type**	**Intercept**	**Effect**	**95% CI of effect**	***p***
APX	Compact-filled	1124	850	[579…1122]	<0.001
Filtek Supreme	Nano-filled	1806	387	[173…600]	0.001
Tetric EvoCeram	Midway-filled	2617	40	[-126…206]	0.624
Heliomolar	Micro-filled	2876	-187	[-642…269]	0.405

Figure 3.1

Graphs of failure load vs. layer thickness for all four tested materials. In table 3.2 the results for the regression analysis are shown.

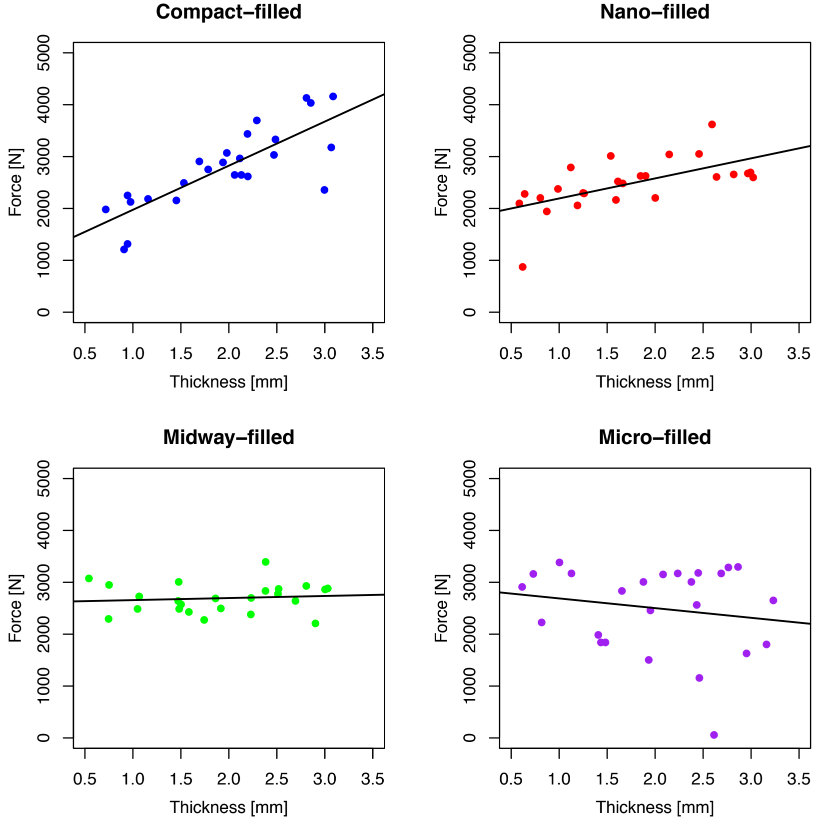

Table 3.3 shows, at various layer thicknesses, whether the predicted compressive strengths show a statistical significant difference (T-test at $p<0.05$).

Table 3.3

Regression analysis translated in comparisons of load at yield at various thicknesses. Significant difference of t-tests.

0.5 mm	1.0 mm	1.5 mm	2 mm	2.5 mm	3.0 mm	3.5 mm
A<B	A<B	A<B	No diff.	A>B	A>B	A>B
A<C	A<C	D<B		A>C	A>C	A>C
D<B	D<B				D>C	D>C

A: Compact filled (APX)

C: Micro filled (Heliomolar)

B: Midway filled (Tetric Evoceram)

D: Nano filled (Filtek Supreme)

Discussion

In this study we established that there is an effect both of layer thickness and material composition on the strength of direct composite restorations and that the two factors interact.

For reasons of standardization in this study a disc shape was chosen that only varied in thickness. Also, for bonding procedure and type certain choices had to be made. The disks were all bonded in the same way to dentin, resulting in a situation partly resembling the clinical one. The adhesive system used was a 3-step etch and rinse material, which is considered the gold standard for bonding direct restorations.[18, 19]

In this study, the complex interaction between thickness and composite composition was addressed using only static loading. Loading teeth in occlusion and bruxism are complex processes that can hardly be simulated while controlling all variables.[20] However, studies have shown that repetitive loading will cause fatigue. Repetitive loading may thus reduce fracture resistance of composite restorations[21] and therefore, it is necessary to perform a follow up study using mechanical ageing. In such a study, variation in layer thickness may be reduced guided by the results of the present study, in order to enhance study efficiency.

The curing protocol used in this study was aimed at standardizing the received energy levels at different layer depths to be similar for all materials. Forty seconds curing time using a QTH device showed to result in sufficient degree of cure even in 3 mm deep layers of composite[22-24] although it is generally recommended to use 2 mm deep layers as a maximum[25]. Thicker layers of composite might be weakened by a lack of polymerization. This might be an explanation for the spread of results at the compact-filled composite and the micro-filled material although the tendency between 1-2 and 2-3 mm does not respond to a decrease in compressive strength at thicker layers of composite. It is improbable that a lack of polymerization at the bottom of the disks is the single explanation for the spread of results at thicker layers of composite resin.

The materials used in this study were selected because they are recommended for use in posterior teeth and for their different composition or physical properties. They differ markedly in composition. Most materials have been used in clinical studies on tooth wear.[2, 11, 26, 27]

In clinical studies good performance was reported for Clearfil AP-X.[2, 6] In a three-year randomized clinical trial Tetric EvoCeram performed well in posterior cavities[26] and its predecessor Tetric Ceram showed good results for restoring teeth with severe tooth wear, although according to the authors the etiology for wear was mainly erosive[3, 28]. Although Heliomolar showed good performance in a clinical study with class II restorations[29], clinical results in patients with severe tooth wear were not satisfactory[11]. Little is known about the clinical performance of Filtek Supreme[27], but it might be suitable for the treatment of tooth wear because of its high polishability[12] and smooth wear resistant surface.

Some explanation for differences in performance between materials may be found in their varying E-modulus. Materials with a low E-modulus are more likely to deform under pressure because of their more elastic properties compared to materials with a higher e-modulus. The stiffer materials may be more fragile when the material has a small thickness and become stronger when thicker. This dependence of the effect of layer thickness on E-modulus is supported by the increasing slope of the regression lines for increasing E-modulus in figure 3.1.

Another possible explanation for the difference in behavior for the various composites resins may be the nature of the subsurface. Differences in the E-modulus between the subsurface and restorative material may affect mechanical behavior. When the difference in E-modulus is small, the dentin-composite sample may function like a monobloc, resulting in an even distribution of stresses. On the other hand a stiffer material placed in a thin layer will be more vulnerable once supported by a more elastic subsurface. The elastic modulus of the most thickness dependant material in the present study (Clearfil AP-X) is much higher than that of bovine dentin (4-8 GPa[30]), while the other composites have lower E-moduli, more in the range of the substructure (table 3.1). This might partially explain the thickness dependent behaviour of the stiff AP-X material.

Conclusion

Both material composition and layer thickness influenced the fracture behavior of composite restorations bonded to dentin. The compact filled composite, the material with the highest E-modulus, showed a strongly positive relationship between layer thickness and failure force, whereas the midway filled composite showed no relationship. At the lowest layer thickness the latter material showed the highest compressive strength.

Acknowledgments

The authors would like to thank Kuraray, 3M and Ivoclar-Vivadent for supplying the composite materials used in this study.

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Chapter 4

Indirect restorations for severe tooth wear: Fracture risk and layer thickness

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Journal of Dentistry

2014;42(4):413-8

Abstract

Objectives

This in vitro study investigated static failure risk related to restoration layer thickness for different indirect materials and compare them to direct composites.

Methods

Two ceramics (IPS e-max CAD, EmpressCAD (Ivoclar Vivadent)), two indirect composites (Estenia (Kuraray), Sinfony (3M)) and two direct composites (Clearfil AP-X (Kuraray), Tetric EvoCeram (Ivoclar Vivadent)) were chosen. Of each material, 25 discs varying in thickness (0.5-3.0 mm) were prepared and cemented to bovine dentine. For measuring compressive strength, samples were placed in a universal testing device. Each sample was uniaxially loaded until failure occurred. For each material a regression model based on the Weibull distribution was used to estimate the relation between restoration layer thickness and failure. Using these models, the chance of failure, standard error and 95% confidence interval for that chance is estimated. Groups of materials were compared as well.

Results

Except for Tetric EvoCeram, all materials show a significant positive association between layer-thickness and compressive strength, with an increased strength of increased thickness. ProCAD performed significantly worse than all other materials, especially when compared to the other ceramic material (IPS e-max CAD) ($p=0.001$).

Conclusion

For most tested materials, a thicker layer offers more strength, however, this property seems to be material/brand specific.

Clinical relevance

As direct composites showed the best results within the limitations of this in vitro study, dentists should consider these materials as a good choice for restoring severe tooth wear, and may offer superior performance compared to indirect composites and ceramics. For some brands of materials thicker layers result in a stronger restoration.

Introduction

Severe tooth wear is mainly caused by erosion, bruxism or a combination of these factors[1] and results often in loss of vertical dimension. In order to gain sufficient space for restoring worn down teeth, an increase of this occlusal vertical dimension is often required. It is still unclear which materials are the best for treating this specific patient group. Recent literature shows that fracture of restorations is the most important reason for failure[2,3] for restorations placed in severe tooth wear cases which is explainable from bruxism as an important aetiology[2]. Therefore, it is expected that for patients with severe tooth wear restorations are exposed to considerable forces, especially when the vertical dimension is increased and all occlusal forces are supported by the restorative material. Restorative materials should therefore be able to withstand these occlusal forces when bonded to the tooth. As the anatomical shape of worn teeth is preferably restored in a minimally invasive way, this results in restorations with various thicknesses, depending on the loss of tooth substance and the increase in vertical dimension. In these situations this results in restorations of various thickness, even within different sites of the restoration itself. Therefore, the most desirable material for restoring severe tooth wear, would offer strength in every thickness applied. In a recent study four restorative direct composites in different layer thicknesses were tested in an in vitro study, showing different variations in fracture strength when applied in various thickness. It showed that for some materials the strength is more thickness dependant then for other materials. Also the type of material and its filler volume has its influence on physical properties of composite resin restorations.[5,6] As in severely worn dentitions, restorations have to be made in various thickness that are exposed to heavy loading, it is important which materials, either direct or indirect, either resin based or ceramic based offer the best fracture resistance in these circumstances. The first hypothesis tested was that compressive strength of restorative materials bonded to dentine are dependant from the thickness of the layer. The second hypothesis tested is that compressive strength is dependant from the used material. The aim of this study was to investigate static failure risk related to restoration layer thickness for different indirect materials and compare them to direct composites.

Materials and methods

For this study, four indirect materials were chosen, two indirect composite resins and two ceramic materials. As indirect composite materials, Estenia (Kuraray, Osaka, Japan) a highly filled hybrid indirect composite and Sinfony (3M, St. Paul, MN, USA), a hybrid indirect resin composite material, were selected. As ceramic materials a lithium disilicate type (e-max CAD, Ivoclar Vivadent, Schaan, Lichtenstein) and a leucite material (EmpressCAD Ivoclar Vivadent, Schaan, Lichtenstein) were selected. As control groups, two direct composite materials from a recent study were used: the material that showed to result in the highest fracture resistance (Clearfil AP-X Kuraray, Osaka, Japan) and the material with the most thickness independent performance (Tetric EvoCeram Ivoclar Vivadent, Schaan, Lichtenstein), the material properties are described in table 4.1.

Of each material, 25 discs varying in thickness were prepared and cemented in a standardized way to bovine dentine prior to measuring static failure load.

Bovine front teeth were ground at the buccal surface until dentine was exposed. Subsequently, these teeth were embedded into a mould with PMMA to give all samples a standardized form. For the indirect composites teflon square plates of 0.5-3.0 mm height with an open circle of 5 mm diameter in the middle were used as a mould. This mould was placed on a glass-plate, filled with resin composite and cured with a microscopic slide on top for 40 s using a KaVo PolyLux II curing device with a minimum output of 500 mwatt/cm^2. To achieve variable height for the sample, the mould was ground down using 22 grit sandpaper. This resulted in samples with a diameter of 5 mm and thickness varying from 0.5 to 3.0 mm. The indirect composites were self-made according to manufacturer's

Table 4.1

Materials specification

Material	Type	Manufacturer	Resin matrix	Filler	Content (w/v)	FS (Mpa)	E (GPa)	filler particle size
Clearfil AP-X	Hybrid	Kuraray	BisGMA, TEGDMA, di-camphorquinone	Silanated barium glass, silanated colloidal sillica, silanated sillica	86/70	204	16,6	0.2-17 µm
Tetric Evo Ceram	Nano-hybrid	Ivoclar-Vivadent	BisGma, UDMA, DMDMA	Ba glass, YbF3, MO, PPF	76/55	120	7,6	~ 550 nm
E-max CAD	lithium disilicate	Ivoclar-Vivadent	SiO2	LiO2, K2O, MgO, Al2O3, P2O5 and other	*	360	95	0.2-1.0 µm
Empress CAD	leucite-reinforced ceramic	Ivoclar-Vivadent	SiO2	Al2O3, K2O, Na2O, other oxides and pigments	*	160	62	1-5 µm
Estenia	hybrid	Kuraray	Polyurethane methacrylmonomer and methacrylic acid series monomer	glass powder and aluminium micro filler	92/82	*	23,1	2.0 nm-2.0 µm
Sinfony	Hybrid	3M	mathacrylic acid series monomer	Glass, SiO2, GIC, Silane	/50	105	3,1	0.5 - 0.7 µm + microfiller

FS: Flexural strength, FM: Flexural modulus, E: E-modulus, *: unknown instructions. With Estenia discs, both microscopic slides contained an Air Barrier paste to reduce degeneration of the unpolymerised resin. Then, the Estenia discs were heat cured for 15 min. at a temperature of 100 °C. Sinfony discs were light cured afterwards for 14 min in a vacuum environment.

The ceramic discs were fabricated in a dental technician's laboratory using a CAD/CAM technique resulting in discs in varying in thicknesses between 0.5 mm and 3.0 mm. After the milling procedure the crystallization process, in which the discs are heated on to a temperature of 840 °C for 25 min, has taken place for IPS e-max CAD discs.

For adhesion, the surface of the indirect composite and porcelain discs were sandblasted with 40 mm alumina particles. All discs were cemented to the dentine surface using Clearfil Panavia composite cement (Kuraray, Osaka, Japan). The dentine surface was treated with 40% phosphoric acid aqueous solution and colloidal silica (K-etchant gel, Kuraray). After 30 s, dentine was washed thoroughly and dried with an air syringe. Subsequently the composite surface was silanized using Clearfil Porcelain Bond Activator (Kuraray, Osaka, Japan) and gently dried. EDprimer was applied to the dentine surface and Panavia 2.0 was mixed according to the manufacturer instructions and applied to surface of the disc. The discs were placed on the dentine, remaining paste at the margin was removed with an explorer and the cement was light cured along the cement margin for 20 s using a KaVo PolyLux II curing device with minimum output 500 mwatt/cm^2.

The thickness of the bonded restoration layer was measured three times by measuring the total height of the entire sample with a digital measuring device (Sony, Magnescale LY-101) both before and after making the restoration. The mean value of these 3 measurements, after subtraction of the samples height before restoration, was recorded as restoration layer thickness. This automatically included the adhesive bonding layer. Thickness of the adhesion layer is not measured.

For the control groups, identical cylindrical discs of various thickness were made, directly bonded to the dentine using a dentine adhesive (Clearfil Photobond or SE bond). The details of the process are described in another paper however the procedures of testing were similar to the procedures in the present study. Samples were stored in water before testing and no thermal, mechanical or combined ageing has been applied.

For testing the fracture resistance, samples were placed in an universal testing device (MTS, 858 Mini Bionix1II) using a 6.15 mm diameter ball-shaped stylus at crosshead speed of 0.5 mm/s. Each sample was uniaxially loaded until failure occurred. The failure load was recorded in Newton. Load at failure was determined as the value at the point where a sharp drop in the load occurred after the main part of deformation and energy absorption. From failure point on, the specimen has virtually lost its strength and elasticity and will tear open.[7]

To analyze the relation between layer thickness and load at failure a survival approach was chosen. Although in this study no censoring was observed, for all samples a failure was seen, by replacing "load" with "time", this can be seen as a typical time-to-event study. So survival analyses techniques can be applied. From these techniques the parametric Weibull distribution was chosen because of its flexible nature and the possibility to incorporate covariates, in this case layer thickness, in the Weibull model. For each material a regression model based on the Weibull distribution was used to estimate the relation between restoration layer thickness and failure with layer thickness as a covariate. Using these models, for each material for any given thickness the chance of failure, including a 95% confidence interval for that chance can be calculated. Using these models, for each material for any given thickness, the chance of failure, standard error and 95% confidence interval for that chance is estimated. For any combination of two materials using their two chances of failure and corresponding standard errors, the difference between those changes can simply be tested with a T-test. To combine groups of materials (for instance the direct composites with the indirect composites), first an overall estimate per group has to be made. This is done as a small meta analysis with inverse variance weighting of the studies. In case of heterogeneity DerSimonian–Laird method for random effect estimates was applied. The package R v 2.15.0 was used for all statistical analyses.[16]

Results

Figure 4.1 shows the failure data for each group with the results of the Weibull analysis. The graphs include the Weibull estimated 50% (bold middle line) and 0%, 90% fracture risk (upper and lower lines) at each layer thickness. Except for Tetric EvoCeram, all materials show a significant positive association between layer-thickness and compressive strength, with an increased strength of increased thickness (figure 4.2).

Figure 4.1

Weibull graphs of all tested materials.

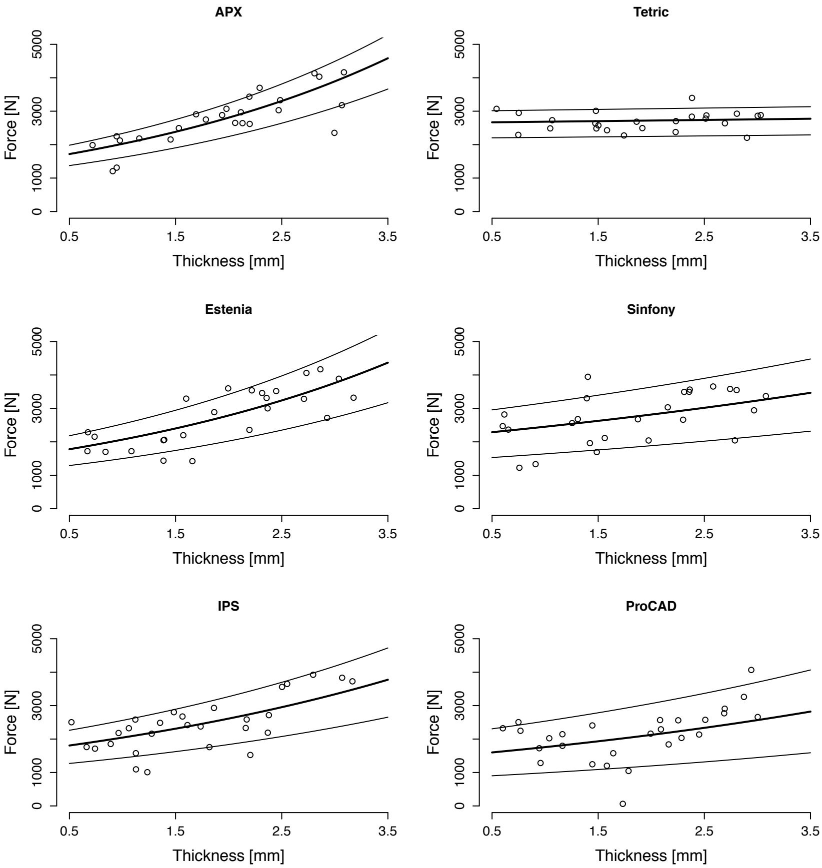
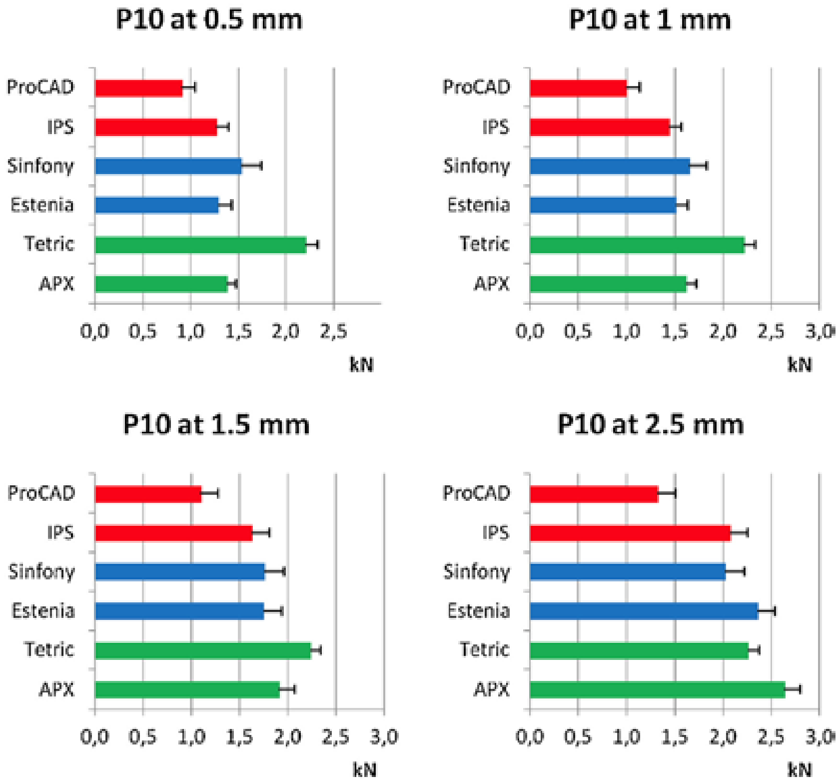


Figure 4.2

Figures represent the chance that 10% of the samples fails at restoration thickness of 0.5, 1.0, 1.5 or 2.5 mm.



Individual group comparisons were performed at 1.5 mm thickness.

The control groups showed the highest compressive strength with Tetric EvoCeram, significantly higher than APX (p=0.034, difference: 327.3, 95% CI of difference: 24.6-629.9), and significantly stronger than all other tested materials. When comparing the ceramic and indirect composite materials, the best indirect composite material (Synfony) showed no significant difference in compressive strength compared to the best ceramic material.

However it should be noted that when both direct composites together are compared to ceramic materials a significant difference was found (p=0.023).

ProCAD performed significantly worse than all other materials, especially when compared to the other ceramic material (IPS) ($p=0.001$, difference: 535.0, 95% CI of difference 62.5-884.7).

The failure visually showed large fracture or the restoration was partially or fully broken off.

Discussion

In this study failure risk of different restorative materials bonded to dentine in different layer thicknesses was investigated using Weibull statistics. The classic way to statistically measure dental materials is by analyzing standard deviations. Weibull demands a different approach of data because survival is measured with an increase of force. A Weibull estimate of risk is given for the applied forces when 10-50% of 90% of the samples survive. There is a strong theoretical foundation for Weibull statistical analysis of strength data based on extreme value theory, fracture mechanisms, and flaw size distributions.[8] An advantage of the Weibull distribution is its flexibility which makes it more closely adaptable to data.[9]

It was hypothesized that compressive strength of restorative materials bonded to dentine are dependant from the thickness of the layer. The second hypothesis tested was that compressive strength is dependant from the used material. Both hypotheses are accepted.

In the present study only compressive strength at static loading has been tested mainly due to the number of materials and different layer thicknesses which makes it not feasible to apply a cyclic loading test. Such a cyclic loading would be more related to the clinical situation but is much more time consuming per sample. Therefore, it could be subject of a further study to select some representative materials for cyclic loading testing in a more limited variation of thicknesses of samples. The shape of the disc samples is not conforming the clinical situation when an anatomical shaped restoration is bonded to the tooth. However for reasons of standardization in this in vitro study it was chosen to do make these standardized discs, bonded in a standardized way to tooth material. Using a total-etch adhesive system with bevel preparation will improve the resistance to fracture as well.[10,11] Another limitation of the study is that no dentine fluid pressure is applied. Even though it is advised not to sandblast lithium disilicate in dental practices because it might decrease material strength it is done in dental laboratories. Small sized particles and at a low pressure are used in laboratories as well as in the present study.

A large variability in maximal bite force has been found. Normal bite force levels range from 50 to 300 N.[12] However occlusal bite forces during clenching and grinding can reach up to 1100 or even 1200 N[13,14] indicating that certain materials applied at lower thickness, might also fail clinically before fatigue. Important factors that affect bite force are craniofacial morphology, age, gender, periodontal support of teeth, signs and symptoms of temporomandibular disorders and pain, and dental status.[13]

When treating patients with severe tooth wear it is often decided to increase the vertical dimension to allow space for the restoration. However, even when the bite is raised considerably, a variation in thickness of restorations still remains, related to the position of the tooth in the arch and circumstances that may differ for individual teeth such as interdigitation, amount of wear, desired position in relation to adjacent teeth. Therefore it is possible that sometimes only 0.5 mm of restoration material is present on the tooth. The results of this study indicates that when certain direct composites are used (Tetric) these limited layer thickness might not be a problem, while for other investigated materials, these thin layers are preferably avoided. Minimal occlusal layer thickness as advised by manufacturers is for e-max CAD 1.5 mm, for empress CAD 1.5 mm in the isthmus and 2.0 mm on the cusp. For Sinfony the advised minimal thickness is 1.0 mm and for Estenia minimal 1.0 mm in the fissures and 1.5 mm on the cusps. Therefore we have chosen to do all direct comparisons between materials for 1.5 mm thick samples. In those cases where this space is not available it can be chosen either to further increase vertical dimension to allow more space for restorations or to make a reduction of teeth by preparation which is not according to minimally invasive principles but might be necessary. However, these aspects have to be tested in clinical studies which are scarce on restorative treatment of tooth wear. In any case, the present study showed the best results for brands of direct composites that have shown favourable results in clinical studies[2,15], although the Tetric used in the clinical study is a predecessor of the material tested in our in vitro study. For the ceramic and indirect composites, only case reports are available. In a study by Schlichting et al. in 2011, ultra-thin occlusal CAD/CAM manufactured indirect composite and ceramic uplay-restorations were cemented on a tooth and subjected to cyclic loading in vitro. The authors concluded that restorative material thickness influenced the fatigue resistance and found a better performance for indirect composite compared to ceramic. Also, the type of material and its filler volume has influence on physical properties of composite resin restorations.[6]

In the present study fracture resistance differed considerably between materials, and it appears that direct composites offer good properties to restore teeth in heavily loaded situations. It should be noted that using the Bonferroni correction in the comparison between direct composites and ceramics, $p=0.023$ is just not a convincing difference.

Conclusion

Most materials show a significant positive association between layer-thickness and compressive strength, however the results differ considerably between materials. Differences within specific material groups show that the choice between direct and indirect, and especially composite resin vs. ceramic, may be more related to specific brands than to material groups. Dentists should keep this in mind when choosing a material for restoring severe tooth wear patients.

Conflicts of interest statement

The authors declare no conflicts of interest with respect to the authorship and/or publication of this article.

Acknowledgements

The authors would like to thank Kuraray, 3M and Ivoclar Vivadent for supplying the dental materials used in this study. The study was supported by the authors’ institution.

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Chapter 5

Clinical performance of direct composite restorations for treatment of severe tooth wear

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Journal of Adhesive Dentistry
2011;13(6):585-93

Abstract

Purpose

The aim of this retrospective clinical study was to evaluate the performance of direct composite restorations that were placed in patients with severe tooth wear requiring an increase of the occlusal vertical dimension.

Methods and Materials

Eighteen patients with severe tooth wear, who had been treated in a private practice between April 1996 and July 2007, were selected. All subjects had been treated with direct composite resin restorations in increased vertical dimension using a three-step etch-and-rinse adhesive system and a hybrid composite resin. From the dental records, information about re-intervention and replacement of restorations was obtained. Patients were then clinically examined to evaluate the status of the restorations and interviewed about their satisfaction with the restorative treatment using a Visual Analogue Scale (VAS).

Results

Eighteen patients (16 male, 2 female with an average age of 44.8 years) with severe tooth wear were included in the study. Time since treatment ranged from 6 months to 12 years and the mean observation time was 3.98 years. Of the 332 restored teeth, 23 restorations showed failures (6.9%). Eight restorations (2.4%) showed major fractures, 11 restorations (3.3%) showed minor fractures, and four restorations (1.2%) failed due to secondary caries. VAS data on a scale of 0 to 10 revealed high patient satisfaction with this type of restoration (mean 9.0).

Conclusion

Treatments with direct hybrid composite restorations placed in an increased occlusal vertical dimension showed good clinical performance in patients with severe tooth wear.

Introduction

Tooth wear is a common clinical finding in patients of all ages[3], and there is some evidence that its prevalence is increasing[15,28]. The etiology of tooth wear may be found in erosion, attrition, abrasion, or a combination of these factors.[1,6] Severe tooth wear can result in significant damage to teeth, leading to short teeth, a reduction of the vertical dimension of occlusion (VDO) or to compensatory vertical growth of the alveolar bone.[3] Traditionally, the restorative treatment for patients with severe tooth substance loss due to tooth wear involves extensive and complex prosthodontic treatment. This concerns the majority of teeth, as building up the reduced VDO must be supported by all occlusal contact surfaces.

Although clinically advocated, only a few case reports have focused on the restoration of severely worn teeth with metal, porcelain-fused-to-metal (PFM), and ceramic crowns of increased vertical dimension.[17,27] A major disadvantage of this conventional approach is the extensive tooth preparation required and the high cost. Especially the low crown height of worn teeth complicates prosthodontic treatment, since retention to the volume of remaining dentin is reduced. Consequently, the life span of these restorations may be suboptimal. Every replacement of restorations requires an extension of the preparation, increasing the risk of complications and early tooth loss[9]. Therefore, extensive prosthodontic treatment in patients with severe tooth wear may compromise the survival of the dentition in the long term, which is especially relevant when patients are relatively young. Adhesive restorations represent a more conservative treatment approach, reducing the need for preparation when restoring the morphology of worn teeth.

Both direct (composite resin) and indirect (metal, ceramic or composite resin) restorations can be placed adhesively. Studies have shown that bonded restorations perform well in Class II restorations[13,18], but data on their performance in patients with severe tooth wear are scarce and contradictory. One randomized clinical study compared direct and indirect composite restorations.[5]. This study produced disappointing results, and the authors concluded that the use of composite resin should not be recommended for patients with severe tooth wear. Another study, however, reported on successful restoration of 7 patients in increased vertical dimension with composite after three years.[25] Further data are only found in case reports documenting favorable short-term results of adhesively bonded restorations[8,16,27]. Nevertheless, positive preliminary clinical experience has been acquired when treating this category of patients with direct composite resin restorations; of course, data on longer-term performance is required. Therefore, the aim of this study was to evaluate the longer-term clinical performance of direct composite resin restorations in patients with severe tooth wear, where the occlusal vertical dimension had to be increased.

Materials and methods

The study was performed in a dental practice partially specialized in adhesive dentistry (NO). Patients were referred to this practice by their dentist for the treatment of severe tooth wear. From the practice files, all patients were selected that met the following inclusion criteria: patients were treated for generalized severe tooth wear using direct composite resin restorations, and treatment resulted in an increased vertical dimension of occlusion. All eligible patients treated in the period 2001 to 2007 were contacted and asked to participate in the study. The study protocol was approved by the Ethics Committee METC of the University of Nijmegen and surroundings (CMO file nr. 2008/018).

Before the restorative treatment was started, the increase of the vertical dimension was determined from the casts mounted in an articulator (Denar) to a level that allowed building up teeth to anatomical proportions. The new vertical dimension was copied from the cast using acrylic or silicon stops placed in the molar area while building up anterior teeth. Generally, an increase of VDO of 2 to 4 mm was realised. Then a 3-step etch-and-rinse adhesive (Clearfil Photo Bond, Kuraray; Osaka, Japan) was applied according to the manufacturer's instructions. The hybrid composite Cleafil AP-X (Kuraray) was used as a restorative material (table 5.1).

Table 5.1

Materials used and description

Material	Type	Filler loading % weight	Filler loading % volume	Speciality
Clearfil AP-X (Kuraray, Japan)	Hybrid composite for posterior use	86 %	70%	Non-abrasive barium glass, average filler size 3 µm
Clearfil Photo Bright (Kuraray, Japan)	Hybrid composite for anterior use	82 %	72 %	filled with quartz (4 µm) and silica (0,04 µm)

Patients visited the dental practice for a routine checkup once a year. In 2008, the performance of the restorations was evaluated using questions and clinical inspection by an independent investigator (JH). Prior to the evaluation, information about the patient and the restorative treatment was obtained from the dental records. The following data were recorded: etiology of the tooth wear (mainly bruxism, mainly erosion, or both) as estimated by the operator, number of teeth included in the treatment (table 5.2), date of the restorative treatment, maintenance treatments of the restored teeth, and whether a night guard was prescribed.

From all patients, study casts and intraoral photographs were available from the situation before treatment. These records were used to establish the amount of tooth wear present before treatment. On the basis of photographs and casts, two independent observers evaluated the level of wear according to the Basic Erosive Wear Examination (BEWE) scores. The BEWE is a partial scoring system recording the most severely affected surface in a sextant, and the cumulative score guides the management of the condition for the practitioner. The four scores evaluate the appearance or severity of wear on teeth: no surface loss (0), initial loss of enamel surface (1), distinct defect, hard tissue loss (dentin) less than 50% of the surface area (2) or hard tissue loss more than 50% of the surface area (3).

Table 5.2 Patients, etiology, BEWE, observation time, guidance and failures.

Patiënt nr.	Age (yr)	Etiology[a]	BEWE	Obs.time (OT) (yr)	Guidance[b]	Nr. of teeth treated (N)	Failure recorded during clinical evaluation[c]						Failure from records		Total nr. failure (f)
							minor failures				major failures		fracture	sec caries	
							1	2	3	4	5	6			
1	59	B	15	4,7	C	25	.	.	1	1	.	.	2	.	4
2	37	B	17	4,0	G	17	.	.	.	.	.	.	.	.	0
3	57	B	17	1,6	C	16	.	.	.	.	.	.	.	.	0
4	29	B + E	17	1,3	G + C	24	.	.	.	.	.	.	.	.	0
5	57	B	13	2,7	C	12	.	.	.	.	.	.	1	.	1
6	41	B	16	8,6	G	22	.	1	1	.	.	1	1	2	6
7	40	B + E	13	4,3	G	12	.	1	.	.	.	.	.	.	1
8	51	B	14	1,3	G	20	.	.	.	.	.	.	.	.	0
9	24	E	15	4,3	G	18	.	.	.	.	.	.	.	.	0
10	44	E	17	4,2	G	22	.	.	.	.	.	1	.	2	3
11	25	E	14	6,1	G	16	.	.	.	.	.	.	.	.	0
12	60	B	17	10,7	G	20	.	1	.	1	.	.	.	.	2
13	53	B	15	1,7	G	14	.	1	.	.	.	.	.	.	1
14	35	B + E	18	12,1	G	21	.	1	1	.	.	.	1	.	3
15	52	B	13	1,1	C	11	.	.	1	.	.	.	1	.	1
16	57	B	13	0,9	C	21	.	.	.	.	.	.	.	.	1
17	38	B	15	1,4	C	21	.	.	.	.	.	.	.	.	0
18	40	B	18	0,6	C	20	.	.	.	.	.	.	.	.	0
Total						**332**	**0**	**5**	**4**	**2**	**0**	**2**	**6**	**4**	**23**

a: B = Bruxism, E = Erosion

b: C = Canine guidance, G = Group guidance

c: 1 = visible crack, 2 = chip fracture marginal ridge, 3 = chip fracture elsewhere, 4 = fracture marginal ridge, 5 = bulk fracture, 6 = lost restoration.

The examination is repeated for all teeth in a sextant, but only the surface with the highest score is recorded for each sextant. Once all sextants have been assessed, the sum of the scores is calculated. The result of the BEWE is transferred into risk levels and can serve to guide management (table 5.3).[4] The answers to the questions provided information about the satisfaction of the patient with the treatment. Scores were given on a Visual Analogue Scale (VAS),[19,31] ranging from "very unsatisfied" (score 1) and "very satisfied"(score 10). Patients who had received a night guard were asked if they used the device as prescribed.

Table 5.3

BEWE risk levels as a guide to clinical management.

Risk level	Cumulative score of all sextants	Management
None	Less than or equal to 2	Routine maintenance and observation. Repeat at 3-year intervals.
Low	Between 3 and 8	Oral hygiene and dietary assessment, and advice, routine maintenance and observation. Repeat at 2-year intervals.
Medium	Between 9 and 13	Oral hygiene and dietary assessment, and advice, identify the main aetiological factor(s) for tissue loss and develop strategies to eliminate respective impacts. Consider fluoridation measures or other strategies to increase the resistance of tooth surfaces. Ideally, avoid restorations and monitor erosive wear with study casts, photographs, or silicone impressions. Repeat at 6=12 months-intervals.
High	14 and over	Oral hygiene and dietary assessment, and advice, identify the main aetiological factor(s) for tissue loss and develop strategies to eliminate respective impacts. Consider fluoridation measures or other strategies to increase the resistance of tooth surfaces. Ideally, avoid restorations and monitor erosive wear with study casts, photographs, or silicone impressions. Especially in cases of severe progression consider special care that may involve restorations. Repeat at 6=12 months-intervals.

During the clinical inspection, every restored tooth was examined according to modified criteria by Hickel et al[14], focussing on presence of fractures of the tooth and/or restoration, esthetic appearance, and presence of secondary caries. A visible crack, chip or a fracture of the marginal ridge was reported as a minor fracture, whereas a bulk fracture or restoration loss was reported as a major fracture (table 5.2). Furthermore, the guidance pattern (group guidance or canine guidance) was recorded.

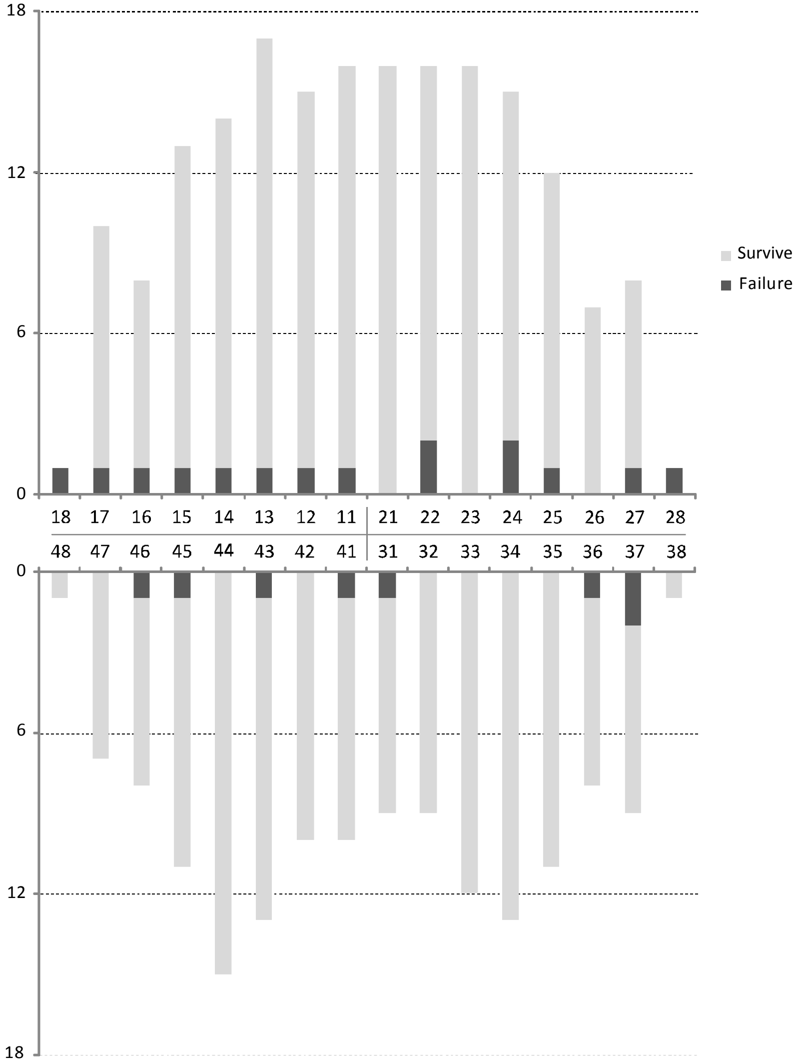
Survival of the restorations was expressed as the failure probability (%) that a restoration will fail in a year per patient. This was calculated as f/N x OT, where N = number of placed restorations, f = number of failed restorations, OT = observation time in years and FF = fail fraction: number of failed restorations in a given patient divided by all restorations placed in that patient. A t-test was applied to statistically analyze a possible relation between etiology of the tooth wear (bruxism only vs. mixed or erosion only) or articulation pattern (canine guidance vs. mixed or group guidance) and the FF of restoration failure.

Results

Nineteen patients met the inclusion criteria. After explanation of the nature and scope of the investigation, 18 patients (16 men, 2 women, ages between 24.1 and 60.2 years, average 44.8 years) agreed to participate (table 5.2). The median observation time was 3.98 years (range: 6 months to 12 years). According to the dental records, the etiology of wear was estimated as bruxism (n=12), erosion (n=3) or a combination of both factors (n=3). The BEWE scores are also shown in table 5.2 and indicated a medium risk level (between 9 and 13) in 4 patients and a high risk level (14 and over) in 14 patients, with an average score of 15.4 for all patients. A total of 332 teeth were restored. Figure 5.1 shows the distribution of these teeth over the patient group. Due to the absence of teeth or the presence of metal or PMF crowns that were preserved, not all teeth were included in the treatments.

Figure 5.1

Overview of localization of treated teeth (all patients). The x-axis shows the location of the restoration by tooth number. The y-axis presents the number of teeth.



The VAS score for satisfaction was 9.0 (± 0.98). None of the restorations required replacement because of dissatisfaction with esthetics, asticatory problems, or other functional problems.

For 11 patients, a night guard was prescribed as part of the treatment. However, only 3 patients reported wearing their night guard every night, 3 patients just occasionally, and 5 patients never used the device. At the time of inspection, 7 patients had bilateral canine guidance, 10 patients were observed to have group guidance, and 1 patient had a canine guidance on one side and group guidance on the other.

Restoration failures were seen in 23 of the 332 restorations. Combined with the years of follow-up, this resulted in an average number of failed restorations of 1.9% (FF) per patient per year.

Most of the failed restorations (65.2%) were located in the maxilla (figure 5.1). The most frequently reported reasons for failure were minor fractures (n=11, scores 1 to 4, table 5.1), major fractures (n=8, scores 5 and 6, and failure fracture from dental records), and secondary caries (n=4). Six patients received subsequent treatment on the previously restored teeth (n=10). This information is incorporated in the number of failures.

With regard to guidance patterns, it was found that patients without canine guidance had a higher failure fraction (FF) than patients with canine guidance (table 5.4).

Table 4

Fail fractions

Cuspid guidance	Y	0.012	difference	0.017
	N	0.029	95% CI of difference	[-0.012…0.047]
			p	0.204
Bruxism	Y	0.024	difference	0.018
	N	0.007	95% CI of difference	[-0.003…0.037]
			p	0.096

The difference between the FFs was not statistically significant: p = 0.204. In terms of etiology, patients with bruxism as the main etiological factor for tooth wear had a higher FF than patients with erosion or erosion and bruxism.

Clinical cases

Two representative clinical cases are presented to illustrate the patient group and the level of treatment provided.

Case 1 (patient nr. 6)

Figures 5.2a to 5.2c show the dentition of a 33-year-old male with severe tooth wear (BEWE score 16, high risk level) leading to sensitivity. The etiology was estimated as bruxism. Twenty-two teeth were treated, and after the treatment a nightguard was prescribed. However, the patient indicated that he seldom wore the device. Figures 5.2d and 5.2e show the situation immediately after treatment, and figures 5.3a to 5.3c show the situation 8.6 years after treatment. In the meantime, several failures had occurred: tooth 36 had a restoration fracture, leading to placement of a new composite resin restoration, tooth 17 was repaired twice due to caries, the restoration in tooth 18 was lost, and two teeth (22 and 28) showed minor fractures. Although restorations showed considerable wear, the patient was still satisfied with the situation (VAS score 8.90).

Case 2 (patient nr. 7)

Figures 5.4a to 5.4c show a 36-year-old female with severe tooth wear (BEWE score 13, medium risk level) suffering from tooth sensitivity due to a combined etiology. She reported having suffered bulimia nervosa periodically, and erosive tooth wear was apparent in the maxillary teeth. However, she also showed signs of bruxism, as can be seen from the fractured porcelain on the crowns placed on the mandibular first molars. It was decided to treat only the maxillary teeth. Figures 5.5a and 5.5b show the situation 4.3 years after treatment. One minor fracture had occurred on the marginal ridge of tooth nr. 25. The VAS satisfaction score was 9.40.

Figure 5.2a

Before treatment, anterior teeth, case 1.

Figure 5.2b

Before treatment, palatal view of maxilla, case 1.

Figure 5.2c

Before treatment, mandible, case 1.

Figure 5.2d

Immediately after treatment, maxilla, case 1.

Figure 5.2e

Immediately after treatment, mandible, case 1.

Figure 5.3a
Case 1 after 8.6 years, anterior theeth.

Figure 5.3b
Case 1 after 8.6 years, maxilla.

Figure 5.3c
Case 1 after 8.6 years, mandible.

Figure 5.4a
Case 2 before treatment, anterior teeth.

Figure 5.4b
Case 2 before treatment, maxilla.

Figure 5.4c
Case 2 before treatment, mandible.

Figure 5.5a
Case 2 after 4.3 years, maxilla.

Figure 5.5b
Case 2 after 4.3 years, mandible.

DISCUSSION

In this retrospective clinical study, the performance of 332 restored teeth in 18 patients with severe tooth wear was evaluated. Despite the small sample size and the retrospective nature of the study, it gives a good impression of the survival of direct composite restorations placed in an increased vertical dimension of occlusion. The established BEWE scores of the patients indicate that most patients had a considerable amount of tooth substance loss, illustrating the need to raise the bite by restoration. Although this scoring list is developed for measuring erosive wear, it is used for all patients in this study to avoid unwanted complexity by having to compare two different scoring systems. Furthermore, it is a manageable method and it scores the amount of tooth loss, independent of the etiology of wear. In other clinical trials, no index for the evaluation of the severity of tooth wear was used.[5,12,23,25]

The increase in vertical dimension was not tested with splint therapy before the restorative treatment was started. Nevertheless, all the patients accepted the new bite without problems. The literature reports that an increase in vertical dimension up to 6 mm appears to be accepted by volunteers wearing splints.[20]

The nature of the dataset posed some problems with survival calculations. Exact date of failure was only available in case the patients reported to the practice immediately after the failure occurred. If the patient did not inform the practice immediately, the failure was seen at the moment of evaluation. Therefore, an exact longevity of the failed restorations could not be determined. The annual failure rate was not calculated because of the risk of clustering information. The calculation used in this study did not compensate for the moment of failure. To take into account that there is uncertainly in the FF due to lack of information on the exact longevity, a worst case scenario analysis was performed assuming that the failure occurred immediately, on the day the restoration was made. Because this resulted in an average probability failure of 2.2% per year, the decision was made to leave the moment of failure out of the calculation. The observed value of about 2% compares favorably to failure rates of traditional amalgam or composite Class II restorations.[11,21,22] Although a larger, prospective study would be necessary to estimate annual failure rates, the low number of failures combined with the high satisfaction of the patients leads to the tentative suggestion that direct composite resin restorations are successful in the treatment of severe tooth wear in the medium term, where crowns have previously been required.

All restorations were reparable, but depending on the type of fracture or the extent of the secondary caries, sometimes total replacement was necessary. The reported failures are specific for this patient group. In most clinical longevity studies, caries is the most common reason for restoration failure.[18] Since bruxism is the most common etiological factor in wear patients, fracture was the predominant failure mode of restorations in this study. The etiology of the tooth wear in this study was taken from the records of the general dental practitioner. It is often difficult to determine the etiology of tooth wear, and it is usually multifactorial.[1] However, attrition due to excessive contact between teeth in opposing jaws is generally considered to be more easily diagnosed than other factors, due to the resulting wear facets often fitting together. Moreover, a bruxing habit is often reported by the patient during anamnesis.

The intuitive hypothesis that a diagnosis of bruxism as the cause of the severe tooth wear would increase the risk of subsequent restoration failure was not confirmed, as the observed effect was not statistically significant. The small sample size and the relatively low failure rates did not allow for statistical significance, but an estimate of the maximal effect can be made. Comparing patients with or without canine guidance, the maximum difference in the rate of failed restoration was 0.047. For a model patient with 20 restored teeth, this implies that the difference in restorations lost per year between patients with and without canine guidance would be 0.94. This estimate of the maximum effect can be considered to be clinically relevant. Using the same line of reasoning, the maximal difference between people with or without bruxism is 0.74 failed restorations per year. This can also be considered clinical relevant.

In a clinical trial, it was concluded that the use of indirect and direct composite resin was contraindicated for the treatment of patients with tooth wear.[5] The study reported a 3-year failure rate of 56% for direct restorations and 42% for indirect restorations, which is dramatically worse than the present failure rates. There may be several explanations for this difference. First, the etiology of the patients involved in the two studies may not be similar. Unfortunately, the etiology of tooth wear in the study by Bartlett and Sundaram[5] is not reported. Second, there may be an operator effect, as different operators placed the restorations. Moreover, details about the treatment protocols are not presented. Third, a likely cause for the discrepancy is the difference between the applied composite resins. In the earlier trial, a microfilled composite resin was used, while patients in the present study were treated with a highly filled hybrid composite resin.[26,29] The microfilled material demonstrated acceptable results in long-term clinical studies of conventional, relatively small restorations,[7,26] but it is known for a risk of cohesive failure (chipping).[10,30] In patients with tooth wear, restorations generally have a large occlusal surface and may be subjected to heavy loads due to bruxism. Since hybrid composites show higher fracture and wear resistance, these materials may be more suitable for patients with severe wear than are microfilled composite resins.

While it is known that most patients with tooth wear are generally less satisfied with their dentition,[2] posttreatment patient satisfaction in this study was very high. This supports the use of direct composite restorations for this patient group to improve masticatory and esthetic function. Other important advantages for the patients are the low treatment costs and the low biological price. The present results throw doubt on the idea that directly applied composite restorations cannot be successful in patients with severe tooth wear. This is substantiated by the results of a recent study on 7 patients treated with a hybrid composite to increase VDO, which indicated that composite resin can be successfully applied in cases of severe tooth wear.[25] In another clinical trial, direct composite restorations were placed only in the anterior region to restore localized anterior tooth wear.[24] These restorations also showed a good clinical behavior in the medium term. Additionally, prospective studies should be conducted, preferably comparing directly applied materials with indirect adhesive restorations. Although not compared, the use of full coverage crowns does not seem to offer greater advantages than the composite technique.

CONCLUSION

In this retrospective study, patients suffering from severe tooth wear who had been treated with direct composite restorations placed in increased vertical dimension of occlusion showed high satisfaction with the treatment and a good clinical performance of the restorations after a mean observation time of 3.9 years.

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Chapter 6

General discussion

General discussion

Dentists often face difficulties in treating patients who suffer from severe tooth wear. Traditionally this treatment was applied by prosthetic dentists using full coverage indirect technique: the “28 crowns” approach. However, a change has been taking place in dentistry: with the advent of adhesive dentistry and the possibility of bonding restorations to teeth instead of having to rely on undercuts, fitting form, and cementing, minimally invasive treatments are increasingly preferred over the traditional approach. As dentists are confidently making ever larger adhesive direct restorations, the possibilities of complete occlusal rehabilitation in patients with severe wear is quickly becoming a realistic option.[1, 2]

The aim of this thesis was to explore different treatment modalities and strategies for patients with severe tooth wear within the boundaries of minimally invasive dentistry. Trends in clinical protocols and materials behavior were addressed in the perspective of the question: which material and technique can be used best for these patients in the future?

Challenges of Clinical Wear Management

In this thesis we clearly and explicitly focus on the minimally invasive adhesive end of the complete spectrum of restorative treatment options for severe wear. In Nijmegen we choose to use this treatment technique for several reasons. Firstly, no preparations have to be made, so the biological price of restorations is low. Costs for the patient are lower as well, for no technical or laboratory steps have to be taken. Finally restorations can be repaired after failure (for example due to caries, wear or fracture), so that more costly (both in biological and in financial terms) replacements can be postponed. We acknowledge that treating patients with direct composite, by modeling teeth in situ, is a complicated and time-consuming procedure (chapter 6) that not all dentists are comfortable with.

The whole spectrum of treatment options for restoration of worn dentitions is thoroughly described in chapter 2. Categories of treatment are: removable prosthesis, indirect restorations and direct restorations. Additional Orthodontics or Dahl treatment can be used to help with the increase of the Occlusal Vertical Dimension. Several reasons for the existing differences in treatment techniques can be given. For example financial (im)possibilities of the patient and reimbursement from the public health system. Also, the educational background of the dentist explains why differences in treatment and material exist. Some universities focus their educational program on restoring teeth with direct materials while other universities give preference to indirect materials. Habits and skills of the dentist who treats the patient can also affect the choice for either direct or indirect materials.

There is a wide variety of treatments that are being performed by dentists. Unfortunately, studies published since the study in chapter 2 was performed still mainly consist of case-reports.[3-10] The majority, 5 out of 8, of these describe the use of minimally invasive treatment techniques solely or in a combination with prosthodontic techniques. The trend as mentioned towards minimal intervention techniques for treatment of severe tooth wear is thus continued, even if high-quality evidence is still lacking. Interesting in this respect is the development of CAD-CAM techniques that can possibly be used to produce indirect build ups with a new developed composite like material (LAVA Ultimate or Paradigm MZ100 - 3M ESPE). A case report shows that the indirect restorations are uplays, with existing composite restorations underneath in the proximal surfaces. This illustrates that minimally invasive dentistry not only involves direct restorations, but that the development of indirect techniques has also moved away from full coverage crowns including the sacrifice of considerable sound tooth substance, to an approach where only lost tooth substance is replaced without removal of existing restorations.[11] However, evidence for these new techniques from high quality clinical studies is lacking until now. It can be assumed that the diversity in treatment choices as presented in the survey still exists among dentists today.

Apart from the differences in treatment strategies another difficulty exists: What is the best moment to initiate restorative treatment? To solve this problem, several indices have been presented in dental literature.[12-17]

Unfortunately, this wide variety of indices makes communication between specialists complicated. The limitations on measuring progression in wear is one of the disadvantages of tooth wear indices. For example, imagine a 40-year-old male patient that has severe tooth wear due to excessive consumption of lemonade in his youth, but whose diet has been normalized for several years. Although there may have been minimal wear progression in the past 10 years, a tooth wear index may well indicate that restorative treatment should be initiated. In this case, however, immediate treatment is not necessary because the condition has stabilized, assuming of course that the patient does experience esthetic or functional problems. It should be kept in mind that an index records the cumulative damage of a lifetime, and not the recent developments.

Adding to that, etiology is an important factor in treatment planning and indices mostly report only the loss of material and not the underlying cause. If, in the case mentioned above, the cause of wear had been bruxism, a nightguard after treatment probably would be indicated, whereas in the case of mainly erosive wear it is not. If it is possible to stop the progression of wear by taking away or reducing the etiological factors, for example by medication in reflux patients or by a change in diet, it may be possible to postpone the moment of treatment. According to the authors of a recently published textbook on tooth wear 'management of the worn dentition does not necessarily imply restoration. Instead, restoration and rehabilitation are procedures the clinician and the patient may agree to embark on in order to improve aesthetics, function and protection of the dentition when balance within the oral environment is reestablished'.[18] Of course in case of bruxism this balance mostly can't be established before restoration and rehabilitation has taken place.

Clearly, many questions remain unanswered by this thesis. Even if we assume that the minimally invasive approach will be the first choice in the future, several material and technique related questions remain. Should we prefer direct over indirect restorations, or may this choice be governed by operator preference and skills? If using indirect restorations should we prefer composite over ceramic materials? Although the body of evidence in the scientific literature is very limited, it is slightly more robust for composite. However, there is a clear trend within prosthetic dentistry of increasing use of ceramic restorations: so called "metal-free dentistry"[19], and this may well tip the scale towards ceramics. Then there is still the question of which specific material to use. Perhaps, as long as we avoid certain clearly unsuitable materials[20] the material may not be as important as certain other patient and operator related factors[21].

Literature Review and Survey

Through closer analysis of the literature, a visible trend appears that highlights the lack of published material on traditional full-coverage approaches to adhesive direct and indirect composite and porcelain techniques. Chapter 2 focuses on the theories surrounding treatment of severe tooth wear and the actual common practice of dentists. It compares information gleaned from a qualitative survey of 57 specialized dentists against a broad literature search. The study shows that there is a wide range of treatments available with very little evidence to support any single one of them.

In 2011 a similar survey was conducted in Norway. This survey was sent to general dental practitioners and the response rate was 60%. The study focused on tooth wear diagnosis and different scoring systems were used as described in other literature. In general, the survey suggests that the dentists are relatively up to date regarding the clinical recording, diagnosis, and treatment of dental erosive wear. However, dietary and salivary analyses were not given priority, and early, preventive treatment was lacking. Operative treatment was the most common choice of treatment for the upper 1st molars. Forty-four percent of the dentists chose to place a filling, and 18.8% chose prosthodontic treatment for these teeth.[1] Among dentists from The Dental Practice-Based Research Network (182 dentists from the USA and Scandinavia) abrasion, abfraction, erosion and tooth fracture were the main reasons for restoring non-carious tooth surfaces. Dentists restored different types of non-carious tooth defects most often with resin-based composite.[2]

Restorative treatment

Technical aspects

For the posterior area, the restorations made are mostly applied on top of the worn occlusal surface, thus bearing the full force of mastication and, where present, parafunctional habits such as grinding and clenching. Unlike conventional restorations, the material is not applied in bulk in a preparation, but in a layer which may vary in thickness according to the height of the tooth tissue loss and the increase in occlusal vertical dimension. The amount of increase in vertical dimension remains subject to debate.[22] Even though the layer of restoration material is not equally thick on each part of the occlusal surface, a minimal thickness should be attainable. As in case of severe tooth wear, grinding down teeth to achieve this space is not considered as a good option, the increase of vertical dimension is crucial in this respect.

Materials

Materials used in this studies are generally used for treating patients with severe tooth wear. Clinical results for the direct composite materials Clearfil AP-X, Tetric EvoCeram and Heliomolar have been reported in recent literature, including treatment of tooth wear patients.[20, 23-28] Reports on the clinical performance of Filtek Supreme are limited in observation time up to five year.[29] This nanofilled composite might be suitable for the treatment of tooth wear because of its high polishability[30] and smooth, wear resistant surface. By including the above mentioned 4 materials, highly filled hybrid, nano-hybrid, nanofilled and microfilled composites were represented in our study.

For indirect restorations both ceramic and composite materials were chosen: a lithium disilicate ceramic: IPS-emax; a leucite ceramic: Empress CAD; and two hybrid indirect composites: Estenia and Sinfony. The applied layer thickness of the materials described in chapter 2 and 3 varied between 0.5 and 3.0 mm and it was concluded that in case of a thicker restoration, some materials will deliver more strength.

In comparison to our study, a recent study show good and excellent results after 2 years for IPS e-max and Empress, respectively, according to 11 criteria.[31] Ultra-thin (0.6 mm) lithium disillicate (e-max CAD) occlusal veneers were investigated and described as a conservative alternative to traditional onlays and complete coverage crowns for the treatment of severe erosion lesions in the posterior dentition.[32] On the other hand part of the same research group concluded that fatigue resistance was influenced by material thickness. A better performance for indirect composite compared to ceramic was found.[33]

Based on the studies in this thesis no clear answer can be provided for the question which material should be preferred although the evidence for composite is more robust. Although the 3-year RCT[20] with microfilled composites showed poor results, most of the other studies using hybrid composites showed excellent clinical results. As the RCT is not clear on the material used it may be that building up severe bruxism patients with microfilled composite is probably not indicated, and stronger hybrid materials should be preferred. When choosing a restoration material, it should be kept in mind that fracture is the main cause for restoration failure in bruxing patients. Such cases may require special, stronger, materials. Within the perspective of personalized health care it would be attractive to design a protocol in which, depending from the diagnosis a patient is restored in a bruxism protective way or an erosive protective way.

Minimally Invasive Treatment

Chapter 5 focuses on the clinical aspects of minimally invasive treatment approach with direct composite resin restoration. It is a longitudinal retrospective study and a first attempt at providing evidence outside of the case reports for the use of this technique. Our research has shown, in a group of 18 patients treated by one operator, that the technique is feasible, well accepted, and performs well. This study was performed in a dental practice were all the patients were treated by the same operator. Although the study was too small for real factor analysis, the data collected on the fracture risk in bruxing patients merits further investigation. The results from this study show that this treatment technique is a minimally invasive alternative for restorations using crowns in addition to enlarging the indication area for direct composite resin restorations.

A detailed description of the technique used in the clinical study discussed in chapter five is presented as a appendix of this thesis. The technique used in chapter 5 is completely new and does not appear in any textbook, hence why it has been provided here. The description includes a complete illustrated overview of the technique in hope that other dentists can utilize this information and to assist further clinical studies.

Further Research

Much research needs to be done before dentists will be able to offer severe wear patients evidence based treatment options. The matter of restorations layer thickness and its limitations and effects on performance need to be studied further. In the present study, static compressive strength was measured in vitro. To improve the clinical relevance of this study, a follow-up with use of cyclic loading testing together with analysis of clinical studies linking restoration dimensions to failure types is vital.

In clinical prospective research etiology of tooth wear should be linked to failure behavior of materials. Bruxism and erosion vary widely so it is expected that these wear types provide different failure characteristics after treatment.

In general there seems to be a need for a large randomized controlled clinical trial to compare crowns, indirect composites, indirect ceramics and direct composites for the treatment of severe wear. However with the recent change in restorative materials from traditional prosthetic dentistry to minimally invasive adhesive dentistry, the right moment for this RCT has probably already passed. The difference in price between these two treatment techniques is so large that it may not even be ethical to perform such a study. Questions might arise of what is care and what is luxury? The best alternative for such a RCT may be retrospective and prospective studies in centers with different restorative protocols including meticulous registration of patient factors and pre treatment situation.

Results of the studies presented here have contributed to the setting up of a large and multi-facetted prospective clinical study that is now taking place at the Radboud University Nijmegen Medical Centre. The study contains 2 randomized controlled trials: one is evaluating the effect of pre-treatment splints for testing the increased VDO, and the second is evaluating the performance of a completely direct and a mixed direct / indirect (composite) approach. Finally, this study also hopes to evaluate wear etiology on restoration performance and the effects of treatment on patient quality of life.

Looking ahead

How will severe tooth wear be managed 10 years from now?

At this moment, treatment of patients with severe tooth wear mostly takes place in specialized treatment centers. Depending on the number of patients with tooth wear, this type of dentistry might become more standard in general practices, but the complicated protocols still may prevent the GDP from doing this. As the field of digital dentistry evolves, it might become easier for dentists to establish the ideal new occlusion with help of computer modeling. A large group of software developers are working on digital tooth wear measuring devices and it can be assumed that these computer programs will be ready for use in general dental practices in a few years from now. Images of the occlusal plane can be compared to one another, results of salivary tests and bruxism measuring tests will be added and can be used to ease the decision to start restorative intervention or not. Images can easily be shared with dental laboratories where minimally invasive restorations based on the original anatomy of teeth will be manufactured.

This development probably goes hand in hand with the emerging trend of using composite more often in indirect procedures. In this material group the benefits of composite and ceramics are merged together because this is a minimally invasive technique with which computer aided designs can be helpful in creating the desired occlusal patterns and increase in vertical dimension.

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Summary

Samenvatting

Summary

Tooth wear is a common phenomenon that exists in almost every mouth. It can be caused by erosion, attrition, abrasion, abfraction or a combination of these factors. Erosion is the progressive loss of tooth substance that does not involve bacterial action. Attrition results from tooth-to-tooth contact without the presence of food and is typically characterized by wear facets that are matched by corresponding facets on teeth in the opposing arch. There are two parafunctional activities that are associated with attrition: tooth grinding (the process where teeth rub together repeatedly in a predefined way and with great force) and tooth clenching (teeth are pressed in occlusion without or with minimal movement, applying great forces on small areas). Abrasion occurs when there is friction between a tooth and an exogenous agent (for example, overzealous tooth brushing). Abfraction is defined as the microstructural loss of cervical tooth substance in areas where there is consistent concentration of stress. It occurs at the cement enamel junction area of teeth. Unacceptable levels of wear are categorized as pathological tooth wear.

There has been very little research into treatment of severe tooth wear and general practitioners encounter only a handful of these patients each year. The right moment for intervention and treatment is hard to find as well as the type of treatment. The treatment options (removable partial dentures, indirect restorations, direct restorations and Dahl) are briefly described in **chapter 1** and more in detail in **chapter 2**. Removable partial dentures are a traditional treatment and sometimes a temporary treatment option. Indirect restoration is used to describe any fixed treatment using materials manufactured outside the mouth such as crowns, bridges, and porcelain veneers. Direct (composite) restorations are used to buildup the worn dentition directly in situ, while the Dahl concept is based on intrusion of the lower anterior teeth and eruption of premolars and molars. In this thesis, we focus on the minimal invasive, adhesive treatment options because of the low biological price, minimal preparation needed, and the low cost for the patients. Additionally, restorations are easily repairable after failure. The objective of this thesis is to explore the different options for treatment of patients with severe tooth wear.

Chapter 2 describes an explorative survey of restorative management approaches of severe tooth wear. The aim of this study was to explore differences in management strategies in the treatment of patients with severe tooth wear. A questionnaire was sent to specialized dentists in the UK, Germany, and the Netherlands. The questionnaire was distributed digitally to 117 dentists, and contained questions about indication, examinations used, treatment approaches, and materials used. Total response rate was 54.7%. Dentists were grouped according to their main choice of direct and indirect treatment options. Overall, 26 out of 57 responding dentists reported using indirect techniques, whereas 31 reported using mainly indirect techniques. Attrition, abrasion, and a combination of factors were seen by direct and indirect treating dentists, in similar frequencies. The survey showed that indirect treating dentists tended to replace restorations more often and were shown to have tested the increase in occlusal vertical dimension more often. None of the listed problems associated with the treatment were reported to occur ‘regularly’ or ‘often’. However, problems such as bulk fracture was reported to occur both in the first 12 months and later.

A wide range of treatment choices for severe tooth wear was found among specialized dentists. The survey showed division into direct and indirect treating dentists appears to be related to the country of practice. This variation could not be explained by differences in treatment goals, and in rare instances problems with techniques were reported for either approach.

The aim of the study presented in chapter 3 was to investigate the compressive strength of composites with different physical properties bonded as a restoration to dentin in layers of varying thicknesses. Four types of direct composite materials were analysed: a midway-filled (Tetric EvoCeram), a compact-filled (Clearfil AP-X), a nano-filled (Filtek Supreme), and a micro-filled material (Heliomolar) were bonded in 0.5-3.0 mm thick layers onto bovine dentin. Each material group contained 25 samples, which were then loaded until fracture. The nano-filled and compact filled material showed a significant association between layer thickness and compressive strength. The midway-filled composite was the most consistent material showing similar failure load over the complete thickness range. A clear influence of layer thickness on compressive strength was found in some composite resin materials. When restorations are placed that have been heavily loaded, such as in patients with severe wear due to bruxism, it is advisable to choose a material that is adequately strong in all thicknesses.

Chapter 4 is an in vitro study investigating static failure risk related to restoration layer thickness for different indirect materials and compares them to direct composites. Two ceramics (IPS e-max CAD, EmpressCAD (Ivoclar Vivadent)), two indirect composites (Estenia (Kuraray), Sinfony (3M)), and two direct composites (Clearfil AP-X (Kuraray), Tetric EvoCeram (Ivoclar Vivadent)) were chosen for this study. For each material, 25 discs varying in thickness (0.5-3.0 mm) were prepared and cemented to bovine dentin. When measuring compressive strength, samples were placed in a universal testing device (MTS, 858 Mini Bionix®II) using a 6.15 mm diameter ball-shaped stylus at crosshead speed of 0.5 mm/s. Each sample was uniaxially loaded until failure occurred. For each material, a regression model based on the Weibull distribution was used to estimate the relation between restoration layer thickness and failure. Using these models, the chance of failure, standard error and 95% confidence interval for that chance is estimated. Groups of materials were compared as well. Except for Tetric Evoceram, all materials showed a significant positive association between layer-thickness and compressive strength: an increase of thickness equals and increase of strength. These results appear to be material/brand specific. For instance, ProCAD performed significantly worse than all other materials, especially when compared to the other ceramic material (IPS e-max CAD) (p=0.001). This in vitro study has shown that direct composites achieved the best results and thus, dentists should consider these materials as good choice for restoring severe tooth wear.

The clinical performance of direct composite restorations for treatment of severe tooth wear is investigated in chapter 5. The aim of this retrospective clinical study was to evaluate the performance of direct composite restorations that were placed in patients with severe tooth wear requiring an increase of the occlusal vertical dimension. Patients with severe tooth wear, who had been treated in a private practice between April 1996 and July 2007 were selected. All subjects had been treated with direct composite resin restorations in increased vertical dimension using a three step etch and rinse adhesive system and a hybrid composite resin. From the dental records, information about re-intervention and replacement of restorations was obtained. Patients were then clinically examined to evaluate the status of the restorations and interviewed about their satisfaction with the restorative treatment using a Visual Analogue Scale (VAS). Eighteen patients (16 male, 2 female with an average age of 44.8 years) with severe tooth wear were included in the study. Time since treatment ranged from 6 months to 12 years and the mean observation time was 3.98 years. Of the 332 restored teeth, 23 restorations showed failures (6.9%). Eight restorations (2.4%) showed major fractures, 11 restorations (3.3%) showed minor fractures and four restorations (1.2%) failed due to secondary caries. VAS data on a 0-10 scale revealed high patient satisfaction with this type of restoration (mean 9.0), and thus this study proves that treatments with direct hybrid composite restorations placed in an increased occlusal vertical dimension shows good clinical performance in patients with severe tooth wear.

Results of this thesis are discussed and put in a broader context in chapter 6. In the whole spectrum of treatment options for restoration of worn dentition, choosing the right material and best moment for treatment can be challenging for dentists. There is a tendency for dentists to choose minimal intervention techniques. Thus far, very little research has been undertaken in the treatment of severe tooth wear. For dentists to be able to provide patients with evidence based treatment options, a larger clinical trial are required. Suggestions for further studies are provided in chapter 6. In vitro wear simulation and cyclic loading should be added to these trials to improve the clinical relevance of the study. In clinical prospective research, etiology of tooth wear should be linked to failure behaviour.

Moreover, chapter 6 also provides a glimpse of where technology and advancement is heading in this field. New digital techniques can be of great help in treatment planning. Used in combination with indirect manufactured minimally invasive restorations based on the original anatomy of teeth, this can be of great benefit for treating patients with severe tooth wear.

Finally, in addition to the general chapters, the appendices provides a step-by-step explanation of the treatment of severe tooth wear using direct composite resin.

Samenvatting

Gebitsslijtage is een algemeen fenomeen dat in bijna iedere mond voorkomt. Het kan veroorzaakt worden door erosie, attritie, abrasie, abfractie of een combinatie van deze factoren. Erosie is het progressieve verlies van tandstructuur, zonder invloed van bacteriën. Attritie ontstaat door tand-tand contact zonder aanwezigheid van voedsel en wordt gekenmerkt door slijtfacetten die passen op slijtfacetten bij tanden in de tegenoverliggende tandboog. Attritie kan onderverdeeld worden in twee parafunctionele activiteiten: knarsen (het proces waarbij tanden in een vast patroon herhaaldelijk over elkaar heen schuiven met veel kracht) en klemmen (tanden worden in occlusie, zonder of met minimale beweging, met veel kracht op elkaar gedrukt). Abrasie is niet-fysiologische slijtage die ontstaat bijvoorbeeld door overijverig tandenpoetsen. Abfractie wordt gedefinieerd als het verlies van cervicaal tandweefsel door spanning die op de tand komt te staan. Het vindt plaats in de glazuur-cementgrens van de tand. Bij extreme slijtage wordt gesproken van pathologische slijtage.

Naar de behandeling van extreme gebitsslijtage is nog te weinig onderzoek gedaan en tandartsen (algemeen practici) zien maar een paar van deze patiënten per jaar. Er is weinig informatie over het juiste moment van ingrijpen, het type behandeling en het te kiezen materiaal. Dit maakt het voor tandartsen lastig om de juiste keuzes te maken. Het doel van dit proefschrift is het verkennen van verschillende behandelopties voor patiënten met gebitsslijtage.

De behandelopties voor gebitsslijtage, namelijk een uitneembare voorziening, indirecte restauratie, directe restauratie of een Dahl-behandeling, zijn in het kort beschreven in **hoofdstuk 1** en uitgebreider in **hoofdstuk 2**. Uitneembare voorzieningen werden in het verleden regelmatig gebruikt en worden tegenwoordig nog steeds wel als een tijdelijke voorziening gebruikt. Met indirecte restauraties worden restauraties bedoeld die buiten de mond worden gemaakt (bijvoorbeeld kronen, bruggen en porseleinen veneers) en vervolgens op de tanden worden gecementeerd. Composietrestauraties kunnen ook gebruikt worden om een gebit direct in de mond op te bouwen. Het Dahl-concept is een behandeling die gebaseerd is op de intrusie van de voorste ondertanden en uitgroei van de premolaren en molaren. Van deze mogelijke behandelmethodes is in dit proefschrift vooral gekeken naar de minimaal invasieve, adhesieve methode. Reden hiervoor is de lage biologische prijs voor het gebit omdat er geen preparaties gemaakt hoeven te worden en de lage kosten voor de patiënt. Restauraties zijn bovendien gemakkelijk te repareren na falen.

Hoodstuk 2 beschrijft een exploratief onderzoek naar de restauratieve behandeling van ernstige gebitsslijtage. Het doel van de studie was om verschillende behandelstrategieën in de behandeling van patiënten met ernstige gebitsslijtage te verkennen. Een enquête is verstuurd naar gespecialiseerde tandartsen in het Verenigd Koninkrijk, Duitsland en Nederland. De vragenlijst is digitaal verspreid naar 117 tandartsen en bevatte vragen over de indicatie, gebruikte onderzoeken, benadering van de behandeling, gebruikte materialen etc.. De totale respons was 54,7%. Tandartsen werden gegroepeerd volgens hun benadering van de behandeling van gebitsslijtage. 26 van de 57 responderende tandartsen gebruikten indirecte technieken en 31 respondenten gebruikten voornamelijk een directe behandelmethode. Attritie, abrasie en een combinatie van factoren werden door direct en indirect behandelende tandartsen in dezelfde frequentie gezien. Indirect behandelende tandartsen neigen vaker naar het vervangen van bestaande restauraties en testen vaker een beetverhoging voorafgaand aan de behandeling. Geen van de problemen kwamen ‘regelmatig’ of ’vaak’ voor, maar grote breuken van de restauraties kwamen zowel in de eerste 12 maanden als later voor. Een grote spreiding van behandelkeuzes voor ernstige gebitsslijtage werd gevonden onder gespecialiseerde tandartsen. De onderverdeling in direct en indirect werkende tandartsen kan gelinkt worden aan het land waar de tandarts vandaan komt. Deze variatie kon niet verklaard worden uit de verschillen in behandeldoelen. Problemen met technieken komen zelden voor, onafhankelijk van de gekozen aanpak.

Het doel van de studie die gepresenteerd wordt in hoofdstuk 3, was om te onderzoeken wat de druksterkte is van gebonden composieten in verschillende laagdiktes met verschillende fysieke eigenschappen. Vier typen directe composiet: een ‘midway-filled’(Tetric EvoCeram), een ‘compact-filled’ (Clearfil AP-X), een ‘nano-filled’ (Filtek Supreme) en een ‘micro-filled’ (Heliomolar) werden gehecht aan runderdentine. Laagdikte van het composiet varieerde van 0.5-3.0 mm. Ieder materiaal bestond uit 25 monsters die belast werden tot het punt van breuk. Het ‘nano-filled’ en het ‘compact-filled’ materiaal lieten een significant verband zien tussen laagdikte en druksterkte. Het ‘midway-filled’ composiet was het meest consistente materiaal met vergelijkbare faalkracht over de hele range van laagdiktes. Een duidelijke invloed van laagdikte op de druksterkte werd in sommige materialen gevonden. Als restauraties heel zwaar belast worden, zoals bij patiënten die knarsen, kan het daarom verstandig zijn om een materiaal te kiezen dat even sterk is in verschillende laagdiktes.

In **hoofdstuk 4** wordt een onderzoek gepresenteerd waarin gekeken is naar de druksterkte van verschillende indirecte materialen in relatie tot laagdikte en deze worden vergeleken met directe composieten. Hierbij zijn twee keramische materialen (IPS e-max CAD, EmpressCAD (Ivoclar Vivadent)), twee indirecte composieten (Esteenia (Kuraray), Sinfony (3M)) en twee directe composieten (Clearfil AP-X (Kuraray), Tetric EvoCeram (Ivoclar Vivadent)) gebruikt. Van ieder materiaal werden 25 monsters in verschillende laagdiktes (0.5-3.0 mm) vervaardigd en gecementeerd op runderdentine. Voor het meten van de druksterkte werden de monsters in een universeel testapparaat geplaatst (MTS, 858 Mini Bionix®II). Hierbij werd gebruik gemaakt van een bolvormige stylus met een diameter van 6.15 mm en een snelheid van 0.5 mm/s. Ieder monster werd uniaxiaal belast tot falen. Voor ieder materiaal werd een regressiemodel, gebaseerd op de Weibull-verdeling, gebruikt om de relatie tussen laagdikte en falen in te schatten. Ook materiaalgroepen werden vergeleken. Behalve Tetric EvoCeram, lieten alle materialen een significante positieve relatie zien tussen laagdikte en druksterkte, waarbij een toenemende sterkte gepaard gaat met een toenemende laagdikte. ProCAD vertoonde significant slechtere resultaten dan alle andere materialen, zeker in vergelijking met het andere keramische materiaal (IPS e-max CAD) ($p=0.001$). Voor de meeste geteste materialen gold dat een dikkere laagdikte meer sterkte gaf, alhoewel deze eigenschap afhankelijk leek van de keuze voor het materiaal en/of de fabrikant. Omdat directe composieten de beste resultaten lieten zien, binnen de beperkingen van deze studie, zou het raadzaam zijn voor tandartsen om deze materialen te overwegen als een goede keuze voor het restaureren van ernstige gebitsslijtage.

De klinische prestaties van directe composietrestauraties voor de behandeling van ernstige gebitsslijtage is onderzocht in **hoofdstuk 5**. Het doel van deze retrospectieve klinische studie was het evalueren van de prestaties van directe composietrestauraties die geplaatst zijn bij patiënten met ernstige gebitsslijtage en waarbij een verhoging van de occlusale verticale dimensie nodig was. Voor deze studie werden patiënten met gebitsslijtage geselecteerd, die behandeld zijn in een algemene tandheelkundige praktijk tussen april 1996 en juli 2007. Alle patiënten zijn behandeld met directe composietrestauraties in een verhoogde occlusale verticale dimensie en er is een drie-staps ets-en-spoel adhesief systeem met een hybride composiet gebruikt. Uit behandeljournaals werd informatie over re-interventie of vervanging van restauraties verkregen. Patiënten werden klinisch beoordeeld om de status van de restauraties te evalueren en er werden vragen gesteld over hun tevredenheid met de restauratieve behandeling met behulp van een Visual Analoge Scale (VAS). Achttien patiënten (16 mannen, 2 vrouwen met een gemiddelde leeftijd van 44.8 jaar) met ernstige gebitsslijtage werden geïncludeerd in de studie. De behandeling was 6 maanden tot 12 jaar geleden uitgevoerd en de gemiddelde observatietijd was 3,98 jaar. Van de 332 behandelde gebitselementen, waren er 23 gefaald (6,9%). Acht restauraties (2,4%) lieten grote breuken zien, 11 restauraties (3,3%) lieten kleine breuken zien en vier restauraties (1,2%) faalden door secundaire cariës. VAS data op een 0-10 schaal liet een hoge patiënttevredenheid zien met dit type behandeling (gemiddeld 9,0). Behandeling met directe hybride composietrestauraties geplaatst in een verhoging van de occlusale verticale dimensie liet een goed klinisch resultaat zien in patiënten met gebitsslijtage.

Resultaten van dit proefschrift worden bediscussieerd en in een bredere context geplaatst in **hoofdstuk 6**. Het kan een behoorlijke uitdaging voor tandartsen zijn om in het hele spectrum van behandelopties het juiste materiaal, de juiste methode en het beste moment van ingrijpen te kiezen. Er lijkt een trend zichtbaar richting minimaal invasieve technieken. Erg weinig bewijs wordt gevonden in de tandheelkundige literatuur voor de behandeling van gebitsslijtage. Veel onderzoek moet nog gedaan worden, voordat tandartsen patiënten evidence based behandelingen kunnen aanbieden. Suggesties voor toekomstig onderzoek worden ook in dit onderzoek gegeven. In vitro slijtage simulatie en cyclische belasting zouden toegevoegd moeten worden aan de druksterkte test om de klinische relevantie van deze onderzoeken te verbeteren. In een klinische prospectieve studie zou etiologie van de gebitsslijtage gekoppeld moeten worden aan faalgedrag. Er lijkt dringend behoefte aan een grote klinische studie. Een blik in de toekomst wordt ook gegeven. Nieuwe digitale technieken kunnen veel hulp bieden in de behandelplanning. Ook in combinatie met indirect gefabriceerde minimaal invasieve restauraties, gebaseerd op de originele anatomie van tanden, kan dit een enorme toevoeging zijn voor het behandelen van patiënten met ernstige gebitsslijtage.

Als toevoeging op de algemene hoofdstukken wordt in de bijlage een voorbeeld gegeven van een behandeling van een patiënt met ernstige gebitsslijtage. De methode wordt stap voor stap uitgelegd.