Prospective case series study on the survival rates of occlusal polymethyl methacrylate veneers as a semipermanent therapy in patients with severe pathologic tooth wear

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Objectives: To evaluate the survival rate of minimally invasive semipermanent occlusal polymethyl methacrylate (PMMA) onlays/veneers in previous temporomandibular disorder (TMD) patients with severe tooth wear and with a loss of vertical dimension after up to 7 years. **Method and materials:** This case series was designed as a follow-up evaluation with consecutive patient recruitment. All patients bearing the indication for this kind of rehabilitation were treated by the same clinician using the same adhesive methodology. The study included 22 patients (3 men/19 women), with a mean ± SD age of 50.7 ± 11.6 years. Controls followed within the first 4 weeks (and subsequently as required). Failure criteria included damage by fracture, chipping, and retention loss. Survival rates were determined based on the Kaplan–Meier analysis. **Results:** 328 semipermanent occlusal/incisal veneers were included (142 maxillary/186 mandibular teeth). Almost 80% of the restorations were in place and in function when starting the follow-up treatment after 180 days; failures predominantly occurred within the first 3 to 6 months but proved reparable. Depending on the patients' priorities, scheduled replacements followed successively, and more than 65% did not show repair or any renewal needs for more than 360 days. **Conclusion:** Within the limitations of this study the survival rates of occlusal veneers made of PMMA were sufficiently high to allow for consecutive treatment of the respective teeth by means of permanent restorations while preserving the restored vertical dimension. In patients with severe tooth wear and a TMD history, semipermanent restorative therapy with occlusal PMMA onlays/veneers would seem a noteworthy option. *(Quintessence Int 2024;55: 518–529; doi: 10.3290/j.qi.b5517911)*

Keywords: attrition, case series, occlusal onlays, occlusal veneers, open bite, oral rehabilitation, polymethyl methacrylate, temporomandibular disorder (TMD), tooth wear, vertical dimension, wax-up

Tooth wear is a multifactorial process that results in the loss of dental hard tissues caused by attrition, abrasion, erosion, or a combination of these.[1-3] In recent years, tooth wear has become a more common problem of increasing concern.[3-5] Consensus-based clinical guidelines published in 2017 recommend that noninvasive therapy approaches should be given priority, if possible, and that invasive restorative treatment should only be used in cases of severe or extreme tooth wear and primarily when signs indicating a pathologic condition are present.[6] By definition of the authors of said guideline, severe tooth wear is considered pathologic if, apart from the loss of tooth substance, other findings indicate that secondary harm is caused by the tooth wear, eg, pain and/or discomfort, crumbling of teeth, esthetics, and/or phonetic problems of impaired function of the craniomandibular system. In these cases, it may be necessary to restore the worn teeth, at the same time reestablishing the vertical dimension.

As long as patients suffer from moderate to severe tooth wear only (but without other signs of pathology), direct composite resin restorations are considered a well-studied treatment option with promising clinical results.[7-10] However, this technique is very demanding on the operator's skills. Furthermore, it does not offer safe control regarding the condylar and the articular disk's position. This is due to the general condi-

tions of intraoral shaping and contouring of such restorations in direct application; changes in the soft contour of the matrices used alter the contour of the restorations, and result in an adjustment of the temporomandibular joint (TMJ) positions. Therefore, the indication for the direct technique – even if it is derived from a matrix made from an indirectly produced wax-up – is limited to situations where the TMJs are expected to maintain the mandibular position during rehabilitation under wide opening and possible extensive loading. In these situations, an alternative is to restore the occlusion and thus the vertical dimension with indirect adhesive polymethyl methacrylate (PMMA) restorations that are cemented intraorally.

If patients suffer not only from severe tooth wear but also from temporomandibular disorders (TMDs), the situation may be more complicated. In general, current concepts on the treatment of TMDs recommend that any treatment should be initially based on the use of conservative and reversible therapeutic means.[11-13] This initial treatment is usually grounded on the use of occlusal relaxation splints and aims to reduce muscle tenderness, improve the mobility of the mandible, and relieve orofacial pain. In certain circumstances, the treatment of TMD may require further restorative treatment (for example, in situations where osteoarthritis has caused a change in condylar position along with posterior tooth wear).[14,15] Restorative treatment is also indicated when malocclusion is present as a posterior open bite after successful functional treatment with reversible therapeutic appliances.[16-19] In addition, there are situations where patients suffer from TMD and tooth wear, and where, after successful treatment of TMD, severe pathologic tooth wear requires restorative treatment.

Several papers have emphasized that pursuing restorative therapy solely for the purpose of alleviating TMD symptoms (referred to as Phase II therapy) is not a viable option and should be abandoned.[20,21] Therefore, from today's point of view, subsequently to functional treatment based on the use of occlusal splints, a restorative treatment is indicated with the following indications:

- severe pathologic tooth wear requiring restoration of advanced loss of enamel and dentin[6,22,23]
- anterior and/or posterior open bite after successful treatment of TMJ pathology which in turn requires an occlusal adjustment (eg, by means of occlusal veneers).[15,21,24]

As major reconstructions and restorations require the successful adaptation of the patient, a positioning splint should simulate the planned restored vertical dimension.[11,13] Only when patients tolerate this over time, ensuring successful adaptation, can the prerequisite for treatment with long-term semipermanent restorations be met.[11,25]

Different materials have been introduced to fabricate long-term restorations, eg, onlays made from base metals, fiber-reinforced composites, and conventionally light-cured or auto-cured composite resins.[25-27] Irrespective of the material used, in previous reports the long-term provisional restorations have been fabricated and cemented solely after tooth preparation; this in turn requires local anesthesia, impressions, and chairside-fabricated provisionals. The combination of these therapeutic measures bears the risk of uncontrollable changes in the previously established position due to the dimensional errors in each step of the procedure. As a result, the posttreatment restorative position will not be sufficiently predictable and might compromise therapeutic success in patients who are sensitive to occlusal changes.

One solution to this dilemma could be the indirect fabrication of treatment restorations that are fixed intraorally to the unprepared teeth. As early as back in 1988, a Swedish working group introduced semipermanent indirect "disk repositioning onlays." In these studies, the restorations were fabricated from metal alloys and fixed to the patients' teeth using temporary cements.[28,29] An adaptation of this approach – using laboratory-cured composite resins – was published in a textbook and book chapter in the 1990s.[30,31] However, this method does not take advantage of any pretreatment wax-ups, which would seem recommendable as part of the preliminary diagnostic and treatment protocol.[32,33]

Therefore, a modified concept has been developed that involves the indirect fabrication of respective restorations, now called "occlusal onlays/veneers" in the dental laboratory, based on pretreatment wax-ups.[23] To create a wax-up duplicate, a duplicate impression is taken to obtain a wax-up duplicate model. A negative silicone mold is then made from this. This mold is placed on a duplicate of the original model. The remaining space between the inside of the negative mold and the occlusal contour of a duplicate of the original model is used to fabricate the long-term provisional treatment restorations, and these are adhesively cemented intraorally to the tooth surface.

The current paper presents a clinical follow-up on the survival of occlusal veneers and illustrates the application of this technique with a clinical case representing a highly complex situation. Being reported for the first time, the results presented with the current paper are intended to provide insights into the longtime survival of a semipermanent treatment approach using occlusal PMMA veneers with patients suffering from severe tooth wear, and with a history of TMD.

Method and materials

Study design

All patients had been referred to the first author's specialized dental center for treatment of TMD and/or tooth wear, and they represented a subset of the much larger number of patients who could be treated by education and counseling only, or with conservative and reversible means (eg, physical therapy, relaxation-techniques, jaw-stretching exercises, occlusal guards in terms of relaxation- or positioning-splints, and/or acupuncture).

The inclusion criteria for this prospective case series were fulfilled by all patients, who:

- had been diagnosed with generalized severe pathologic tooth wear (TWES 2.0-Code ≥ 3)[34]
- had undergone successful functional therapy by noninvasive means, including information on the nature and treatment of TMD, instruction on relaxation techniques, such as progressive muscle relaxation, physiotherapy, and the use of occlusal relaxation splints, later transferred into positioning splints (for more information on these treatment aspects, please refer to[11,13,35])
- exhibited nonocclusion of one or more teeth in the sense of an anterior or posterior open bite, and
- maintained the position supported by the positioning splint in all dimensions.

Exclusion criteria were persistent pain in the TMJ or masticatory muscles after functional therapy, a nonreproducible position of the mandible, unrealistic expectations expressed by the patients, allergies to the materials used in the study, and patients' reluctant attitude towards the proposed methodology.

According to the Hamburg Medical Association, no ethical vote was required for this study (decision number: 2021-300127-WF, 20 December 2021). All included patients gave informed consent to the treatments and were consecutively enrolled in the study. Due to the observational character of the current investigation, no randomization was performed, and no controls were included. Moreover, no further DC/TMD (Diagnostic Criteria for Temporomandibular Disorders[36]) screening was performed with the patients, as they were no longer considered to suffer from a clinically active TMD at the time of treatment start (see inclusion/exclusion criteria). Methodologically, the number of teeth, restorative materials, and dates of placement and subsequent examinations were recorded in a spreadsheet (Excel, Microsoft). After the documentation of these data, the personal information was removed, thus ensuring the anonymization of the data in accordance with respect to German and European legislation.

The day after occlusal veneer placement was considered baseline. Follow-up visits were performed at 1 week, 4 weeks, 12 weeks, and 26 weeks (and additional visits were possible if required). If the restorations remained in place rather than being replaced with permanent restorations, they were examined every 6 to 12 months. All treatments and follow-ups were performed by the same clinician (MOA).

Single case and workflow description

Clinical examination and technique

The technique used in the present study is illustrated by the treatment of a 43-year-old man who presented in good general health and had been referred to the TMD Centre by several general dental practitioners because of his challenging situation. This was characterized by severe tooth wear with vertical substance loss due to attrition and erosion, multiple incisal and cuspal fractures, and cervical erosion. Several teeth were hypersensitive. Fortunately, however, no single tooth was missing. The patient's esthetic appearance and phonation were severely compromised, and prevalent incisal fractures indicated a progressive situation considered inappropriate for the patient's age. In addition, the patient presented with functional complaints and pain in the TMJ and stomatognathic muscles (arthralgia, myalgia). The patient's treatment goal was to have his teeth restored to allow for adequate chewing function, phonetics, and esthetics. The referring dental practitioner requested functional therapy followed by restorative treatment to stabilize the position and function of the TMJs without the need for constant wearing of a splint (Fig 1). After functional therapy according to applicable clinical guidelines and assessment of tooth wear,[6,34] restorative treatment was planned.

Semipermanent (long-term provisional) restoration

Provisional and permanent restorations were planned on the basis of a full diagnostic wax-up. To fabricate the occlusal veneers, diagnostic models were fabricated using a double-mix impression technique (single-stage, two-phase technique) using an addition-curing silicone (polyvinylsiloxane; Silagum putty and Silagum light, DMG). Casts were made from these impressions using a Type IV stone plaster (Fujirock, GC). A duplicate cast of the original model was also made in white Type IV stone

Fig 1a to d Initial situation of a 43-year-old man suffering from severe tooth wear, and with a history of TMD symptoms. Note the advanced attrition, along with incisal and occlusal reduction. Several fractured teeth indicated progressive destruction of dental hard tissues. View of the maxilla and mandible *(a)*. Inserted repositioning splint, indicating the amount of loss of vertical dimension *(b)*. Dynamic occlusion to the right *(c)* and to the left *(d)*, unveiling excessive tooth wear along with incisal and cuspal fractures, and loss of canine guidance.

plaster. The original casts were mounted in an individual articulator (Artex AR, Amann Girrbach). The position of the maxillary cast was oriented using an arbitrary facebow (Artex, Amann Girrbach). The mandibular cast was mounted in the exact position of the splint after the successful completion of functional therapy using the splint as record plate. Based on this setup, a diagnostic wax-up was fabricated using a diagnostic wax designed for high abrasion resistance during the wax-up process (Nawax Compact Modelling Wax, Yeti). This model was then duplicated by means of a negative mold of the wax-up. The negative mold of the wax-up was then placed on top of the duplicate of the original cast and the space between them was filled with a high-performance laboratory acrylic polymer (New Outline, anaxdent). The model with the negative mold was then placed in a relining device and stored in water under high pressure (3 bar) for the recommended setting time (20 minutes). The occlusal veneers were then removed from the mold and separated by a saw. Finishing followed, with the occlusion fine-tuned and the restorations polished to a high gloss. A first set of mock-ups of the maxillary teeth for intraoral visualization was fabricated for consultation with the patient (Fig 2).

Upon diagnostic incorporation using a tooth-colored try-in gel (Vitique, DMG), the patient agreed with the new contour, while he considered the color shade A1 (according to the Vita Classical Shade, Vita) as "too bright" (Fig 2). It was, therefore, decided to fabricate the original occlusal veneers in a different shade (A2), but in the same shape. Once the occlusal veneers had been fabricated, they were placed intraorally to check the fit. Subsequently, they were cleaned (Ivoclean, Ivoclar) and dried. An individual rubber dam (Ivory Rubber Dam Latex, Kulzer) was placed over each sextant, and the occlusal veneers were inserted using a specific adhesive protocol used for fixation, depending on the respective surface of each tooth:

- In teeth with (severe) enamel attrition, the enamel was acid etched for 20 seconds (Ultra Etch, Ultradent) and thoroughly rinsed. Where dentin was exposed, a dentin primer (Optibond FL Primer, Kerr) was applied to the exposed dentin, followed by gently air-drying.
- The protocol was modified for teeth with remnants of ceramic restorations and for teeth with amalgam or cast metal restorations; after application of etching gel to the occlusal hard tissues, subsequent removal with an air/water syringe

Fig 2a to c Test fitting of the mock-up. Smile without mock-up *(a)*. Smile with mock-up, placed with try-in gel (Vitique, DMG) for assessment of esthetic appearance under conditions as realistic as possible *(b)*. Mock-up placed on maxillary teeth with try-in gel, intraoral view (frontal perspective) *(c)*.

and thorough drying of the surface, the metal or ceramic surfaces were treated with a tribochemical metal primer surface preparation (CoJet, 3M ESPE).

Then, for fixation, the following sequence was employed with all teeth:

- Enamel bond was applied to the pre-treated surface (Optibond FL Adhesive, Kerr).
- The occlusal veneers were glazed on the inside (Glaze & Bond, DMG). The material was used as an adhesive, and was diluted with air pressure but not light-cured at this stage.
- Composite resin cement was applied to the inside of the occlusal veneers and to the pretreated dental surfaces (Vitique, DMG). The occlusal veneers were placed on the respective teeth, pressed on, and cured briefly (3 seconds) for an initial setting. Excess cement was then carefully removed with scalers before the cement was fully cured.

In terms of placement sequence, the occlusal veneers were first placed onto the respective molars and premolars, starting with the maxillary right quadrant, followed by the mandibular right quadrant, and then switching to the maxillary and mandibular left molars and premolars, respectively. Finally, the incisal veneers were placed on the maxillary and mandibular incisors and canines (Fig 3). Intensive instructions on brushing and flossing and daily home care followed, and the latter was controlled regularly.

After 6 months the semipermanent restorations were subsequently replaced in groups according to a special protocol designed to preserve the restored vertical dimension and the condylar position. For the permanent restorations, the second molars were fabricated as gold cast restorations, and the maxillary and mandibular incisors, canines, and premolars/first molars were restored with leucite-enhanced alumina ceramic (IPS Empress, Ivoclar) and adhesively cemented with the same products used to fix the long-term temporary occlusal veneers (not presented in the current paper; the outcome referring to those definitive restorations will be published separately).

Clinical follow-up and statistical analysis

To assess the performance, all occlusal veneers were continuously monitored to capture the semipermanent restorations' durability during clinical use. According to the protocol, the PMMA based restorations were adhesively inserted after a completely symptom-free term of 6 months and were observed for another 180 days with each patient. Survival or failure/loss rates were statistically evaluated by means of a Kaplan–Meier analysis (Sigma Plot, Systat Software).

After this first (symptom-free) 180-day period, definitive restorations were offered to the patients, as initially agreed upon. However, though this rehabilitation was initially planned, it depended on the patient's willingness to follow through. Some patients refrained from the scheduled next steps be-

Fig 3a to d Postoperative situation of the indirectly fabricated restoration. Long-term provisional restorations for repositioning the mandible by means of occlusal veneers in an individual articulator after finishing and adjusting the occlusion with respect to the previously determined condylar position *(a)*. Occlusal veneers fixed adhesively onto the maxillary and mandibular teeth (frontal perspective) *(b)*. Occlusal veneers fixed adhesively onto the maxillary teeth (the dark discoloration at the first maxillary right molar is caused by the tribochemical preparation of the gold crown) *(c)*. Occlusal veneers fixed adhesively onto the mandibular teeth (the dark discolorations at the first mandibular molars and adjacent teeth on the left side are caused by the tribochemical preparation of the gold crowns on the first molars and the amalgam fillings on the adjacent teeth on the left and are due to the translucent properties of the occlusal PMMA veneers; with the final restorative treatment, these diaphanous areas were restored) *(d)*. The inflammatory aspects observed with the anterior maxillary teeth resumed after implementing a meticulous mouth hygiene regimen.

cause the semipermanent restorations worked well and continued to function. In patients where invasive retreatment was performed, replacements started successively and involved both the second molars and those restorations considered in need of urgent renewal. In a first instance, all other semipermanent restorations were kept in place; they helped to fix both the defined mandibular position and the occlusal height, at the same time ensuring the condylar position. These occlusal veneers temporarily remained in situ and were included in the Kaplan–Meier analysis (Sigma Plot, Systat Software). Subsequently, they were replaced in groups of four to six by definitive adhesive ceramic or cast precious metal restorations, except for the occlusal veneers in patients who decided not to follow through the planned successive treatment.

Results

The mean ± standard deviation (SD) age of the patients was 50.7 ± 11.6 years; the youngest patient was 22 years old, and the oldest was 69 years at baseline. Over 7 years, a total of 328 semipermanent occlusal PMMA veneers (17 values had been lost with the recorded data) were placed in 22 patients (3 men and

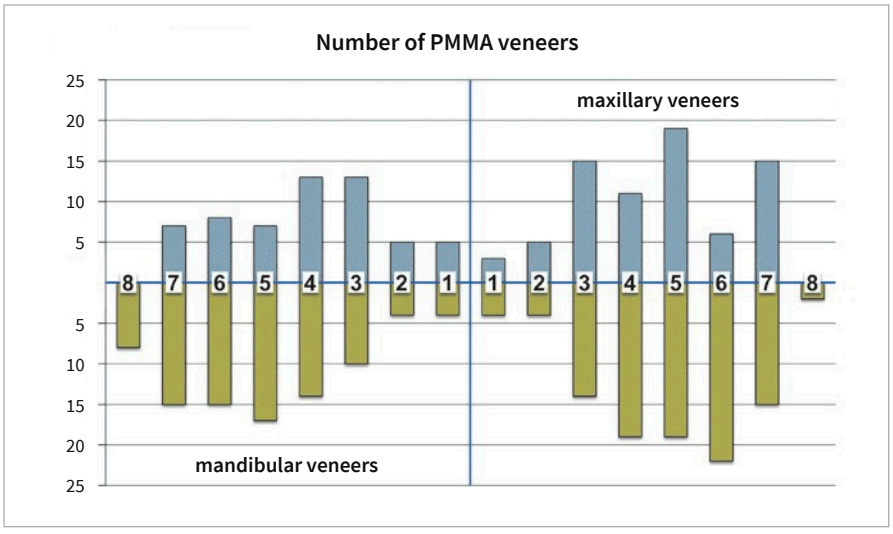

Fig 4 Graphical distribution of the 328 maxillary and mandibular occlusal PMMA veneers. Note the high numbers of treated canines and premolars both in the maxilla and mandible of the patients.

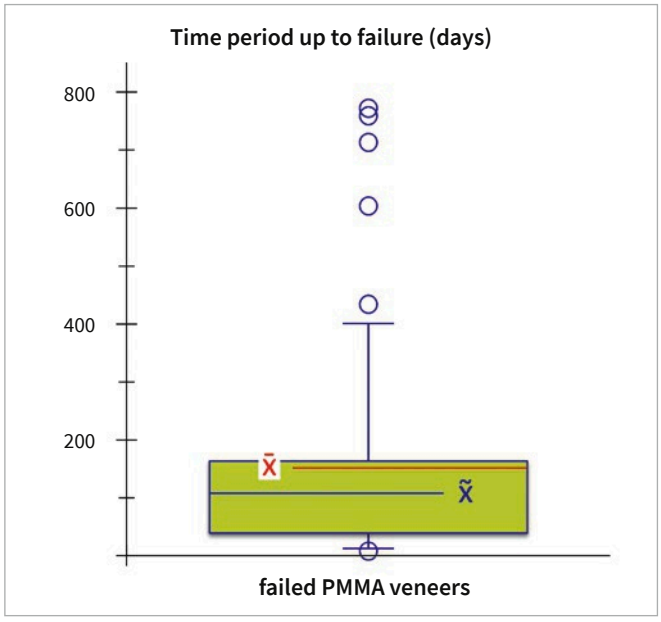

Fig 5 Box-and-whisker plot presenting the outcome referring to total days' survival of the failed occlusal PMMA veneers (n = 93). The horizontal blue line splitting the box indicates the median/second quartile (x̃/Q2); the red line denotes the mean (x̄) survival time. Upper and lower boundaries of the box define lower and upper quartiles (Q1 and Q3). Minimum or maximum values lying outside the 1.5 × interquartile range value are shown as outliers (○).

19 women). With 142 maxillary and 186 mandibular restorations, canines and premolars were the predominantly treated teeth, followed by molars (for a detailed distribution, see Fig 4). During the treatment with occlusal PMMA veneers, resurgence and deterioration of the symptoms were noticed in two patients, resulting in early removal of the restorations. Other failure criteria included loss by fracture, chipping, and loss of retention.

Amongst the 328 occlusal PMMA veneers, a substantial number fractured or were displaced (n = 93). Regarding those occlusal veneers, the authors performed a statistical subanalysis regarding the time of fracture after placement (Fig 5). These data indicate that if fractures or displacements occurred, this event took place rather early within the first 100 days (up to 6 months). In total, the fractured maxillary and mandibular occlusal PMMA veneers revealed a mean ± SD survival time of 158 ± 194 days (x̃ [median] = 105 days), thus clearly prolonging the asymptomatic period of time, and further stabilizing the treatment success.

Despite the number of losses due to fracture or displacement, the survival analysis indicated that after an observation time of 180 days, the probability of the semipermanent occlusal PMMA veneers to be still in place (and in function) was close to 80%. Figure 6 shows the Kaplan–Meier analysis of the 328 occlusal PMMA veneers' survival rate over the course of 180 days after successful functional treatment. With a survival rate close to 80% within this time frame, the semipermanent treatment regimen presented here seems to allow for stabilization of patients with a history of TMD and suffering from loss of vertical dimension due to severe tooth wear and/or anterior or posterior open bite.

However, not all of the semipermanent restorations were replaced after 180 days, due to time constraints and other patients' issues. Continuous monitoring of the remaining semipermanent restorations revealed that after 360 days, more than 65% of all restorations were still in place and in function (Fig 7). This analysis was based on data collected from each patient

having been consecutively treated over a period of 7 years, and demonstrated that semipermanent restorations will be stable for more than a year in 65% of the cases in patients with a history of TMD and suffering from loss of vertical dimension.

In the subsequent periods, not all the restorations were replaced as initially planned (due to various individual reasons). Consequently, as these semipermanent occlusal veneers were not substituted by definitive restorations (n = 68); they were checked regularly and were gradually replaced, depending on the patients' needs, or in case of any damage. This resulted in a total mean ± SD theoretically projected survival time of 997.1 ± 68.8 days.

Discussion

This article presents a technique for restoring the vertical dimension by using PMMA veneers. To determine the clinical suitability of the technique presented, the longevity of occlusal and incisal veneers in clinical use was evaluated based on the data collected in one clinical center. This information is crucial because in such situations the maintenance of the restored vertical dimension over (and beyond) the planned period depends on the survival rate and wear of the semipermanent restorations. If the latter fail altogether before the scheduled period, the vertical dimension (and, possibly, the condylar position) could collapse again. This in turn would jeopardize the intended future replacement of the semipermanent occlusal veneers with permanent dental restorations.

In cases of generalized severe tooth wear, single tooth restorations are often technically impossible due to the lost relationship between the maxilla and mandible (Fig 1). Instead, restorative treatments that do not elevate the vertical dimension may require the additional removal of sound tooth substance. Although individual incisal edges or cusps can be repaired with minimally invasive direct adhesive techniques, in case of extended defects (severe pathologic tooth wear) and/or hypersensitivities, the restoration of the vertical dimension is advisable.[6,13,37]

The second indication for the described rehabilitation approach using occlusal onlays/veneers arises from patients with a history of TMD suffering from severe tooth wear or other hard substance defects (eg, due to fracture) requiring restoration. As mentioned above, all initial treatment approaches of TMD should be based on conservative and, if possible, reversible therapeutic measures.[12] However, if patients present with a persistent anterior and/or posterior nonocclusion at the end of such a conservative therapy, this should be an indication for a subsequent restorative rehabilitation.

In such cases, a Swedish randomized controlled clinical trial investigated whether disk-repositioning onlays (ie, occlusal/incisal veneers) could be effective in reducing pain and dysfunction associated with disk displacement.[28,29,38] Said studies showed that both the reduction of symptoms and the maintenance of the repositioned disk-condyle-relationship were superior in the group treated with the semipermanent repositioning onlays if compared both to the group treated with splints and to the controls. As the symptoms returned after the disk-repositioning onlays had been removed 6 months later, the authors raised the question of whether a permanent change of the intercuspal position might be necessary for long-term success.[28,29]

Technically, increasing the vertical dimension would call for a simulation of occlusion and hinge axis motion.[32,33,37,39,40] This requires an indirect technique that allows for a simulation of the existing and the therapeutic occlusion by means of casts mounted in an individual articulator based on an arbitrary facebow as well as on therapeutic static and dynamic relation records. When these data are available, the specific advantage of the technique presented with the current study is therefore the predictability of the mandibular position after the procedure. The technical prerequisite for this regimen is a therapeutic relation record that positions the mandible accurately in its exact condylar location; at the same time, the vertical relation of the final positioning splint that has proven clinically successful must be preserved. As a preliminary step, the 3D contour of the restoration is designed using a wax-up.[32] This allows for accurate planning of the therapeutic occlusion, concomitantly taking into account the curves of Spee and Wilson to ensure a stable occlusion.[37,39,40]

As an alternative to any indirect restorative techniques, direct techniques could be employed. In fact, Swiss authors have published such a direct approach, followed by a scientific evaluation.[30,31,41] With survival rates of 99.3% after an observation period of 3.5 years, these results were quite favorable.[7] Even after 5.5 years, 97.7% of the composite resin restorations did not show any severe damage requiring replacement, and no endodontic treatments (or even extractions) of the teeth had proven necessary.[8] This trend has prevailed leading to a favorable long-term outcome (10.7 years).[9] Beyond the exceptionally high survival rate of 94.9% for these restorations, the success rate was 78% in the long run, meaning that 22% of the restorations required repair or replacement. However, patients with TMDs were excluded from this study.

In addition, a randomized controlled trial comparing the use of direct and indirect composite resin restorations in patients with tooth wear alone was published in 2021.[42] The re-

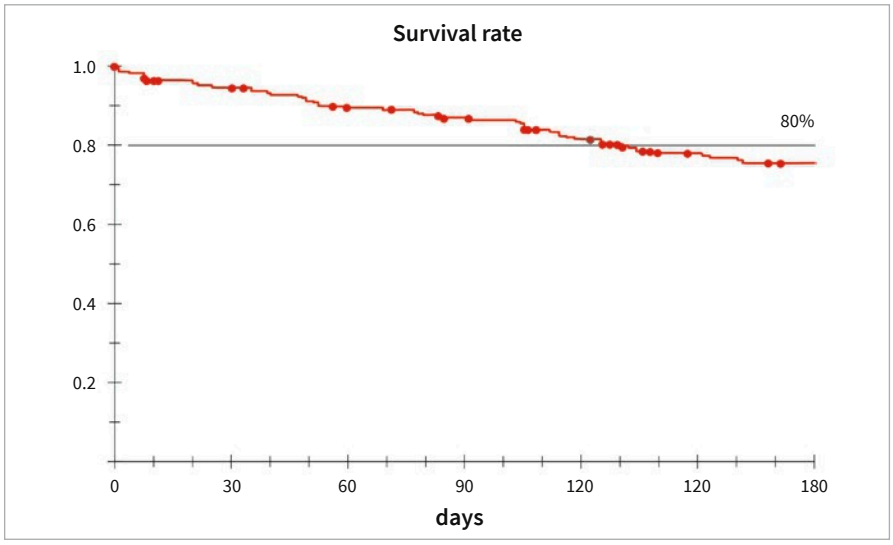

Fig 6 Kaplan–Meier analysis of the 328 occlusal PMMA veneers' survival rate over the course of 180 days after successful functional treatment.

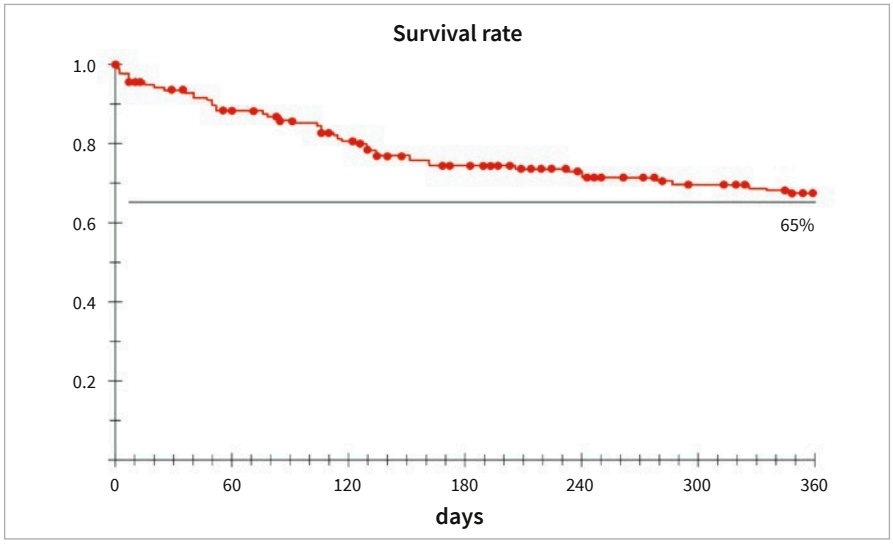

Fig 7 Kaplan–Meier analysis of the nonreplaced semipermanent occlusal PMMA veneers' survival rate over 360 days after successful functional treatment.

sults of this 3-year clinical trial suggested that in patients suffering only from tooth wear, direct techniques should be preferred when used in the molar region, at least when focusing on the time frame investigated in the study.[42]

Based on the results of the studies presented above, in patients with severe tooth wear (but without other disorders), the direct technique would seem promising. However, this result does not apply to patients with or after treatment of TMD, since these patients were excluded from the cited studies. In addition, clinical experience has shown that with patients suffering from TMD symptoms and a known vulnerability to a nonstable condylar position, the predictability of the 3D condylar (and thus the mandibular) position was not considered satisfactory.[43] One reason might be the difficulty to determine the (occlusal) contour of the restorations. To some extent the direct techniques are based on the same initial steps as the indirect technique presented with the current study. Even with the "direct" procedures in question here, the dental technician is responsible for the wax-up, followed by the fabrication of a duplicate mold, a duplicate cast derived from the mold, and finally a thermoplastic transparent foil formed over this duplicate cast.[41] Nevertheless, the process is termed "direct," as the ac-

tual shaping of the restorations is performed intraorally by filling the foil with the composite resin prior to its placement on the teeth that are to be relined. Therefore, the later dimensions of these restorations depend solely on the accuracy of the 3D contour of the thermoplastic transparent foil and its horizontal (and vertical) intraoral placement during light-curing of the composite resin. The only way for the clinician to assess the indispensable accuracy is by checking the occlusal contacts, followed by a repetitive arbitrary reduction of the composite resin where necessary until an occlusal equilibrium is achieved. Therefore, in clinical situations where a definite 3D condylar position is required and/or with indications involving condylar instability, the direct technique does not provide the necessary control or predictability of the mandibular position.[44]

In comparison, with the indirect technique provided with the current case series, not only the planning but also the fabrication of the restorations is performed extraorally, including the use of an individual articulator by the dental technician. This allows for the exact vertical dimension, and, this way, the occlusal relationship, including the curves of Spee and Wilson, can be controlled.

Therefore, the indirect technique presented with the present piece of work (Fig 3a) allows for 3D control of both the condylar position and the vertical dimension and is considered the treatment of choice in situations comparable to the case presented here. No doubt, this could be particularly important in patients with unilateral or bilateral disk dislocation. In these patients, changes in the condylar position of more than 1 mm occur almost regularly during an extended dental treatment. Unfortunately, after occlusal restoration, the condylar position cannot be analyzed with respect to the pre-restoration situation anymore because this technique requires identical casts. Therefore, in situations comparable to the cases reported with the current study, the clinician must rely on a technique that ensures a predictable position of the new occlusion.

The clinical success of this regimen clearly depends on the long-term survival of the occlusal veneers until the planned permanent restoration is completed. A sufficiently long waiting period of approximately 6 months has been recommended between the semipermanent treatment and the permanent restoration.[12] At this stage the material used should be able to withstand any subsequent wear. The data collected with the present study showed that almost 80% of the semipermanent restorations were still in place and in function after 180 days, and that this figure did not decrease substantially in the following period (Fig 7). Interestingly, the Kaplan–Meier estimate revealed a mean theoretical survival time of 997 days for the non-replaced cases, and this computed survival time by far exceeded this recommended period. In all cases where the integrity of restorations was compromised prior to the 6-month limit, it was possible to either repair or replace the latter, without total loss of the 3D stability.

With the current study, a PMMA-based long-term temporary restorative material was selected in accordance with the manufacturer's intended use of the material. However, when reflecting on the outcome presented in Fig 5, it should be clear that (partial) fractures may occur early, and this would seem associated with mechanical overload (ie, by severe bruxism). Mean failure time of the fractured PMMA veneers was 158 days, and this would call for an even more stable material. With this in mind, case reports focusing on high-density polymers and using a technique comparable to the present study seem interesting,[45-47] and future material developments should provide further safety in such cases. This would suggest that composite resins may offer an adequate choice for the fabrication of occlusal onlays/veneers, which may offer better properties and therefore even greater longevity. Another alternative could be fiber-reinforced composite resins.[26,48] However, the delicate dimensions of the occlusal veneers may not provide sufficient space for this technique, in particular since the fibers must always be fully covered.[26]

With the current case series all patients matching the inclusion criteria were treated; thus, some shortcomings of the study design (in particular selection bias) could be ruled out. Other limitations of the case series approach (eg, absence of a control group or missing randomization) were considered second-order with the current rationale, since the primary objective was to provide descriptive information on treatment outcomes, but not to compare risks among groups. With such knowledge, hypotheses may be generated, and the latter should allow for advanced studies evaluating alternative materials. The fabrication of the occlusal veneers from ceramic materials could be such an alternative. Lithium disilicate glass-ceramic (IPS e.max press/CAD, Ivoclar) offers superior properties as compared to leucite-reinforced alumina, and can be wax-modeled prior to heat-pressing; this would allow a laboratory-based fabrication similar to the technique presented. If this restorative material holds to the authors' expectations in terms of clinical performance, the occlusal veneers (conceived as semipermanent or long-term provisional treatment restorations) presented with the current approach can gradually be replaced by permanent restorative treatments. The esthetics of the added restorations may not be perfect, but are certainly acceptable, and the procedure is completely noninvasive and

highly predictable. The presented study design will be applied to alternative materials in the future.

Conclusion

With reference to the aims of the current study, it can be concluded that semipermanent occlusal PMMA veneers show sufficient longevity in the context of a semipermanent treatment of patients suffering from loss of vertical dimension due to severe tooth wear and/or anterior or posterior open bite in combination with a history of TMD. The presented treatment approach will stabilize the mandibular position without the need for invasive preparations and represents a promising alternative to the conventional treatment sequence of extensive tooth preparation prior to chairside fabrication of provisional restorations (usually being replaced by indirect long-term restorations).

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Disclosure

The authors state that there is no conflict of interest.

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