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Vertical tooth surface loss – a narrative review

Part II: therapy and aftercare

Introduction: Tooth surface loss (TSL) is a physiological process, which is multifactorial and progresses throughout life. Depending on the extent and progression of TSL, it may be necessary for the dental practitioner to initiate individualized preventive and/or therapeutic measures in cooperation with the affected patient.

Methods: In the first part of this narrative review, a literature search on PubMed and in the S3 guideline on bruxism was conducted; various studies appearing up to February 2020 were evaluated. Within this framework, the second part of this article explains when pre-restorative treatments are indicated, when a bite elevation should be performed, as well as, how it can be implemented and to what extent it is limited. Moreover, the various pre-prosthetic and restorative treatment options are elucidated. Additionally, the different dental materials and their advantages and disadvantages in terms of esthetics, function and long-term results are described.

Results: Although physiological, age-related TSL is an indication for treatment only in exceptional cases, extensive TSL affecting the supporting zone of the dentition or reaching far into the dentin usually must be treated. In such cases, it may be necessary to restore and secure the occlusal and vertical jaw relation by means of prosthetic rehabilitation. Most commonly, extensive TSL is treated by means of indirect restorations made of metal and ceramics. In this respect, tooth preparation for crowns and bridges can be seen as a disadvantage as it results in additional circular loss of tooth substance. Tooth-colored, minimally invasive restorations are considered a good alternative depending on the financial means of the patient.

Conclusion: At present, there is no universally suitable restorative therapy concept for patients with TSL; rather, highly individualized treatment decisions must be made for each patient whereby both esthetic and functional parameters are taken into consideration in the decision-making process.

Keywords: bite elevation; bridge; ceramic; composite; crown; non-cariogenic tooth surface loss (TSL); splint

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1. Introduction

According to the findings of the Fifth German Oral Health Study, the number of carious lesions in Germany is steadily declining. At the same time, younger seniors have fewer missing teeth in their dentitions compared to the findings in previous surveys (Third or Fourth German Oral Health Study; DMS III: 10.4 teeth, DMS V: 16.9 teeth) [22]. Meanwhile, a reverse trend is occurring with regard to the prevalence of non-cariogenic tooth surface loss, as it is steadily increasing [9]. Tooth surface loss (TSL) is a physiological process, which is multifactorial and progresses throughout life [5]. Depending on the extent and progression of TSL, especially when considering the specific age of the patient, it can be pathological, and therefore, oblige the dental practitioner to initiate individualized preventive or therapeutic measures in cooperation with the affected patient (Figures 1 and 2) [49]. In the first part of this narrative review (Dtsch Zahnärztl Z Int 2021; 3: 148–157), the causes of non-cariogenic TSL were examined, diagnostic options were presented, and a decision tree was used to summarize the particular cases in which different treatments may be indicated. For this purpose, various studies published on PubMed and in the S3 guideline on bruxism up to February 2020 were evaluated on the basis of topic-related search terms; a manual search of these studies' respective reference lists was also conducted. In this context, the second part of this narrative review aims to discuss the possible treatment options in more detail, focusing on pre-prosthetic and restorative measures.

Figure 1 Initial situation before the start of treatment, extraoral.

Figure 2 Initial situation before the start of treatment, intraoral. The 67-year-old patient presented himself with the wish for prosthetic rehabilitation. Pronounced non-cariogenic TSL and severe bruxism were present. Clinically, soft plaque, tartar and generalized gingivitis were identified. As specified in the medical history the clinical functional analysis confirmed that parafunctions were present, however these were asymptomatic. Furthermore, untreated interdental gaps in the missing tooth regions 014 and 046 were particularly noticeable. The maxillary incisors displayed reduced crown heights to varying degrees and dentin exposure was clinically evident.

Figure 3 Based on dentofacial and cast analyses, an increase in height by 10.5 mm and 7.5 mm was planned for the maxillary and mandibular central incisors, respectively, together with a 4 mm increase of the vertical jaw relation. Using splint therapy, the new jaw relation was tested for a period of 3 months (Figure 2). Meanwhile, extensive oral hygiene and prophylactic measures took place.

2. Pretreatment

2.1 Bite elevation – when and how?

In the majority of patients, TSL is accompanied by dentoalveolar compensation [5]. This physiological compensation mechanism ensures that, despite the loss of tooth structure, antagonist tooth contacts and the efficiency of his masticatory system are maintained [5]. Simultaneously, this process leads to a deficit of interocclusal space and creates a dilemma for the dental practitioner, especially in cases of localized TSL. One solution is to further reduce the occlusal surfaces of the affected teeth. Besides further loss of tooth substance, this procedure often results in a greatly reduced crown height of the abutment teeth, which in turn, reduces the potential retention and resistance forces needed for prospective prosthetic restorations [42]. Surgical crown lengthening can counteract this problem in certain circumstances, but it involves a risk of complications associated with the surgical procedure [42] and it always causes a

Direct composite restorations	
Advantages	**Disadvantages**
Low costs with an acceptable esthetic result	Polymerization shrinkage causes marginal gap formation and generates heat
Non-invasive procedure, conserves tooth substance and pulp	Faster wear compared to prosthetic restorations made of metal/ceramic
Suitable for diagnostic purposes	Low fracture strength
Minimally abrasive towards antagonist teeth	Esthetic deterioration due to discoloration
Simple to repair and expand	Technique sensitive (moisture control is mandatory)
	Result and long-term stability depend on the quantity and quality of the enamel
	Reduced potential for shaping proximal contacts compared to crowns
	For large restorations with changes in the vertical dimension, optimal fitting is difficult to achieve

Table 1 Advantages and disadvantages of direct composite restorations [31]

Indirect composite restorations	
Advantages	**Disadvantages**
Improved ability to shape occlusal morphology and proximal contacts	Reduced marginal fit compared to metal/ceramic restorations
Improved potential to adequately increase the vertical dimension for large restorations	More treatment steps necessary compared to direct composite restorations
Better esthetic results compared to metal restorations	Additional dental laboratory costs
Reduced treatment time for the dentist as intraoral modifications can be performed at the same time	Potential undercuts of the tooth substance must be corrected leading to additional tooth surface loss
Low abrasiveness towards antagonist teeth	Technique sensitive (moisture control mandatory)
Compared to direct composite restorations, increased fracture strength and longer durability	Lower long-term stability compared to ceramic/metal restorations
No or reduced intraoral polymerization shrinkage	

Table 2 Advantages and disadvantages of indirect composite restorations [31]

reduction in the periodontal attachment.

Bite elevation should be performed when dental treatment is needed for medical and/or esthetic reasons. For instance, this is the case when there are extensive defects affecting the entire dentition, with a considerable reduction of the vertical crown height and esthetic deficits (Figure 1 and 2), and these can no longer be selectively restored by means of direct or indirect measures, and when other alternatives to acquire space, such as a surgical crown extension, are not suitable. [21, 25, 45]. In spite of the fact that physiological, age-related abrasions/attritions are only an indication for treatment in exceptional cases, TSL associated with parafunctions can frequently be treated just symptomatically. In cases of extensive TSL, which affects all supporting zones of the dentition or extends deep into dentin, it may be necessary to treat the affected teeth using prosthetic measures in order to restore and secure the occlusal and vertical jaw relation in the long-term [8, 13].

Before raising the vertical jaw relation using definitive restorations, depending on the extent of the desired change, a preliminary test phase should be considered in order to test this change using reversible procedures [9]. Beforehand, however, functional diseases should be excluded for forensic reasons; if necessary, the pre-restorative procedures should then be performed together with the functional treatment measures.

2.2 Determination of the vertical jaw relation

For all definitive restorative treatment options, regardless of whether they are non-invasive, minimally invasive, invasive or additive, the planned vertical jaw relation must be determined in advance. In the posterior tooth region, sufficient space should be created for the future restoration and the required minimum material thickness, while simultaneously, taking care not to exceed a crown/root ratio of 1:2. Also, in the context of an increase or change in the vertical jaw relation, an anterior canine guidance in dynamic occlusion should be pursued while also adhering to the Spee and Wilson curves. Frequently, in an abraded dentition, both jaws must be adjusted due to the heavy wear of the occlusal morphology. Especially in the anterior region, esthetic aspects play a decisive role in determining the vertical jaw relation. It is therefore recommended to simulate the treatment result with the help of a mock-up (Figure 4).

2.3 Pre-restorative options for simulating the treatment result

There are currently only a few scientific studies regarding the influence of changes in vertical jaw relation on the genesis of craniomandibular dysfunctions. In systematic reviews, however, various authors assume that raising the vertical jaw relation in the context of a bite elevation of up to 5 mm is not critical; generally speaking, patients would adapt well to the new jaw relation and only mild and temporary complaints would occur, if at all [1, 2, 37]. Nonetheless, in principle, care should be taken to ensure that a resting position is still present after the vertical jaw relation has been changed; major changes should be carried out incrementally [36]. According to current case law and the view of the German Society for Functional Diagnostics and Therapy (DGFDT), a functional examination of the craniomandibular system as part of a clinical functional analysis is indicated before reconstructive measures are performed in order to detect any latent functional problems and plan treatment. From a forensic perspective, the Higher Regional Court of Munich decided in 2017 (file number 3U 5039/13) that screening to clarify hidden craniomandibular dysfunction (CMD) prior to prosthetic treatment is a medical standard and that failure to carry out the required screening prior to the start of prosthetic treatment constitutes a diagnostic error.

A common pre-restorative pretreatment that is used for the scope of complex rehabilitation of patients with non-cariogenic TSL is splint therapy (Figure 3). Owing to their adjustable characteristic, splints have a wide range of indications and serve as a standard dental procedure during pre-prosthetic treatment. Especially in patients with parafunctions, occlusal splints such as equilibration splints (also known as Michigan splints, stabilizing splints, or relaxation splints) can eliminate occlusal interferences or reduce parafunctional activities [39]. Occlusal splints can be used to test possible changes in the vertical, and if needed, also in the horizontal jaw relation [13]. This allows the new intended bite position to be reversibly tested over a defined period. Based on the authors‘ knowledge, in these cases, there is no reliable evidence regarding the question of how long splint therapy should take place for the purpose of testing a new bite position. Depending on the clinical case, periods between 3 and 12 months have been shown to be effective based on the authors‘ experience. In the context of treatment planning, a generally reduced patient compliance should be taken into account during a prolonged wearing period. These steps enable the patient to adapt to the new vertical, and perhaps horizontal, jaw relation; readjustments are possible afterwards. According to the authors‘ experience, if pronounced wear facets that indicate parafunctional activity are visible on the splint, performing a bite elevation is associated with the risk of non-adaptation [36]. New digital technologies in the field of computer-aided design and computer-aided manufacturing (CAD/CAM) also make it possible to manufacture tooth-colored and flexible polycarbonate splints; they represent a non-invasive, removable, and thus reversible, functional and esthetic solution in contrast to conventional transparent splints or fixed long-term temporaries (Figure 9) [12, 13]. In this way, the esthetic appearance can be noticeably improved at an early stage of treatment; moreover, CAD/CAM-milled splints are dimensionally and chromatically stable, have better biocompatibility and show less wear while also displaying improved fitting accuracy compared to conventional polymethyl methacrylate splints [12, 13]. If there is severe TSL, the vertical dimension can be increased by manufacturing a separate polycarbonate splint for each jaw.

The Dahl concept represents an alternative approach. It describes an axial tooth movement that occurs when an appliance is introduced in supraocclusion; teeth that are not supported by the bite block elongate in a vertical direction [8]. Originally, Dahl described a removable cobalt-chromium bite platform [8, 42], but a wide variety of materials such as direct or indirect composite core build-ups or CAD/CAM milled table-tops are used nowadays. The thickness of the appliance corresponds to the later anticipated gain of interocclusal/incisal space [42]. The effect is achieved

Figure 4 After the fabrication of a conventional wax-up for the upper and lower jaws, the casts were duplicated and molds for an intraoral mock-up were created. The molds were then filled with tooth-colored composite-based temporary material and positioned over the existing tooth hard substance. In this manner, a quick and simple visualization of the prospective treatment result is possible.

Figure 5 Where necessary, the teeth were restored by means of adhesive composite core build-ups. After creating a retention form, preparation of the restored abutment teeth ensured.

Figure 6 A diagnostic wax-up was used to check if he required amount of tooth substance was removed during preparation. With the help of the wax-up and the finished molds, temporary crowns and bridges could be made inexpensively by means of the chairside technique; these were worn for a period of 3 months to test the patient's adaptation to the new bite. The anterior mandibular teeth could be adjusted to the desired jaw relation using direct composite fillings.

by a combination of intrusion (40 %) and extrusion (60 %) of the teeth that are not in contact [7]. Scientific studies have substantiated a 94–100% probability of success, which appears to be independent of the patient's age and sex [7, 19, 20]. Moreover, it was shown that an increase in the vertical dimension of up to 5 mm could be achieved in this manner, whereby the result was achieved on average after 6 months. Nevertheless, depending on the amount of required space, periods between 18–24 months have been described [20, 46]. Additionally, there is of course the option of increasing the interocclusal space using orthodontic procedures [15].

Every definitive dental rehabilitation in patients with non-cariogenic TSL should be adequately tested in order to identify any potential problems with the occlusion at an early and reversible stage; this facilitates that any supplementary fine adjustments are made quickly and easily. As a rule, long-term temporaries are used during this phase [39]. They are indicated before the definitive prosthetic treatment in the case of therapeutic changes to the vertical and/or horizontal jaw relation, as they permit the testing of the changed vertical position to be performed with as little risk as possible [18]. The prosthetic requirements for long-term temporary restorations are in the broadest sense the same as those for permanent dentures. Conventional laboratory-fabricated long-term temporaries are made from non-precious alloys, which are veneered with composite according to requirements; however, with the emergence of CAD/CAM technology, these have been largely replaced by pre-polymerized polymethyl methacrylate in blank form and indirect composites. In concordance to the clinical findings and prognosis, long-term temporaries should be worn for a period of about half a year [39]. Especially in complex cases with craniomaxillofacial anomalies requiring interdisciplinary prosthetic-surgical treatment, such digital pre-prosthetic pretreatments can represent an important component [12]. In some treatment cases, it is also possible to directly handcraft a temporary restoration; for instance, the platinum foil technique can be applied to simulate the treatment results for a couple of months. Such an approach is considerably less expensive than laboratory-fabricated indirect restorations. Yet, both approaches still have the disadvantage of generally necessitating extensive and invasive measures for the fitting of the temporary restorations.

Metal restorations	
Advantages	**Disadvantages**
Can be fabricated even in very thin layers (0.5 mm)	Esthetic deficits – limited use in the anterior/visible region
Very good marginal fit	Intraoral modifications only possible to a limited extent
Low abrasiveness towards antagonist teeth	Additional dental laboratory costs compared to direct restorations
Good and stable long-term protection of the remaining tooth substance	Close proximal contacts with adjacent teeth in the posterior region can be a problem when using onlay restorations (YAP et al)
Especially suitable for posterior restorations in patients with parafunctions	Additional removal of tooth hard substance compared to adhesive composite restorations
More conservative tooth preparation design compared to ceramic crowns	

Table 3 Advantages and disadvantages of metal restorations made from gold and Co-Cr [31]

Ceramic restorations	
Advantages	**Disadvantages**
Very good esthetic results	Good polish necessary, otherwise high abrasion of the antagonists
High flexural strength and fracture toughness for ceramic restorations made from zirconia	High costs (compared to direct restorations)
Different ceramic materials for different requirements	Silicate ceramics are technique sensitive
Can be produced in very thin layers (0.5 mm zirconium dioxide)	
Very good marginal fit	
Good and stable long-term protection of the remaining tooth substance	
Different preparation designs possible (partial crowns, crowns or onlays) using adhesive cementation, minimally invasive preparation also possible	

Table 4 Advantages and disadvantages of of ceramic restorations [31]

In contrast, in some cases, when tooth preparation is not desired, it is possible to apply alternative temporary restorations in the form of chairside-produced or laboratory-fabricated veneers or table-tops made of polymethyl methacrylate or PMMA-based polymers that can be milled using various CAD/CAM systems (e.g. Telio CAD, Ivoclar Vivadent; CAD-Temp, Vita Zahnfabrik). They can be fixed on the tooth areas in form of a non-prep solution; self-adhesive luting composites are generally used for this purpose [10].

The basic prerequisite for the changeover from a temporary to a definitive jaw relation is the func-

Figure 7 Due to the patient's limited financial means and his desire for a long-term restoration given the existing parafunctions, crowns and bridges made from non-precious metals were fabricated by sintering (Sintron, Amann Girrbach, Koblach, Austria). Within the vestibular veneering limits, ceramic was used (dental technology: Polyakov and Müller, Regensburg). The sintering process was chosen in this case due to the abundant supply of non-noble alloys and the possibility of producing highly homogeneous restorations without voids using the CAD/CAM process.

Fig 1–8: S. Hahnel

Figure 8 After the successful try-in, the restorations were cemented using conventional zinc oxide-phosphate cement (Figure 6) and the patient was included in a recall system that included closely spaced check-ups.

Fig. 9: O. Schierz, Leipzig

Figure 9 Tooth-colored mandibular splint composed of polyoxymethylene.

tional freedom from symptoms of the patient [4]. Finally, it is recommended to record the initial, and when necessary, intermediate, and final functional findings in a standardized data entry form (for example, the clinical functional status of the DGFDT or similar documents) for forensic reasons. Material selection according to the clinical needs and conditions is essential for the subsequent restorative procedure; the required tooth preparation design, the manufacturing technology and the intended type of cementation of the final restoration should be reflected in the selection [4].

3. Definitive restorative phase

3.1 The right material for the definitive restoration

Currently there is no single restorative treatment concept for patients with TSL. On the contrary, a highly individualized treatment decision must be made for each patient. In order to be able to make a goal-oriented treatment concept and choose the correct material, various parameters should be taken into account in the decision-making process; these include the extent of the TSL, the additional loss of substance that is expected due to preparation, the final functional findings, the desired occlusion concept and the esthetic expectations regarding the restoration. Depending on the condition of the antagonists, the required minimum layer thickness and the material-related luting technique employed, a distinction must be made between the different available materials [4]. In addition, the type of material used in patients with bruxism is also important for example, as many manufacturers list bruxism as a contraindication. A retrospective clinical study followed 1335 all-ceramic restorations and found that the risk of material-related failure is 2.3 times higher in patients with bruxism [33]. Currently, there is no generally applicable rule. It is however worth considering to keep the treatment options as simple as possible and to favor non-veneered restorations in patients with pronounced TSL and additional parafunctions.

3.1.1 Composite

Minimally invasive, yet esthetically pleasing results, can be achieved with direct composite restorations [9]. Particularly milder forms of TSL need no additional preparation measures as this is a purely defect-oriented approach (Table 1). However, this procedure often requires preliminary work in the indirect process such as creating a wax-up/mock-up when a new jaw relation is to be set-up. Using nano-filler composites and nanohybrid composites, extended occlusal TSL can be treated by cusp replacement therapy using direct composite restorations [9]. This procedure represents a substance-preserving and cost-effective form of treatment for patients and it produces a good esthetic result with minimal occlusal wear in the long-term [9]. Furthermore, direct composite restorations can be used for diagnostic pretreatment in the case of a reconstruction of the bite height and they are much easier to repair than indirect restorations made of ceramic or metal (Table 1). A case-control study demonstrated that reconstructions of the vertical jaw relation with direct composite restorations was clinically satisfactory even after more than 5 years; however, negative changes such as marginal gaps, wear and discoloration were also evident [3]. Based on the Radboud Tooth Wear Project, a study by Loomans et al. showed that the clinical evidence for an increase of the vertical dimension in patients with severe TSL using direct composite restorations has so far been limited to a 5-year follow-up [27]. In this manner a study in which 34 patients with pathological TSL were treated with 1256 direct composite restorations (687 anterior, 324 premolar and 245 molar restorations) showed that the survival rate of direct restorations depended on which tooth the restoration was applied. Molars showed the worst prognosis [28]. In patients with parafunctions such as bruxism, TSL often progresses faster than in patients without additional parafunctions. Moreover, the materials used must be able to withstand additional parafunctional activities. This is the reason why the application range of direct composite restorations is often limited in patients with parafunctions. Other drawbacks are polymerization shrinkage, which can lead to gap formation at the edges of fillings, discoloration, as well as, high technique sensitivity (moisture control, ensuring enamel adhesion) [24, 32]. When direct composite restorations are used to reconstruct the vertical jaw relation, the high time expenditure and the difficulty in accurately reproducing the occlusal morphology is often criticized [4]. Clinical approaches to solving this challenge make use of template-based techniques such as splints or silicone indices [3,53]. In areas with high occlusal load, the material should also have a minimum layer thickness of 1.5–2 mm [42].

Currently, indirect composite restorations are rarely used in everyday clinical practice, but they do have some advantages over direct restorations. This includes reduced polymerization shrinkage due to the fact that polymerization of CAD/CAM composites already occurs during the manufacturing process. This eliminates the negative effect of clinical polymerization shrinkage which occurs with direct composites. Other advantages include reduced treatment duration, simple adjustment possibilities in the patient‘s mouth as well as lower abrasiveness towards the antagonists compared to ceramic restorations [32]. Some drawbacks include reduced marginal fit compared to metal or ceramic restorations and the higher costs compared to direct restorations (Table 2).

3.1.2 Indirect metal and ceramic restorations

Extended TSL is still most frequently treated with indirect restorations made from metal and ceramics (Figures 5 – 8). To date, it is worth mentioning that little scientific data is available regarding the clinical performance of restorations in the context of bite elevation [11].

In principle, metal crowns and bridges display very good long-term results (Table 5) [40]. Restorations made of metallic materials exhibit high elasticity and tensile strength as well as a good accuracy of fit with less tooth preparation compared to restorations made of ceramic. From an esthetic point of view, however, the grey/silver color and metallic luster must be criticized, which is why these restorations are generally veneered with an additional ceramic material in the visible area (Table 3). Ceramic restorations reflect the initially required material properties most broadly (Table 4). Ceramics, particularly glass-ceramics, show a more stable maintenance of the physiological occlusion in the long term compared to composite restorations, although again, losses are more frequent described in the posterior region than in the anterior region [40]. In order to combine proven conventional restorations with less invasive preparation designs, minimally invasive ceramic restorations such as table tops have been developed [9]. In this case, the preparation margin ends far supragingivally and usually at the level of the prosthetic equator. Silicate ceramics provide the best esthetic results and can be used in the anterior region as veneers and in the posterior region as smaller restorations [17, 29, 54]. In a long-term study, 34 patients were treated with 96 silicate ceramic inlays and onlays. After an observation period of 12 years, the survival rate was 84 % and it was shown that restorations cemented with dual-curing luting composites had a better survival rate than restorations cemented with light-curing luting composites [17]. Lithium disilicate ceramics have a higher flexural strength than classical silicate ceramics and can therefore sometimes be used as a material for 3-unit bridges (up to the 2nd premolar). To date, no manufacturers have indicated that these materials can be used for rehabilitating posterior areas [6, 14, 23, 30, 40, 43, 50]. In a prospective, non-randomized clinical study, 7 patients were treated with a total of 103 adhesively luted occlusal onlays made of lithium disilicate ceramic (IPS e.max Press, Ivoclar Vivadent). After 11 years, a survival rate of 100 % (Table 5) was observed, whereby 4 restorations in one patient showed slight discoloration at the restoration margin and one restoration exhibited marginal fissures after 10 years; however, no biological complications, decementation or carious lesions could be identified at the crown margins [11]. It should be noted that the study included a total of only 7 patients with no periodontal disease and optimal oral hygiene. In addition, lithium disilicate

Survival data for various treatments				
Study	**Restoration**	**Material**	**Observation period (years)**	**Survival rate**
Pjetursson und Lang 2008 [40]	Crowns/Bridges (N = 2088/1218)	Not further specified	5/10	93,8 %/ 89,2 %
	Extension bridges (N = 432/239)	Not further specified	5/10	91,4 %/ 80,3 %
	Implant-supported fixed partial dentures (N = 1384/219)	Not further specified	5/10	95,2 %/ 86,7 %
	Implant-supported fixed partial dentures (N = 199/72)	Not further specified	5/10	95,5 %/ 77,8 %
	Implant-supported crowns (N = 465/69)	Not further specified	5/10	94,5 %/ 89,4 %
	Adhesive bridges (N = 1374/51)	Not further specified	5/10	87,0 %/ 65,0 %
Sailer et al. 2015 [48]	Single crowns (N = 4663)	Metal-ceramic	5	94,7 %
	Single crowns (N = 9434)	Full ceramic – Lithium disilicate – Glass-infiltrated aluminum oxide – densely sintered aluminum & zirconium dioxide	5	96,6 % 94,6 % 96,0 %
Pjetursson et al. 2015 [41]	Fixed partial dentures (N = 1796)	Metal-ceramic	5	94,4 %
	Fixed partial dentures (N = 1110)	Full ceramic – Glass ceramic – glass-infiltrated aluminum oxide – zirconium dioxide	5	89,1 % 86,2 % 90,4 %
Rinke et al. 2018 [47]	Veneers (N = 101)	Pressed glass ceramic	7	93,6 %
	Extended veneers (N = 101)	Pressed glass ceramic	7	95,0 % im OK 91,2 % im UK
	Veneers with less than 50 % exposed dentin	Pressed glass ceramic	7	94,3 %
	Veneers with more than 50 % exposed dentin	Pressed glass ceramic	7	71,8 %
Edelhoff et al. 2019 [11]	Onlays (N = 103)	Lithium disilicate ceramic	11	100,0 %

Table 5 Summary of several scientific studies with survival data pertaining to various types of prosthetic restorations.
(Fig. 1–8, Tab. 1–5: A. Roesner)

ceramics have a higher flexural strength and fracture toughness than classical silicate ceramics which therefore facilitates a more minimally invasive preparation [16]. Restorations made of zirconia are used for both crown and bridge restorations of anterior and posterior teeth [44]. Zirconia is characterized by its high strength and fracture toughness, low minimal layer thickness, good marginal seal and esthetics combined with acceptable light transparency as well as the simultaneous possibility of masking tooth discoloration. Since the introduction of CAD/CAM technology, production has been simplified and manufacturing costs have been significantly reduced [38]. Also, the formerly well-known chipping issues related to veneered zirconia restorations [26, 52] have largely been offset by adapting the firing parameters and the establishment of an anatomical framework design [38]. Furthermore, continued advances in zirconia-based material sciences has made it possible to produce monolithic versions for patients with high esthetic demands. Overall, studies have shown a survival probability of 90.0–96.8% over an observation period of at least 5 years for 3-unit zirconia bridges (Table 5) [6, 14, 23, 30, 40, 43, 50]. According to the S3 guideline, there is insufficient scientific evidence regarding all-ceramic two- or multiple-unit bridges [35].

Metal-ceramics combine the positive properties of metals and ceramics (Figures 7 and 8). Their advantages include high elasticity due to the metallic framework, high tensile strength, good accuracy of fit combined with good esthetics and oral stability due to the ceramic veneering [51].

Regardless of the used material, the extended circular tooth substance loss is a disadvantage of conventional crown and bridge restorations. It has been shown that up to 70% of the tooth structure may be removed during tooth preparation for a conventional crown; this can be significantly reduced if table-top, partial crown or onlay preparation designs are selected [9]. In the case of endodontically treated teeth, the decision in favor of a partial crown instead of a crown can preserve up to 45% of the tooth substance [9]. Due to the high risk of chipping, the veneering layer should only be extended vestibularly or should be avoided completely. In case of extensive tooth structure loss, the standard care offered by the statutory health insurance covers a crown restoration made of non-precious metal with the veneering limited to the vestibular surface up to the premolars. In addition, a prospective study has shown that the annual failure rate of direct and indirect composite restorations is between 6.9–26.3 %. However, the 26.3 % rate of loss that is specified as being unacceptable by the authors is based on the results from a single study on microfilled composites. In summary, it should be noted that no clear evidence is available to suggest that one material is better than the other [34].

4. Conclusion

Although physiological, age-related TSL is an indication for treatment only in exceptional cases, extensive TSL affecting the supporting zones of the dentition or extending far into dentin must normally be treated. In such cases, it may be necessary to rehabilitate the affected teeth by prosthetic means in order to restore and secure the occlusal and vertical jaw relation in the long term. Various treatment options are available for increasing the vertical jaw relation such as splint therapy, temporary restorations or the Dahl concept. The basic prerequisite for the transfer of the jaw relation defined in the pre-restorative phase is the functional freedom from symptoms of the patient. Different types of restorations and materials can be used for the ensuing definitive restoration. At the moment, there is no universally suitable restorative therapy concept for patients with TSL. Rather, a very individualized treatment decision must be made for each patient, in which both esthetic and functional parameters are taken into account in the decision-making process. The most common treatment for extended TSL are indirect restorations made of metal and ceramics. Nevertheless, studies based on the Radboud-Tooth-Wear-Project have shown that, even in patients with severe TSL, restorative treatment is not always indicated. If patients have no complaints or esthetic concerns, close monitoring and aftercare are also possible options. In general, the extensive circular loss of tooth substance during tooth preparation for crown and bridge restorations can be considered a drawback. Tooth-colored, minimally invasive restorations can thus represent a good alternative, depending on the financial resources of the patient. Restorations, including permanent ones, may have a limited life span in patients with severe tooth wear due to bruxism and erosion. A detailed explanation of the possible treatment options and the potential complications should be included in the informed consent form.

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Conflict of interest:

The authors declare that there is no conflict of interest within the meaning of the guidelines of the International Committee of Medical Journal Editors.

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