Minimally invasive treatment options in fixed prosthodontics

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Minimally invasive treatment options have become increasingly feasible in restorative dentistry, due to the introduction of the adhesive technique in combination with restorative materials featuring translucent properties similar to those of natural teeth. Mechanical anchoring of restorations via conventional cementation represents a predominantly subtractive treatment approach that is gradually being superseded by a primarily defect-oriented additive method in prosthodontics. Modifications of conventional treatment procedures have led to the development of an economical approach to the removal of healthy tooth structure. This is possible because the planned treatment outcome is defined in a wax-up before the treatment is commenced and this wax-up is subsequently used as a reference during tooth preparation. Similarly, resin-bonded FDPs and implants have made it possible to preserve the natural tooth structure of potential abutment teeth. This report describes a number of clinical cases to demonstrate the principles of modern prosthetic treatment strategies and discusses these approaches in the context of minimally invasive prosthetic dentistry. (Quintessence Int 2016;47:207–216; doi: 10.3290/j.qi.a35115; Originally published in Quintessenz 2014;65(5)589–600)

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At present, conventional treatment methods using metal-based crowns and fixed dental prostheses (FDPs) are considered to be the gold standard regarding clinical survival and success. 1 However, the extensive removal of tooth structure associated with the crown and abutment preparation for these restorations is seen as a disadvantage. A retrospective clinical study showed that the 15-year survival probability of vital pulp was 81.2% in metal-ceramic single crowns and 66.2% in FDP abutments. 2 Foster 3 determined a 21% endodontic complication rate for FDP abutments after 6 years. An initial quantification of hard tissue removal in relation to different preparation configurations revealed that up to 70% of the clinical crown is removed in complete coverage crown preparations, regardless of whether the preparation was in the anterior or posterior region. 4–5 These findings have recently been confirmed in a study using modern measuring technology 6 and are increasingly affecting treatment decisions. Several in-vitro studies on endodontically treated teeth have shown that a high volume of remaining natural tooth

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structure has a significantly positive effect on fracture resistance, independent of the type of tooth. Up to 45% more tooth structure can be saved by opting for a partial rather than a complete coverage crown when restoring an endodontically treated molar. Similar results were found in relation to the preparation of retainers for resin-bonded FDPs and attachments.

It is noteworthy that clinical studies on all-ceramic partial coverage crowns showed either no or a very low endodontic complication rate after observation periods between 7 and 12.6 years, compared to studies on metal-ceramic complete coverage crowns. In veneer restorations, the rate of endodontic complications was as low as 2.51% after an observation period of 20 years. Hence, a less invasive preparation and restoration design appear to have a favorable effect on the vitality of restored teeth. Against this background, fixed prosthodontics have been undergoing a paradigm shift towards less invasive treatment methods in recent years. A few treatment methods offering substantial reductions in the removal of tooth structure are described and discussed below.

Resin-bonded anterior FDPs

Resin-bonded anterior FDPs were first described in the 1970s. Today they are used as an alternative to implant-supported restorations in single teeth if:

- implant treatment is contraindicated
- extensive surgical interventions should be avoided
- the space available is inappropriate for implant treatment
- the patient is of an inadequate age, or
- an implant is simply not wanted.

Most modern resin-bonded FDPs are manufactured on the basis of frameworks made of materials featuring a high modulus of elasticity such as base metal alloys or zirconia ceramics (Fig 1). A removal rate between 0.5 mm and 0.7 mm is recommended for the preparation of the retentive wings. Additional requirements are healthy abutment teeth that are primarily free of both caries and fillings, sufficient interocclusal space (approximately 0.8 mm), and sufficient amounts of enamel.

In a long-term clinical study (literature review), adhesive FDPs comprising two wing retainers showed a significantly poorer survival probability than full crown abutment FDPs over a period of 10 years. However, it is important to bear in mind that anterior maxillary teeth are considered to be particularly vulnerable to vitality loss if they are used as abutments in conventional FDPs. Additionally, a retentive preparation geometry has been shown to play an essential and determining factor for the success of resin-bonded FDPs and should by all means be considered in the preparation design together with the properties of the ceramic or metal being used.

With the introduction of metal-based single-retainer adhesive FDPs in the 1980s, the level of invasiveness was once more lowered and the need for unphysiologic splinting of the abutment teeth was eliminated. In the 1990s, glass-infiltrated aluminum oxide ceramic was used for the first time in a clinical study to manufacture all-ceramic adhesive FDPs with...
two retainers. In the further course of the study, zirconia-based single-retainer adhesive FDPs appeared to be advantageous. The data available from the clinical long-term study indicate a survival probability of 94.4% for the single-retainer zirconium oxide-based adhesive FDPs after a clinical service time of 10 years. In certain cases, lithium disilicate ceramics might be suitable as the framework material for single-retainer adhesive FDPs (Fig 2).

All-ceramic anterior veneers
Given their favorable long-term results, excellent esthetic properties, and low level of invasiveness, resin-bonded veneers offer an attractive alternative to conventional single crowns in many cases. Silicate ceramic materials are considered to be the material of choice to replace lost natural enamel due to their favorable optical and mechanical properties. However, minimally invasive veneer preparation, provisionalization, and adhesive bonding set higher demands on the skills of the operator compared with complete coverage crown preparation and conventional cementation.

Enamel preservation represents an essential and determining factor for the success of a veneer restoration. Therefore, veneers should be designed using a mostly exclusively additive technique. Well-defined principles apply to the preparation for veneers; nonetheless, these principles can offer a high degree of flexibility in the design of the restoration, depending on the clinical situation (tooth position, degree of destruction, occlusal conditions, periodontal surroundings, etc). This is true for both the incisal design and interproximal extension. Preparing a palatal chamfer offers the highest degree of freedom for the positioning of the incisal edge, which is particularly important if a large amount of tooth structure has been lost. Similar considerations apply to the interproximal extension of the preparation.

If the popular medium wrap design is used, the contact area and therefore the width of the existing tooth are maintained and, consequently, the height is determined by the defined width-to-length ratio. By contrast, the long wrap design leads to the elimination of the contact areas due to the deep interproximal extension and therefore offers considerably more scope for variation with regard to the shape and position of the restoration (Fig 3). The long wrap design is therefore particularly advantageous in the treatment of severe discolorations, diastemas, extensive shape modifications, black triangles, and large fillings. Further-
more, the long wrap design is recommended for veneers that are located in the immediate vicinity of crowns, as this allows the contact area between the two restorations to be created in ceramic (Fig 4).

Interproximal preparation can be conveniently accomplished with oscillating preparation instruments (eg, Sonicflex micro tip no. 28 or 29, diamond coating D25, half torpedo shape REF 0.571.6741/0.571.6731; KaVo Dental) and Soflex disks (2382 M, 3M Espe) (Fig 5a). In periodontally compromised situations, the long wrap design may be combined with a horizontal insertion axis. This method eliminates the need for an extensive reduction of the coronal tooth structure. Furthermore, distance C (cervical) can be designed to be smaller than distance D (dentin) (Fig 5b). Substantial amounts of tooth structure can be preserved if this configuration is used (Fig 5b). On the downside, however, the clinical and technical implementation of this technique is considered to be challenging.

In certain indications, the design may seamlessly evolve into a full coverage crown (Fig 6). A circular preparation design (360 degrees), also known as a full wrap veneer design, is particularly indicated for complex cases that necessitate an increase in the occlusal vertical dimension to close the resultant free space on the palatal side of the maxillary anterior teeth. As an alternative, the three-step technique described by Vailati and Belser may be followed. If this technique is applied, the palatal space is first built up with composite before restoring the labial surface with a resin-bonded veneer (so-called sandwich technique).

Essentially, a diagnostic template or silicone mold should be created from the wax-up and used as a guide during tooth preparation to reduce the amount of tooth...
If severe discoloration is present, the preparation depth may be slightly extended to allow the dental technician sufficient scope to mask the tooth structure.\textsuperscript{24}

Silicate ceramic veneers present a predictable and successful treatment modality. In a recently published retrospective 10-year cohort study, these veneers have been shown to offer a 93.5\% survival probability.\textsuperscript{13} The first results of a 7-year prospective clinical study on full
veneers are promising; however, sufficient data are as yet unavailable for either long wrap veneers or full wrap veneers. Bruxism, insufficient enamel support, and endodontically treated teeth are seen as essential risk factors for the success of veneers. All-ceramic occlusal onlays
Adhesive all-ceramic partial coverage restorations are also considered to be a reliable treatment option for the posterior region. In this context, it should be borne in mind that the majority of clinical long-term studies are based on leucite-reinforced glass-ceramics, whereas today considerably stronger ceramic materials based on lithium disilicate are available (Fig 7). As they permit a defect-oriented preparation method and eliminate the need for a retentive preparation design, all-ceramic onlays offer a sensible treatment option to avoid conventional invasive treatment methods. The Fourth German Oral Health Study (DMS IV) revealed a high prevalence of root caries and non-carious defects, on the basis of which it is expected that the need for single-tooth restorations will increase in the future. Young patients affected by severe abrasion- and/or biocorrosion-induced changes of the dentition may particularly benefit from a durable, minimally invasive treatment modality as their pulps are much larger than in the adult population (Fig 8a). In addition to eliminating the abrasion- and biocorrosion-inducing causes, restoring the esthetic and functional properties and reconstructing the biomechanical properties of the affected teeth are considered the main treatment objectives. Furthermore, any restorative measures should be aimed at preventing any further pathologic wear in the long run.
Compared with conventional silicate ceramics, lithium-disilicate ceramic materials (IPS e.max Press or IPS e.max CAD, Ivoclar Vivadent) offer enhanced flexural strength and fracture toughness. Since the introduction of lithium disilicate, the recommended preparation depths for glass-ceramic onlays have been reduced significantly. Today, a minimum occlusal thickness of 1 mm is recommended for monolithic restorations (staining technique). Currently a further reduction in the layer thickness is brought to discussion if appropriate enamel support is present.
Glass-ceramic onlays appear to be ideally suited for rebuilding abraded and eroded posterior teeth because they offer enamel-like properties and an optimal interface behavior. They permit a particularly gentle preparation of the tooth structure as long as the preparation does not extend beyond the equator into the infra bulge (Fig 8b). Consequently, these onlays can be used to circumnavigate conventional prosthetic procedures that are substantially more invasive. It is of essential importance for the preparation margins to be predominantly located in the enamel. In in-vitro studies, extensive silicate ceramic onlays displayed a favorable stress pattern and almost pure compression at the interface, which is of advantage for the ceramic. However, all transitions should be soft and rounded to prevent stress peaks within the restoration (Figs 8b and 8c).
It is generally useful to distinguish between pure onlays (involving only the occlusal surface) and onlay-veneers (involving both the vestibular and occlusal surfaces). The latter is indicated if a major modification of the shade in the esthetic region (premolar) is required. In a controlled prospective clinical study, the silicate ceramic onlays showed satisfactory long-term
results after 12 years and are also suited for use in conjunction with extensive tooth structure defects. Another clinical study over an observation period of 12.6 years revealed a failure rate of 20.9% in vital teeth and 39% in endodontically treated teeth.

**Restorations made of CAD/CAM polymers**

Modern manufacturing technologies enable the use of industrially prefabricated polymers or acrylates, which offer material qualities that are clearly superior to the qualities of direct temporary restorations. As these high-performance polymers are polymerized under industrial conditions, they feature a highly homogeneous structure and therefore offer numerous advantages. They exhibit increased long-term stability, better biocompatibility and a more favorable wear behavior than manually produced polymers. Furthermore, they offer more favorable computer-aided design/computer-assisted manufacture (CAD/CAM) processing characteristics and can be used in thinner thicknesses than ceramic materials.

Complex rehabilitations represent a particular challenge for the restorative team, especially if the vertical dimension of occlusion (VDO) needs to be reconstructed or redefined. The introduction of high-density polymers has enabled a significant extension of the pretreatment phase to establish the esthetic and functional aspects of the reconstruction. If the adhesive technique is applied correctly, these materials can be used on both natural teeth and existing restorations. This allows clinicians to evaluate the treatment objective over an extended period of time and therefore generates a high predictability of the definitive rehabilitation.

High-density polymers are currently especially indicated for single-tooth restorations. Basically, we can distinguish between polymethyl methacrylate (PMMA)-based, mostly unfilled materials for long-term provisionalizations (eg, Telio CAD, Ivoclar Vivadent; or Vita CAD-Temp, Vita Zahnfabrik) and materials, featuring a high inorganic filler content for final restorations (eg, Lava Ultimate, 3M Espe; or Vita Enamic, Vita Zahnfabrik). Except for Vita Enamic (etchable with hydrofluoric acid), careful airborne particle abrasion of the restoration’s bonding surface (Rocatec Soft, 3M Espe; grain size 33 μm, 1 bar pressure) followed by the application of a bonding agent is recommended to establish a durable adhesive bond.

Using an intraoral silicoating system (eg, CoJet, 3M Espe) is advocated for the intraoral bonding of CAD/CAM polymers to existing restorations. It is advisable to use a thermoplastic foil and to selectively perforate it to...
expose exactly those areas that should be surface treated. This measure ensures that only the bonding areas are silicoated. By using an especially designed silicoating powder agent (Rocatec Soft), the surfaces of the existing restorations are cleaned, roughened, activated, and silicoated all in one step. Upon completion of the silicatization process, the protective foil is carefully peeled off and any remaining particles are removed from the bonding surfaces with the help of an air syringe (Fig 9). Currently, clinical studies are being carried out to assess the suitability of high-density polymers for permanent restorations. Against this background, special attention should be given inter alia to the wear resistance and behavior of these materials when they are in direct contact with the opposing dentition.

The use of high-density polymers allows clinicians to increasingly explore interesting new treatment options and fields of applications. For instance, less invasive restorative procedures to treat periodontally damaged teeth may be developed, because polymers are characterized by a low modulus of elasticity and are therefore less susceptible to fracture than ceramic materials if they are used in delicate configurations (Fig 10). Additional advantages result from the superior CAD/CAM processing characteristics compared with ceramic materials. Higher edge stability, in particular, enables clinicians to use purely additive procedures for certain indications without sacrificing any tooth structure.

DISCUSSION

Reliable resin bonding to natural enamel and silicate ceramics has ushered in a shift in preparation designs towards considerably more conservative methods in the last few decades. Minimally invasive restorations are considered to be beneficial because they reduce the risk of devitalization, are kind to the tooth structure, and offer a high esthetic potential. Whilst these possibilities inspire a great deal of euphoria, we should bear in mind that the methods described above involve a high degree of technique sensitivity with regard to preparation (mainly in the enamel), adhesive bonding, and final fine-tuning of the static and dynamic occlusion. Adhering to the defined guidelines during the various clinical and technical treatment phases presents a key factor for achieving clinical long-term success. While numerous clinical long-term studies are available on minimally invasive restorative treatment methods with ceramic materials, valid clinical data on the long-term behavior of minimally invasive final restorations made of CAD/CAM polymers are still lacking.

So far the authors of this report have had excellent experiences with long-term temporary single-tooth restorations made of PMMA-based CAD/CAM polymers. A prospective controlled clinical study using highly filled CAD/CAM polymers as the material for the final restoration in patients with generalized loss of tooth
structure was initiated at the Department of Prosthodontics at the University of Munich recently (Project No 541-12). In the meantime, more than 12 patients have been treated and, without a single exception, they all responded enthusiastically to the predominantly additive treatment modality, as most of these complex cases could be treated with no, or hardly any, preparation. However, as the observation period of this study is still short, a scientifically valid conclusion cannot yet be drawn.

CONCLUSION

Dentists performing prosthetic treatments have a vast array of alternative treatment options at their disposal, which they can use instead of conventional and essentially more invasive procedures. Many treatment modalities are already backed up by valid long-term data. With regard to the material class of ceramics these treatment options are considered to be scientifically validated for numerous indications. Long-term results on the use of CAD/CAM polymers in permanent restorations are not yet available. Generally, the methods described above are considered to be highly technique-sensitive and therefore require the clinician and technician to have well-founded skills and experience to carry them out. Furthermore, the present report has only touched on a small section of the spectrum of minimally invasive treatment options currently available.

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