DENTAL TECHNIQUE

Virtual diagnostics and guided tooth preparation for the minimally invasive rehabilitation of a patient with extensive tooth wear: A validation of a digital workflow

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Recent developments in digital technologies in dentistry have led to significant changes of treatment concepts in prosthodontics. Optical scanning allows digitalization of the initial clinical situation, delivering virtual files of the initial status of the dentition in the standard tessellation language (STL) format. The STL files can be input into a computer-aided design (CAD) software program and analyzed. Digital diagnostics, including digital waxing and trial restorations, can then be performed. Subsequently, the type and design of the planned restorations can be exported as digital files and milled or printed by means of computer-aided manufacturing (CAM) technology to fabricate CAD-CAM trial restorations. After tooth preparation, the planned restorations can be fabricated with the CAD-CAM technology.

Different types of ceramic and composite resin materials have been developed for fabrication, opening up new prosthetic treatments. Less-invasive restorations, such as veneers, onlays, and partial-coverage crowns, can be milled from ceramic or composite resin materials and cemented with adhesive material as an alternative to conventional fixed prostheses.

Studies have shown that conventional preparation of complete coverage ceramic crowns necessitates anterior or posterior tooth reduction ranging between 40% and 70%. In contrast, tooth reduction for ceramic veneers on maxillary central incisors ranges between 17% and 30%. Extensive tooth preparation can cause hypersensitivity and pulpal damage. For this reason, and consistent with the development of materials and adhesive dentistry, current prosthodontic concepts have proposed less-invasive restorations before preparing a crown.

ABSTRACT

The recent evolution of digital technologies in dentistry has enabled virtual 3D diagnostic analysis of a dentition before treatment, allowing for virtual, minimally invasive treatment planning. In this report, an extensively worn dentition was 3D virtual analyzed at an increased vertical dimension of occlusion. Virtual waxing (exocad DentalCAD; Exocad) and subsequent analysis of the need for minimally invasive preparations were performed. Areas of each tooth without adequate clearance for the minimal thickness of a definitive restoration (set at 1.5 mm in the software), including the amount of tooth substance to be removed (GOM Inspect; GOM), were visualized in color. A preparation guide was virtually designed according to this diagnostic plan (3-matic; Materialise) and 3D printed (Connex3 Objet260; Stratasys) from resin (VeroMagenta RGD851; Stratasys). The teeth were minimally prepared using the guide, and the amount of preparation was validated by superimposing the scan of the prepared model on the initial scan and comparing it with the diagnostic plan. (J Prosthet Dent 2019; )
One prerequisite for minimally invasive prosthodontic treatment is thorough pretreatment diagnostics to define the treatment goals. To provide the least invasive approach, clinicians should determine the exact area and amount of tooth preparation needed before clinical treatment. To define the preparation needed, pretreatment diagnostics, including diagnostic waxing of the planned restorations, are essential. The conventional methods of transferring this information to the patient are trial restorations and silicone matrices. Trial restorations reproduce the diagnostic waxing and can be transferred to the existing dentition. They are used to visualize and communicate the treatment outcome to the patient, dentist, and dental laboratory technician.2


Figure 2. Virtual arbitrary relief in pit and fissure areas on maxillary cast for better adaptation of guide.

Figure 3. Construction of 2-mm-thick structure surrounding maxillary model.
approved, silicone matrices of the waxing can be used to define the tooth preparation.12-20

Limitations of this conventional workflow include the time and effort needed to produce a conventional diagnostic waxing and trial restoration and their associated costs. One further limitation is the predictability of the transfer of this plan to the patient. Silicone matrices may help evaluate the area and amount of tooth preparation needed during the procedure, but the predictability of the procedure is not ensured. Silicone matrices deliver 2D information during the preparation and are limited to 1 or 2 buccolingual or mesiodistal slices. To ensure minimal invasiveness and optimal standardization, a 3D preparation guide is desirable.

The 3D information of maxillary and mandibular dentitions obtained by means of optical scans can be used for virtual diagnostics and treatment planning. Furthermore, in clinical situations with reduction of the vertical dimension of occlusion (VDO), a virtual increase of VDO can be performed.21,22 Optimal interocclusal clearances can also be determined in the 3D analysis by following the recommendations for different restorative materials. Locations without sufficient clearance are color coded on the 3D image (virtual 3D diagnostics), indicating the amount of tooth substance to be removed based on the 3D virtual diagnostics. To transfer this 3D information predictably to the clinical situation and to ensure least invasive tooth preparation, CAD-CAM preparation guides need to be designed and produced.

In this report, restoration of an extensively worn maxillary dentition without the loss of VDO but with space available is presented—category 2 according to the treatment options in the restoration of an extremely worn dentition.23 The VDO was increased to obtain space, but some preparation was still needed on the posterior teeth to achieve the minimal clearance for ceramic restorations.

The casts of a previously treated patient were used to evaluate this concept. A 3D diagnosis was performed to determine the needed amount of VDO increase and define the areas with insufficient clearance for the planned reconstructions after a virtual VDO increase. A 3D-printed guide based on the virtual 3D diagnostics was named K-L (Kwon & Lee) preparation guide, and it was used for the minimally invasive preparations.
TECHNIQUE

1. Scan maxillary and mandibular dentitions to obtain STL data by using intraoral digital scans or a laboratory scanner (iScan D104; Imetric) to scan diagnostic casts.

2. Diagnose the optimal increase in VDO, that is, the opening in the incisal area, considering the minimum thickness of restorations in the posterior region and esthetics in the anterior area. Establish this with a 3D virtual analysis software program (GOM Inspect; GOM) (Fig. 1A, B).

3. Fabricate an anterior guide at the established VDO (Pattern resin LS; GC) to make a clinical occlusal registration (Jet bite; Coltène) based on the previous 3D virtual analysis.

4. Align the maxillary and mandibular STL files according to the occlusal registration by applying a best-fit algorithm (GOM Inspect; GOM) (Fig. 1C).

5. Relieve the maxillary cast to virtually fill in pits and grooves on the teeth that might interfere with the adaptation of the guide (3-matic; Materialise) (Fig. 2).

6. Construct a 2-mm-thick structure, resembling an occlusal device, to cover the teeth and surrounding structures of the maxillary model (cast A) (Fig. 3).

7. Define a 1.5-mm occlusal clearance on the mandibular cast (cast B). This clearance is defined by the minimum thickness of the material selected for the definitive restoration (for this restoration, it is lithium disilicate glass-ceramic) (Fig. 4A, B).

8. Virtually subtract cast B from cast A. The areas not fulfilling the space requirements are thereby visualized. Subsequently, design 2 separate preparation guides (first quadrant, second quadrant) to allow for removal of the respective parts from cast A (Figs. 4C, D, 5).

9. Fabricate the preparation guides by using a 3D printer (Connex3 Objet260; Stratasys) and place it on the cast for analysis of the needed preparation (Fig. 6A-C).

10. Perform the guided tooth preparation by removing only the tooth substance extending beyond the guide. Use a football-shaped diamond rotary instrument (no. 250/4250 red, Guided Universal Prep Set; Intensiv) (Fig. 6D).

After tooth preparation, the result was compared with the initial virtual plan for validation of the concept. The clearance obtained from the guided preparation was evaluated by scanning the cast after the preparation and superimposing the STL file on the file of the plan. The results indicated accurate transfer of the guided preparation plan to the clinical execution (Figs. 7, 8).

DISCUSSION

With the development of reinforced ceramic materials and adhesive dentistry, minimally invasive partial coverage restorations with increased VDO can be selected in preference to complete coverage crowns to restore an extensively worn dentition. However, sufficient clearance for the restoration in the posterior area may not be possible even with an increase of VDO.
Turner and Missirlian\textsuperscript{23} identified 3 distinct categories for the restoration of extensively worn dentitions in relation to VDO and treatment options. An increase of VDO should be determined considering various conditions. In this patient, the increase of VDO was established from the anterior esthetics and optimal posterior material. An area with insufficient clearance can be specified through 3D analysis with the presented method. Subsequently, the preparation guide can be designed and fabricated based on the previous 3D analysis to transfer the virtual plan to the clinical situation.

The thickness of the guide in this report was set to 2 mm, considering clinical and mechanical aspects. Determining the VDO increase is an important step in the treatment. Virtual 3D diagnostics of clearance between both dentitions can be made after defining the amount of virtual VDO increase. The tentative amount of increase can be virtually planned with the help of this analysis. However, due to the possible error of a virtual VDO increase, clinical occlusal registration by using an anterior occlusal registration device is also recommended.

In 2008, Vailati and Belser\textsuperscript{18-20} introduced a 3-step technique to rehabilitate extensively worn dentitions. This technique comprised 3 laboratory steps alternated with 3 clinical steps, allowing for the predictable minimally invasive esthetic and functional rehabilitation of patients with dental erosion. The concept in this report can be integrated into the 3-step technique to virtually plan for complete mouth adhesive restoration of extensively worn dentitions. Conventionally, analysis of the mounted cast is one of the main factors in determining the amount of VDO increase. A tentative amount of VDO increase was performed through visual inspection of the mounted cast in the articulator. With the help of a 3D digital software program, a virtual vertical increase of VDO is now possible.\textsuperscript{21,22} Precise evaluation of maxillary and mandibular dentitions can be obtained.

The K-L preparation guide was virtually designed, CAM fabricated, and used for the minimally invasive tooth preparation for this patient. Once the STL files of both dentitions and the occlusal registration were acquired, the guide could be designed automatically by inserting intended clearance values. As this guide was designed by using a CAD software program, the shape and dimensions of the guide were predictable and clearly defined. The magenta color of the guide helped to easily distinguish the needed amount of tooth reduction (Fig. 9). Virtual 3D occlusal analysis indicated the amount of insufficient clearance and, hence, needed tooth reduction.
Figure 7. Validation between before and after preparation using guide. Differences visualized in color—whitish color shows the area with >1.5-mm clearance and colored regions show areas and amount of teeth to be prepared to obtain at least 1-mm clearance. A, Right side before preparation. Color shows area that should be prepared. B, Left side before preparation. C, Right side after preparation. D, Left side after preparation.

Figure 8. Cross-sectional view to validate clearance change before and after preparation. A, Section at right second molar. B, Section at left second molar.
reduction. It provided visualized information on the location and amount of teeth to be prepared. This 3D diagnostic tool can be used for patient consultation and minimally invasive preparation. In addition, although this technique was introduced for VDO increase in the present patient, it may also be applied in various other clinical situations. If the functions used in this report could be integrated into a commercial dental CAD software program, the presented procedure would be easier to apply in daily practice.

SUMMARY

The K-L guide based on 3D virtual diagnostics indicates the location and amount of tooth substance to be removed. It can be easily designed and printed using the CAD-CAM technology.

REFERENCES


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Figure 9. Clinical application of guide. A, Guide placed on posterior area. B, Minimally invasive preparation performed according to contour of guide.