Statement of problem. Treatment of tooth wear is increasing. Because no evidence-based guidelines are available, the clinician may have difficulties deciding which treatment option to choose to resolve complex situations.

Purpose. The purpose of this study was to identify similarities among treatment options for generalized tooth wear and to develop an approach to rehabilitation based on the best evidence available.

Material and methods. A Medline and Cochrane search (for articles published from January 31, 2003, to January 31, 2013) was conducted. Minimally invasive and fully described treatments for generalized tooth wear with esthetically satisfying results were included. Five steps within the treatment procedures were analyzed: diagnostic waxing (DW), occlusal positioning (OP), vertical dimension increase (VDI), restoration, and follow-up.

Results. Common threads were established within the 5 treatment steps. Nine studies used DW, and 6 performed diagnostic tooth arrangement (DTA). Centric relation was used in 5 studies, and VDI was tested in 8 studies, 5 of which used a removable appliance. Seven studies implemented a provisional stage, and 5 used composite resin at that time. For definitive treatment, composite resin (6 studies) and glass ceramic (6 studies) were used. Seven studies applied a protective appliance, and 5 scheduled regular posttreatment evaluation as means of aftercare.

Conclusions. Within the limitations of this systematic review, the present evidence is not strong enough to form conclusions, and the presented similarities cannot be substantiated with evidence. Therefore, comprehensive clinical research into the designated treatment of generalized tooth wear is recommended. (J Prosthet Dent 2014;●:●:●)

Clinical Implications
The available evidence advises the use of diagnostic waxing and diagnostic tooth arrangement. The use of centric relation is advised for the occlusal positioning for rehabilitation. Testing of the vertical dimension increases with a removable appliance and the use of a provisional stage before definitive treatment is recommended. Both composite resin and glass ceramic are indicated, and a protective appliance with regular posttreatment evaluation is advised for follow-up.
The prevalence of the pathological loss of calcified tooth substance in a mechanical but particularly in a chemical way is globally perceived as an increasing problem. Tooth wear affects tooth anatomy, and all kinds of complications may arise if it is left untreated. These complications result from the loss of mineralized tooth substance and include a higher risk of tooth sensitivity, pulpal complications, and discoloration. Probably even more important is the loss of function and esthetics. The loss of occlusal vertical dimension may result in dentoalveolar compensation or an increased interocclusal rest space. This will affect the neuromusculature, efficiency of masticatory function, and esthetics as the position of the smile line, the horizontal occlusal plane, and the incisal edge position changes. Loss of anterior guidance and canine protection may increase horizontal stresses in the posterior occlusal surfaces and thereby cause loss and fracture of restorations. Moreover, instability of the occlusion will decrease masticatory function and increase the incidence of cheek and tongue biting. The described loss of tooth substance influences not only teeth and masticatory system but also quality of life.

Dentists should therefore use adequate diagnostic tools and indices to identify tooth wear while straightforward treatment is still possible. Accurate monitoring and use of diagnostic casts, indices, and/or intraoral photographs are recommended. At a certain stage, the restorative treatment of tooth wear is necessary to prevent the negative effects previously described.

The restoration of teeth with severe wear is complex. Several approaches that use different materials and techniques to restore worn dentition have been described. Unfortunately, no evidence-based guidelines are available to help clinicians choose the most appropriate therapy. At present, only expert opinions guide the clinician.

The objective of this systematic review was to identify different treatment options for generalized tooth wear according to modern, and in particular minimally invasive, dentistry. Is there a common thread in these treatment possibilities? In order to ensure a useful approach, the treatment should be simple, stepwise, adjustable, repairable, and cost-effective. Contemporary adhesive techniques meet most requirements. Remaining tooth structure needs to be preserved, and less experienced dentists should be able to treat the patient with satisfactory results.

Important steps to look into are the need for diagnostic waxing (DW), chosen occlusal position (OP), vertical dimension increase (VDI), restorations, and follow-up. Similarities or differences in treatment options are established analyzing these 5 treatment steps. Common similarities within different treatment options could be considered as the best available evidence for the choice of treatment for generalized tooth wear.

MATERIAL AND METHODS

Selection criteria

The purpose of the inclusion criteria was to select articles that described modern adhesive techniques and practical techniques for clinicians to use in the best interest of their patients. These criteria included fully described treatment for generalized tooth wear with data related to the clinical outcome. Both broad and detailed inclusion criteria were used. According to the broad inclusion criteria (Table I), the treatment should be minimally invasive, esthetically satisfying, and performed without the use of long-term removable dentures. Studies were considered minimally invasive when restorative procedures were performed with as little removal of healthy tissue as reasonably possible. This implies the use of adhesive procedures. Treatments were found to be esthetically satisfying when the original tooth proportions, smile line, horizontal plane of occlusion, and incisal edge position were restored. Treatments of wear that had progressed into the dentin were included.

After the broad selection, detailed inclusion criteria (Table II) were applied. Studies were included that described simple, stepwise, adjustable, repairable, and cost-effective treatments. Treatment was considered simple when the procedures were clearly explained and easy to execute, stepwise when treatment could be transferred step by step from a long-term interim restoration to a definitive stage or when a technique with direct composite resin was used, adjustable and repairable when adhesive techniques were used, and cost-effective when a segmented transfer was possible or a direct composite resin was used.

Furthermore, only English-language articles concerning humans published in dental journals in the last 10 years were included. Because only adhesive techniques could meet the selection criteria, the literature search was limited to the past 10 years. This period was expected to contain the best evidence available because the prevalence (and as a result probably the treatment) of tooth wear is increasing. Studies describing highly invasive, esthetically disappointing, complicated, non-adjustable, nonrepairable, or expensive treatments were excluded. Studies describing the treatment of only posterior or anterior dentition or incomplete

<table>
<thead>
<tr>
<th>Table I. Broad inclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Generalized tooth wear.</td>
</tr>
<tr>
<td>Complete description of treatment.</td>
</tr>
<tr>
<td>Wear into dentin.</td>
</tr>
<tr>
<td>Minimally invasive.</td>
</tr>
<tr>
<td>No removable dentures.</td>
</tr>
<tr>
<td>Esthetically satisfying.</td>
</tr>
<tr>
<td>Minimal edentulous spaces prior to treatment.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Table II. Detailed inclusion criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Simple.</td>
</tr>
<tr>
<td>Stepwise treatment.</td>
</tr>
<tr>
<td>Adjustable and repairable.</td>
</tr>
<tr>
<td>Cost-effective.</td>
</tr>
</tbody>
</table>
treatment descriptions were also excluded.

Search methodology

A literature search of the Medline and Cochrane databases (from articles published from January 31, 2003, to January 31, 2013) was performed to identify studies for inclusion. The Medical Subject Heading (MeSH) “Tooth Wear” linked to the MeSH subheading “therapy” was used (“Tooth Wear/therapy” [MeSH]). The Cochrane database search was designed as a permutation of the Medline search strategy by manually selecting the studies of the last 10 years. To ensure a highly sensitive search strategy, only the MeSH term “Tooth Wear/therapy” [MeSH] was used. This MeSH term also covers tooth abrasion, tooth attrition, and tooth erosion.

The results of the search were extended by hand searching. Hand searching was performed by citation mining and expert recommendations. The performed searches are shown in Table III.

<table>
<thead>
<tr>
<th>Database</th>
<th>Search No.</th>
<th>Search Terms</th>
<th>No. of Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medline (up to January 31, 2013)</td>
<td>1</td>
<td>“Tooth Wear/therapy” [MeSH]</td>
<td>1366</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>#1 AND (“last 10 years” [PDat] AND Humans [MeSH] AND English [lang] AND jsubsetd [text])</td>
<td>518</td>
</tr>
<tr>
<td>Cochrane (up to January 31, 2013)</td>
<td>1</td>
<td>MeSH descriptor: [Tooth Wear] explode all trees and with qualifier(s): [Therapy-TH]</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>#1 AND “last 10 years” (manual)</td>
<td>32</td>
</tr>
</tbody>
</table>

Data collection

All 550 identified titles were assessed for subject relevance and screened for inclusion. The abstracts were then obtained from 111 appropriate titles and assessed for inclusion according the broad inclusion criteria (Table I). Then 36 full texts were obtained and assessed according to the broad and detailed inclusion criteria (Table II). This selection process was chosen to prevent unjustified exclusion at an early stage. Twenty publications were excluded.

To support the use of the inclusion criteria, some excluded articles will be explained. The study by Meyers15 was excluded because the esthetic result was disappointing and the original tooth proportions were not restored. The study by Avinash16 was also excluded because of the invasive treatment procedures performed, even though enough space was available for noninvasive restorative treatment. The study by Fradeani et al17 was excluded because the treatment was considered to be neither stepwise nor cost-effective.

Table III. Search conducted in Medline and Cochrane databases

<table>
<thead>
<tr>
<th>Database</th>
<th>Search No.</th>
<th>Search Terms</th>
<th>No. of Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Medline (up to January 31, 2013)</td>
<td>1</td>
<td>“Tooth Wear/therapy” [MeSH]</td>
<td>1366</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>#1 AND (“last 10 years” [PDat] AND Humans [MeSH] AND English [lang] AND jsubsetd [text])</td>
<td>518</td>
</tr>
<tr>
<td>Cochrane (up to January 31, 2013)</td>
<td>1</td>
<td>MeSH descriptor: [Tooth Wear] explode all trees and with qualifier(s): [Therapy-TH]</td>
<td>63</td>
</tr>
<tr>
<td></td>
<td>2</td>
<td>#1 AND “last 10 years” (manual)</td>
<td>32</td>
</tr>
</tbody>
</table>

The included studies were analyzed and described. The year, type of study, number of patients, follow-up period of the definitive treatment stage, and publishing journal of the studies are listed in Table V. The 11 different treatments for generalized tooth wear were also assessed by analyzing the 5 different treatment steps: DW, occlusal position (OP), VDI, restoration, and follow-up.

These steps were chosen because they provide the basics of treatment procedures, depend as little as possible on the preference of the practitioner, and are probably well described in most studies. More detailed procedures (such as, interocclusal record registration) depend more on practitioner preference. Each step was analyzed by means of research questions, and the results were schematized on a chart. To determine a common thread in different treatment steps, there should be similarity in at least 5 studies.

Seven research questions were asked about each included study in accordance with the 5 different treatment steps, as shown in Table VI.

Results

Description of studies

A total of 16 publications on the treatment of generalized, complete-arch tooth wear met the inclusion criteria (Table IV). By merging sub-studies, a total of 11 studies were included and analyzed.
All included studies were case reports (8 studies) or case series (3 studies) that studied between 1 and 4 patients and were published between 2007 and 2012 (Table V). The follow-up period after the definitive treatment stage ranged from 0 to 20 months. The follow-up of the interim stage was not included.

**Results of analysis**

The 5 treatment steps and potential similarities between the treatment options were analyzed by following the specific research questions. The results of the analysis are described below and are shown in Table VII.

DW was used in 9 studies for communication with both the patient and the dental laboratory, for the fabrication of templates, for diagnostic tooth arrangements (DTA), and for interim and definitive restorations. One study used computer-aided design (CAD) waxing. Both diagnostic and anatomic waxings were used. Six studies performed a DTA with templates and (temporary) composite resin to evaluate the treatment outcome and, if needed, to make adjustments.

Centric relation (CR) was the occlusal position of choice for rehabilitation in 5 studies, and maximum intercusption (MI) was used in 2 studies. The remaining studies did not mention the use of the occlusal position.

The VDI was tested before treatment in 8 of 11 studies. Five studies used a removable appliance, one of which combined it with anterior composite resin. Four studies used a fixed method with different materials, including (in) direct composite resin and metal interim restorations. The overall period of testing ranged from 1 to 3 months, but 1 study used an extended period of 6 months. When using a removable splint, the study authors recommended 24 hours of use a day.

**DISCUSSION**

**Key findings**

The objective of this systematic review was to identify recent treatment options for generalized tooth wear and to identify within these treatment options a common thread of 5 important
treatment steps. These findings could guide the clinician through the complex treatment of generalized tooth wear.

Level of evidence

All included studies were case reports or case series with small numbers of patients and short or no follow-up treatment. Assessing the included studies on the rating of the publishing journals is not possible, and therefore no study quality rating was performed. The case reports and case series should be accepted as proof of principles and provide the best evidence to guide the clinician during treatment. Nevertheless, the present evidence is not strong enough to form conclusions (low level of evidence). 10

Interpretation of results

DW and DTA were frequently used (in more than 5 studies) so a common thread was determined. During the treatment of severe tooth wear, the use of DW and DTA may benefit the clinician in the following ways: it allows the treatment outcome to be previewed while adaptations are still possible; it informs the patient; it aids the fabrication of templates that are advantageous during adhesive foundations and preparation; and it provides better communication between dentist, patient, and dental technician. 4,14,23,29,30 The disadvantages are the costs and time associated with DW and DTA. 33

CR was most frequently used and was determined to be a common thread. Although the use of CR may help the clinician during treatment, considering the molar occlusion in the decision whether to choose MI or CR is probably wise. 29,34 Moreover, determining CR may be difficult, and combined with an unfavorable molar occlusion, it may lead to an unnecessary increase in the horizontal overlap. 29 In contrast, CR is often recommended because of its reproducibility. 34 Changes in the occlusal scheme appear not to cause temporomandibular disorder-related problems when absent before treatment. 35

The VDI was tested before treatment in most studies; this step was determined to be a common thread. According to previous studies, testing the VDI is only needed when the remaining interocclusal rest space after rehabilitation will be less than 2 to 3 mm. 6,22 Increasing the occlusal

---

**Table V.** Overview of included studies

<table>
<thead>
<tr>
<th>Study</th>
<th>Year</th>
<th>Type of Study</th>
<th>No. of Patients</th>
<th>Follow-up Period (mo)</th>
<th>Publishing Journal</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dietschi 18</td>
<td>2011</td>
<td>Case report</td>
<td>*</td>
<td>*</td>
<td>Eur J Esthet Dent</td>
</tr>
<tr>
<td>Edelhoff 19</td>
<td>2012</td>
<td>Case report</td>
<td>1</td>
<td>0</td>
<td>Quintessence Int</td>
</tr>
<tr>
<td>Mizrahi 23</td>
<td>2008</td>
<td>Case report</td>
<td>1</td>
<td>0</td>
<td>Eur J Esthet Dent</td>
</tr>
<tr>
<td>Spreatfeco 27</td>
<td>2010</td>
<td>Case report</td>
<td>1</td>
<td>9</td>
<td>Eur J Esthet Dent</td>
</tr>
<tr>
<td>Mehta 22</td>
<td>2012</td>
<td>Case series</td>
<td>2</td>
<td>0</td>
<td>Br Dent J</td>
</tr>
<tr>
<td>Schwarz 26</td>
<td>2011</td>
<td>Case report</td>
<td>1</td>
<td>6</td>
<td>J Prosthet Dent</td>
</tr>
<tr>
<td>Reston 24,25</td>
<td>2010, 2012</td>
<td>Case series</td>
<td>2</td>
<td>0</td>
<td>Oper Dent</td>
</tr>
<tr>
<td>Stumbaum 28</td>
<td>2010</td>
<td>Case report</td>
<td>1</td>
<td>0</td>
<td>Int J Comput Dent</td>
</tr>
<tr>
<td>Garcia 20</td>
<td>2009</td>
<td>Case report</td>
<td>1</td>
<td>20</td>
<td>Bull Tokyo Dent Coll</td>
</tr>
<tr>
<td>Hayashi 21</td>
<td>2007</td>
<td>Case report</td>
<td>1</td>
<td>12</td>
<td>Oper Dent</td>
</tr>
</tbody>
</table>

*No result could be established.

**Table VI.** Research questions

<table>
<thead>
<tr>
<th>Treatment Step</th>
<th>Research Question</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 DW</td>
<td>Was DTA performed?</td>
</tr>
<tr>
<td>2 DW</td>
<td>Was DW used for treatment or treatment planning?</td>
</tr>
<tr>
<td>3 VDI</td>
<td>Was VDI tested before treatment?</td>
</tr>
<tr>
<td>4 Restoration</td>
<td>Which restorative materials were used, including possible provisional and definitive restoration?</td>
</tr>
<tr>
<td>5 Follow-up</td>
<td>How was follow-up performed?</td>
</tr>
</tbody>
</table>

CR, centric relation; DTA, diagnostic tooth arrangement; DW, diagnostic waxing; MI, maximum intercuspation; VDI, vertical dimension increase.
vertical dimension seems to be a safe procedure (signs and symptoms tend to be self-limiting) and well accepted up to 5 mm.\textsuperscript{34,36} The testing periods varied in this study. If necessary, testing the VDI for a period of at least 1 month for 24 hours a day is probably advised.\textsuperscript{5,22} In addition, Abduo\textsuperscript{34} concluded that testing patient acceptance or adaptation with a removable method is less predictable than with a fixed method. In this review, 4 studies used a fixed method; therefore, this method was not considered to be a common thread.

The majority used an interim stage before definitive treatment. The implementation of an interim stage during the treatment of generalized tooth wear was established to be a parallel within 7 studies and could be used as guidance. The implementation of this stage is performed to evaluate treatment outcome and patient acceptance.\textsuperscript{14,19} Changes in esthetics and

\begin{table}[h]
\centering
\begin{tabular}{|l|c|c|c|c|c|c|c|c|c|}
\hline
Study & DW & DTA & OP & VDI & Method & Wk & Interim & Definitive & Follow-up \\
\hline
Dietzch\textsuperscript{18} & Yes & * & MI & * & * & * & None & Composite resin (direct/indirect), lithium disilicate & Protective splint, regular check-ups \\
\hline
Edelhoff\textsuperscript{19} & Yes & Yes & CR & Yes & Occlusal splint & 12 & High-density PMMA (CAD/CAM) & Lithium disilicate & Clinical evaluation and modification, segmented transfer \\
\hline
Garcia\textsuperscript{20} & Yes & * & CR & Yes & Occlusal splint & * & None & Composite resin (direct), metal resin, gold & Protective splint \\
\hline
Hayashi\textsuperscript{21} & Yes & * & * & Yes & Acrylic resin (anterior), metal (posterior) & 26 & Acrylic resin, metal & Gold, glass ceramic & Protective splint, 3 mo recall \\
\hline
Mehta\textsuperscript{22} & Yes & Yes & CR & Yes & Occlusal splint & 4 & Composite resin (indirect) & Gold, metal ceramic, composite resin (indirect) & Protective splint (Michigan type) \\
\hline
Mizrahi\textsuperscript{23} & Yes & Yes & CR & Yes & Direct composite resin (anterior), occlusal splint (posterior) & 8 & Composite resin (direct/indirect) & Glass ceramic, gold, metal ceramic & Protective splint (Michigan type) \\
\hline
Reston\textsuperscript{24,25} & Yes & * & * & * & * & * & None & Composite resin (direct) & Protective splint, segmented transfer (when necessary) \\
\hline
Schwarz\textsuperscript{26} & Yes & Yes & * & Yes & Direct composite resin & 12 & Composite resin (direct) & Lithium disilicate & Evaluation of occlusion, oral hygiene instruction \\
\hline
Spreatfico\textsuperscript{27} & Yes & Yes & * & * & * & * & None & Composite resin (direct/indirect) & Evaluation of occlusion \\
\hline
Stumbaum\textsuperscript{28} & Yes & * & CR & Yes & Occlusal splint & 4-8 & High-density PMMA (CAD/CAM), composite resin (indirect) & Zirconia ceramic & Protective splint, segmented transfer to zirconia ceramic \\
\hline
Vailati\textsuperscript{29-32} & Yes & Yes & MI & Yes & Direct composite resin (posterior) & 4 & Composite resin (direct) & Composite resin (indirect), glass ceramic & Segmented final restoration posterior \\
\hline
\end{tabular}
\caption{Overview of analyzed treatment steps}
\end{table}

\textsuperscript{CR, centric relation; DTA, diagnostic tooth arrangement; DW, diagnostic waxing; MI, maximum intercuspation; OP, occlusal positioning; PMMA, polymethyl methacrylate; VDI, vertical dimension increase.}

\textsuperscript{*No result could be established.}
function can still be made with little effort and without consequences before starting the definitive restorative phase. This simplifies the rehabilitation and creates the opportunity to perform a stepwise treatment and to spread accompanying costs over several years. In contrast, implementing an interim stage does lengthen the treatment period and increase total treatment costs. In this review, composite resin was established to be the restorative material of choice during the interim phase.

For the definitive treatment procedure, both composite resin and glass ceramics were the most commonly used restoratives and were used in at least 5 of the included studies.

According to the recent literature, composite resin seems to be a suitable restorative material for restoring worn dentition. Jaeggi et al recommended the use of an indirect restorative material when the VDI exceeds 2 mm because restoring the anatomy and occlusion is difficult and depends on the sculpting skills of the dentist. In the long term, there seems to be little difference between direct and indirect composites. Therefore, other indirect materials are indicated for long-term stability; glass ceramic (lithium disilicate) and gold are preferred.

Both a protective appliance and regular posttreatment evaluations were found to be a common thread in the treatment procedures and could be used as guidance. An appliance protects the restored dentition from nonfunctional (damaging) habits during the night.

Limitations

The literature research was limited to the period of 2003 to 2013 to simplify the data collection and to exclude studies based on nonadhesive techniques. Studies based on adhesive techniques published before 2003 may have been excluded, but all included articles were published in 2007 or later, indicating that suitable studies are likely to have been published in the last 10 years.

The selection criteria used limited the reproducibility of this review. By using examples of exclusion, this was obviated as much as possible. Assessing the outcome of the studies was almost impossible because most studies did not provide useful photographs. For example, the study performed by Smale and Berekally did not provide any photographs for judgment.

Only 5 treatment steps were analyzed in this review. Obviously, the treatment procedure consists of many more treatment steps. For example, making a facebow registration was not included. Only 1 researcher performed data collection and data analysis. Therefore, the selection and analysis procedure was not controlled by a second researcher and may have been biased.

This review identifies and summarizes different treatment options for treating generalized tooth wear. Common similarities in different treatment steps may be considered as the best evidence available to guide the clinician in these steps. Unfortunately, evidence-based guidelines are still unavailable.

CONCLUSIONS

Within the limitations of this systematic review, it can be concluded that the present evidence is not strong enough to form firm conclusions, and the presented similarities cannot be substantiated with evidence. Therefore, comprehensive research into the designated treatment of generalized tooth wear is highly recommended.

The similarities established within various treatment steps may still be helpful to the clinician. The present available evidence advises the use of DW and DTA and the use of CR as the OP for rehabilitation. Furthermore, testing of the VDI with a removable appliance and the use of a provisional stage before definitive treatment is recommended. Both composite resin and glass ceramic are indicated materials for final treatment. A protective appliance with regular evaluation is indicated for follow-up.

REFERENCES


