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# 3D-Printed Restorations as a New Treatment Option after Failed Dental Reconstruction: A Case Report

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## ABSTRACT

**Aims:** There is a lack of immediate and non-invasive treatment options for complex prosthetic rehabilitation, including bite calibration. The present case report presents a complex prosthetic situation accompanied by multiple gnathological problems. The treatment was conducted using 3D-printed restorations and a complete digital workflow.

**Methods:** The patient was treated in small steps following an expectative concept. First, polycarbonate splints were used to stabilize the occlusion. The adjusted maxillo-mandibular relationship was transferred with the help of intraoral scans. Individual movements were also electronically recorded and transferred digitally. 3D-printed restorations were additively manufactured in the maxilla and after three months in the mandible.

**Results:** The patient's gnathological problems could be eliminated. The patient was pain free and without functional impairments after the insertion of the 3D-printed restorations. Esthetic rehabilitation was achieved.

**Conclusion:** 3D-printed restorations can be a new treatment option for an initial treatment of gnathological problems. A step by step treatment offers the opportunity to evaluate each treatment step carefully. The digital workflow supports an accurate transmission of the maxilla-mandibular relationship and individual parameters for dynamic movements of the lower jaw. Splints can be avoided. Esthetic improvements can non-invasively be achieved.

**Keywords:** CAD/CAM; 3D-printing; Additive manufacturing; TMJ disorders; Bite calibration

## INTRODUCTION

Treatment options for bite adjustments in patients with complex initial prosthetic situations have been lacking up to now. Because these treatments can pose a challenge to the dentist,[1] alternative treatment options are desired. For some years, computer-aided design/computer-aided manufacturing (CAD/CAM) have offered great new

treatment possibilities.[1,2] Mainly high-density polymers based on highly cross-linked polymethylmetacrylate (PMMA) or composite materials have been used for CAD/CAM.[1,3] Because additive manufacturing in dentistry has become increasingly advanced, the advantages of 3D printing could be used for the treatment of complex prosthetic rehabilitations and bite adjustments.

To perform a bite adjustment, splints are often used for initial temporary rehabilitation. However, many patients do not tolerate wearing a splint in the long term[4] due to esthetics and speech impairments.[5,6] Adhesively cemented 3D-printed restorations could adopt the esthetics and the already set maxilla-mandibular relationship identically using the digital workflow. Meanwhile, digital articulators can also be integrated into the design software.[7,8] They can recognize not only the lower jaw's static position but also the individual digital registration of dynamic movements and their influence on occlusal parameters.

Due to the potential benefits of 3D-printed restorations for the patient, they can be applied to readjust the static and dynamic occlusion. In addition to the low printable layer thicknesses, a printing of individual non-invasive restorations became possible. Dental hard tissue is protected, and restorations need not be exchanged. 3D-printed restorations as a new treatment option for complex prosthetic rehabilitations is currently the subject of a clinical study in our department. One case in this study is described below. The patient had a complex initial prosthetic situation in combination with gnathological problems, which were restored with the aid of 3D-printed restorations on a long-term provisional basis. A fully digital workflow was applied.

## CASE HISTORY

A 58-year-old woman's dentist referred her to our clinic after a long and unsatisfactory treatment period. The classical concept for increasing occlusal vertical dimension by a splint followed by definitive restoration with crowns had failed. Her dentist used the DROS® concept. Nevertheless, the patient ended up with an instable centric relation and centric occlusion despite the new rehabilitation and a long observational period with occlusal adjustments. A laterally open bite developed (Figure 1A-C).

**Figure 1A:** Initial habitual occlusion with a laterally open bite on the left and right sides. The restorations had no deficiencies.

**Figure 1B:** Initial situation in the upper jaw: The restorations had no deficiencies.

**Figure 1C:** Initial situation in the lower jaw. Sufficient partial and complete crown can be seen.

## Diagnosis

The specific anamnesis revealed that the patient suffered from daily radiating pain in the head and neck area. On the numeric pain scale (0-10), she ranked the pain at a value of six. Nevertheless, she stated that the pain did not limit her daily performance.

The clinical examination included the dental status, periodontal examination and functional examination according to the German Society for Craniomandibular Disorders added by a radiological examination. Radiological examination could exclude pathologic findings of dentition or osseous structures of the temporomandibular joint. Palpation and auscultation of the temporomandibular joint revealed no pathologic findings. The mandible's mobility was not restricted. The palpation of the temporalis muscle and the masseter muscle was painful. The static occlusion was not equilibrated, and the dynamic occlusion was guided by the frontal teeth. The patient was not able to keep her mouth open for a long time. The finally-derived diagnoses were myofascial pain with spreading and occlusal interferences.

### Treatment

Polycarbonate splints were manufactured for improving esthetics and further evaluation of the occlusal situation (exspectative diagnostic) (Figure 2A-E). Before registering the maxilla-mandibular relationship for the splints, the

patient was pretreated by physiotherapy. The splints covered both jaws and stabilized the occlusion with multipoint contact in static and canine guidance in dynamic. The vertical dimension was increased 4 mm. Despite the increased vertical dimension, an interocclusal distance during speaking existed. The patient was reexamined after two weeks and then monthly. Only minor occlusal adjustments were necessary. The pain decreased within one month, and she was pain free over the rest of the 6-month observation period. The occlusion was stable.

splints.

**Figure 2B:** Polycarbonate splints in the maxilla and mandible to stabilize the occlusion and improve esthetics. The laterally open bite could be closed.

**Figure 2C:** Maxillo-madibular relation on the left side. The crown in region 36 was recemented several times. Later on it was rehabilitated using a 3D-printed restoration.

**Figure 2D:** Polycarbonate splint in the upper jaw.

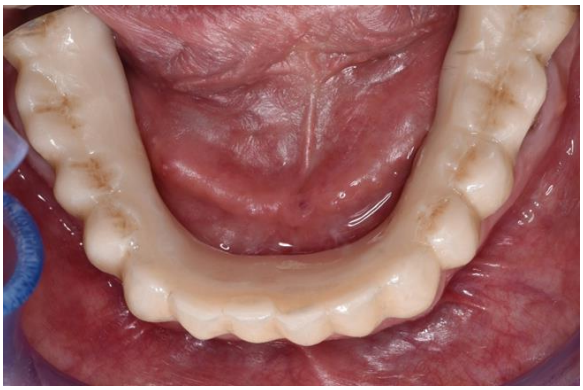

**Figure 2E:** Polycarbonate splint in the lower jaw.

After we received detailed information and her written consent, the patient was included in the clinical study. An intraoral scan (Primescan, Dentsply Sirona, Charlotte, North Carolina, USA) of the dentition without the splints was conducted (Figure 3A-C). The vertical dimension and the maxilla-mandibular relationship was adopted from the polycarbonate splints. 3D-printed non-invasive restorations were manufactured without any preparation of the teeth or removal of the existing crowns. The crown on tooth 36 had become loose and was recemented several times. Because the patient always traveled from another city for treatments in our department, she saved herself the trip after a few recementations. At this point, it was clear that the crown would be replaced with a 3D-printed restoration. She was told that tooth 36 could be restored on a long-term provisional basis as part of the study. Because the tooth's prognosis was mixed and long-term tooth preservation could not be guaranteed, later removal would be possible at any time prior to renewed definitive restoration.

**Figure 3A:** Initial situation after scanning and digital bite elevation.

**Figure 3B:** Initial situation on the right side. The intraoral scan was conducted with the polycarbonate splints. The vertical dimension could be transferred identically.

**Figure 3C:** Initial situation on the left side: The same situation with an increase of the vertical dimension can be seen.

At first, 3D restorations were fabricated for the upper jaw, replacing the upper splint. A perfect occlusal fitting to the splint in the lower jaw was adjusted. After a three-month observation period, the lower jaw was restored with the 3D-printed restorations.

The scans for the maxillo-mandibular relationship were performed using the polycarbonate splints. Because the polycarbonate splint hid the teeth's vestibular surface, a matching of the scanned jaws was impossible with the intraoral scanner. Therefore, a perforation was made in the area of the first molars to make matching the jaws easier. Whereas these scans represent the static occlusion, the dynamic parameters were recorded digitally by Zebris (Zebris for Ceramill, Amman Girrbach, Pforzheim, Germany). A virtual articulator (Artex CR, Amann Girrbach) was used to reflect the temporomandibular joint's (TMJ's) individual movements. The aim was to determine the important parameters for the occlusal design, such as the horizontal steepness of the fossa, the Bennett-Angle and the incisal angle (Figure 4). A digital face-bow transfer was performed with the Zebris equipment (Zebris for Ceramill, Amman Girrbach), as well.

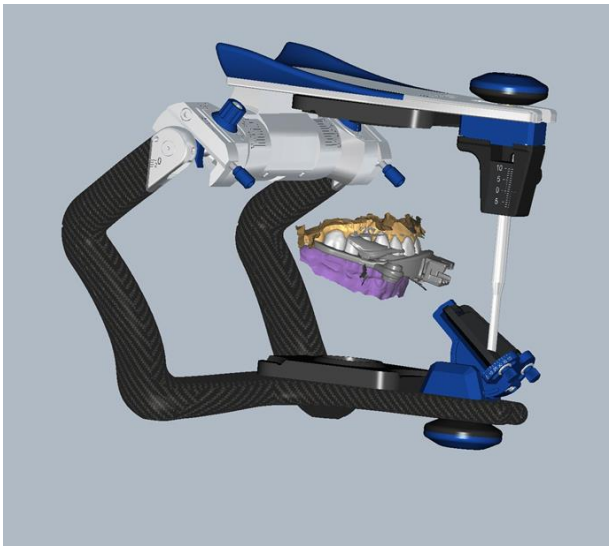

**Figure 4:** Virtual articulator with the models already aligned (Zebris for Ceramill, Amman Girrbach).

The scan data and the jaw motion data were transmitted to the dental laboratory of the Charité. The 3D-printed restorations were designed with Exocad (Exocad Dental CAD Galway 3.0, Exocad, Darmstadt, Germany) (Figure 5), and restorations were printed with Varseo XS (Varseo XS, Bego, Bremen, Germany).

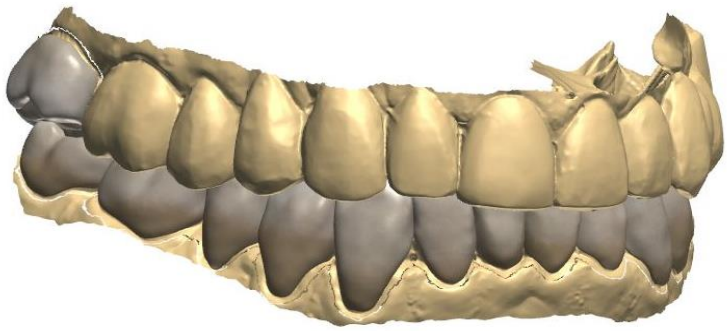

**Figure 5:** Digital design of the restorations (Exocad Dental CAD Galway 3.0, Exocad GmbH).

The design of the 3D-printed restorations was initially set as single crowns (Exocad Dental CAD Galway 3.0, Exocad). The restoration geometries were then individually determined. A defect-oriented design with thin restoration margins was enabled. The facial tooth surfaces of the anterior teeth in the maxilla and mandible were included for esthetic reasons. The other restorations in the posterior region were limited to the tooth structure defects and the occlusal surfaces to increase the occlusal vertical dimension. The cutter-radius correction was not taken into account for 3D printing. It allows for calculation of the geometry of the natural tooth minus the adhesive joint space to be reproduced without distortion in the printing process.

The 3D-printed restorations were inserted adhesively. For this purpose, the restorations were sandblasted with aluminum oxide and conditioned with a universal primer (Monobond Plus, Ivoclar, Schaan, Liechtenstein). If enamel was present, the teeth were etched with 37% phosphoric acid. If a sufficient restoration was present, it was etched with hydrofluoric acid (Ultradent Porcelain Etch 9% Buffered Hydrofluoric Acid, Ultradent Products Inc.,

Utah, USA). Monobond Plus was applied as a universal primer. The adhesive insertion was done under absolute dryness using a rubber dam (Dental Dam, Henry Schein Inc., New York, USA).

Enamel and dentin were pretreated with a self-etching universal adhesive (Scotchbond SE, 3M Espe AG, Landsberg am Lech, Germany). An adhesive luting composite (RelyX Ultimate, 3M) was used for cementation. The proximal contacts were initially cleaned with dental floss. After removal of the cement residue and light curing, the static and dynamic occlusion was checked. The static occlusion was a half-premolar width mesially from an Angle Class I at the left side whereas an Angle Class I was present at the right side according to the initial situation. Therefore, not a canine guidance but a group contact could be established. After adjustment of the occlusion, the restorations were polished from coarse to superfine using Sof-Lex polishing wheels (3M, St. Paul, Minnesota, USA) (Figures 6A-D).

**Figure 6A:** Inserted 3D-printed restorations in the upper jaw. 3D-printed restorations were adhesively fixed onto sufficient restorations, as well. The polycarbonate splint in the lower jaw was maintained as an antagonist. The bite situation, which was adjusted with the help of the polycarbonate splints, could be transferred exactly to the new situation.

**Figure 6B:** Inserted 3D-printed restorations in the upper jaw.

**Figure 6C:** Maxillo-mandibular relation after insertion of the 3D-printed restorations in the upper jaw. The polycarbonate splint in the lower jaw.

**Figure 6D:** Maxillo-mandibular relation on the left side

After the patient had become accustomed to the new situation without any complaints, the restorations in the lower jaw were manufactured using the same workflow as described above (Figures 7A-D).

**Figure 7A:** After insertion of the 3D-printed in the upper and lower jaw, the maxilla-mandibular relation was equal to the situation before wearing polycarbonate splints.

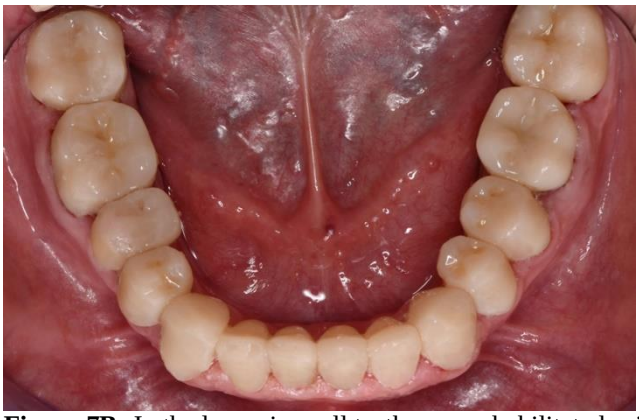

**Figure 7B:** In the lower jaw, all teeth were rehabilitated using 3D-printed restorations. The situation in the upper jaw did not change (Figure 6B).

**Figure 7C:** With the help of 3D-printed restorations, the laterally open bite could be closed. Wearing splints was no longer necessary.

**Figure 7D:** The same maxilla-mandibular relation could be achieved on the right side.

**Outcome**

The patient did not express any complaints after the insertion of the 3D-printed restorations in the upper jaw and later in the lower jaw. She was satisfied with the improved esthetics resulting from the 3D-printed restorations.

At the first follow-up, after five days, the occlusion was checked again. An intraoral scan (Primescan) of the upper jaw was conducted to record the initial situation after insertion.

The aim of our clinical study is to control the reconstruction's occlusal stability, the occlusal wear behavior and color stability of 3D-printed restorations. The first scan represents the baseline situation and allows for fabrication of a vacuum-formed splint (Erkodur, Erkodent, Pfalzgrafenweiler, Germany) with a thickness of 0.8 mm for color determination. The splint is perforated at the teeth's vestibular surface. The perforations have the same size as the measurement head of the spectrophotometer and allow for exact repositioning of the spectrophotometer. Color determination is performed in a second follow-up session after the splint has been fabricated.

## DISCUSSION

The present case report showed a difficult occlusal situation of an unsuccessful pretreated patient. The aim of our treatment was to perform small reversible steps without destroying further tooth substance or the existing reconstructions and to identify problems more quickly. Moreover, the therapy is non-invasive and does not require long treatment sessions that might cause even more problems for patients suffering from myofascial pain with spreading.[9,10]

The 3D-printable material that was used in the present case report is approved for permanent restorations. Definitive materials help alleviate the time pressure that usually occurs in the temporary-treatment phase with splints or provisional restorations. The danger of secondary caries, regular loss of restorations and esthetic deteriorations can be eliminated.[11,12] Consequently, no urgent transfer to another definitive material is necessary. The restorations can be segmentally exchanged later. Furthermore, uncomfortable wearing of a splint for months can be avoided.[4] Often, myofascial pain is temporary. The time period itself cannot be defined. In unfortunate cases, dental rehabilitation takes place in stressful situations.[13] Factors for muscle pain can be traumas, systemic, iatrogenic, occlusal and mental disorders.[14-19] A habitual incorrect posture of the head while using smartphones or other technical devices that cause an incorrect permanent sitting position can also promote temporomandibular disorders (TMD).[20-22] Mental health also plays a decisive role in the development of TMD.[23-24]

The clinical suitability of 3D-printed restorations is currently the subject of research in our department, as no scientific data on this topic is available. In the present case report, 3D-printed restorations are used for long-term provisional restoration of a complex prosthetic rehabilitation.

When one initiates prosthetic rehabilitation, a material's wear resistance is of particular importance for clinical suitability. The patient did not receive a splint to protect the restorations on purpose. The wear behavior can therefore be uninfluenced over years. How the 3D-printed restorations' mechanical stability will be affected clinically is unknown. The occlusion should be adapted optimally. The dynamics should be based on the initial situation. Overloading of individual restorations should be avoided.[25-27] Individual in vitro studies have shown that 3D-printed restorations exhibit the same or even greater wear resistance than conventional composites.[28-31] Determining whether this can be confirmed clinically is one of the aims of our study.

Long-term results have to be awaited for a classification of the 3D-printable material in clinical practice. Results from in vitro studies can hardly be transferred because complex oral conditions cannot be adequately mimicked in vitro.[29] The digital workflow seems to allow for an accurate adoption of the occlusal conditions. It allows for the use of 3D-printed restorations for extended pretreatments and sensitive functional situations. An additional use of

digital recording of temporomandibular movements can ensure an optimal adaption of the 3D-printed restorations to the patient's static and dynamic conditions. All impairments treated with splints for testing the increased occlusal vertical dimension over a long time can be avoided with an esthetic improvement from the beginning.

## CONCLUSION

The present case report shows that 3D-printed restorations are suitable for an initial treatment of occlusal problems. Additively manufactured restorations can initiate and support the gentle and step by step treatment of craniomandibular disorders. A fully digital workflow can be applied. Adjusted occlusal records and electronically recorded individual temporomandibular movements can be transferred. Non-invasive restorations can be printed. Patients benefit from rapid esthetic improvements and no need to wear a splint.

## ACKNOWLEDGMENT

None.

## FUNDING INFORMATION

None.

## CONFLICT OF INTEREST

Elisabeth Prause, Robert Nicic, Ingrid Peroz and Jeremias Hey declare that they have no conflict of interest.

## ETHICAL APPROVAL

The Ethics Committee of the Charité-Universitätsmedizin Berlin approved this clinical study (Ref.-Nr. EA2/013/21), which was conducted in accordance with the Declaration of Helsinki on Ethical Principles for Medical Research.

## DATA AVAILABILITY

Due to the nature of this research, the patient of this study did not agree for their data to be shared publicly, so supporting data is not available.

## CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

## FUNDING STATEMENT

This research did not receive any financial funding.

## CONSENT

Written informed consent was obtained from the patient to publish this case report in accordance with the journal's patient consent policy.

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