Lithography-based Ceramic Manufacturing in Digital Dentistry

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Ⅰ Introduction

The possibility of producing complex parts is what makes additive manufacturing technologies (AMT) interesting for many applications. AM has already found its way into fields as biomedical engineering and dentistry, where customized solutions are relevant. Precision, however, still is the weak point of many systems available. At TU Wien we developed a lithography-based method to produce parts out of different materials such as polymers, highly filled ceramic slurries and composites with a feature resolution down to 20 µm. In case of ceramics, the thermal postprocessing leads to further difficulties regarding precision due to shrinkage and sinter distortion. This study shows the possibilities and current limitations of structuring ceramic slurries using stereolithography by comparing the fitting of stereolithographic manufactured parts to the original digital file and conventionally produced dental restorations. Together with the Bernhard Gottlieb University of Dentistry the crowns were scanned, matched and analyzed.

Ⅱ Additive Manufacturing

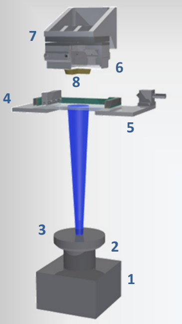


Fig. 1: Stereolithography-based system for processing highly filled photosensitive slurries based on DLP.

A CAD-model in a suitable file format (e.g. STL) is virtually sliced into defined layers. Based on the principle of digital light processing (DLP, Fig. 1) a digital micromirror device (DMD) projects blue light (LEDs with a wavelength of 405 - 460 nm) onto the slurry and cures it layer by layer. After each solidified layer the vat is slowly tilted to minimize the forces during the separating step. A coater blade then ensures that there is enough material in the building area for the next layer[3]. The thickness of this coating combined with the layer thickness influences the resolution of the part, allowing to print delicate structures with a feature resolution of 20 µm.

1. Light Source (LED 405 - 460nm)
2. DMD Chip (dynamic mask)
3. Optics
4. Coating system
5. Tiltable vat
6. Building platform
7. Back light
8. Manufactured part

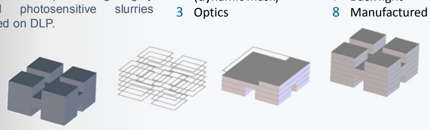


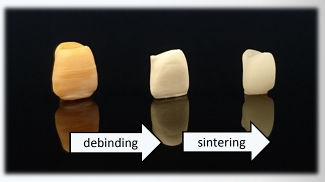
Fig. 2: 3D-printing process from CAD-model to final part. The model is sliced into single layers of defined thickness which are stacked during the printing process.

Fig. 3: Sintered 3D-printed restorations for anterior tooth. The ceramic matches conventionally produced crowns in translucency, biaxial strength and fitting. The color can be customized during the printing process.

Ⅲ Thermal Postprocessing

The slurries for the parts used for this study consist of ceramic powder of particle size in the range of 200 nm (ZrO_2) to 20 µm (glass ceramic) mixed with acrylate-based monomers, an organic solvent (polyethylene glycol or polypropylene glycol), light absorber and a photoinitiator. Depending on the filler material, the solid loading ranged from 42% (ZrO_2) to 54% (glass ceramic). The parts are produced as shown in (Ⅱ). In order to get a dense ceramic part the green bodies have then to undergo a thermal treatment process. Based on TGA measurements the program for this process was developed. At lower heating rates and temperatures initially the solvent and then the whole organic content is removed by decomposing the polymeric binder during this debinding step, leading to a so called brown part. Afterwards sintering at up to 1000°C leads to the final restoration.

Fig. 4: Green part, brown part and sintered restoration with support structure. Thermal post processing leads to a shrinkage of >23% in each direction.



Ⅳ CAD/CAM in dentistry

Goal: automatic production of restorations from digital patient data

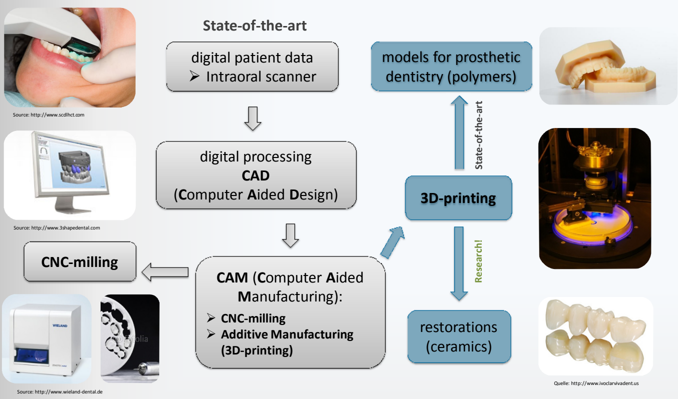


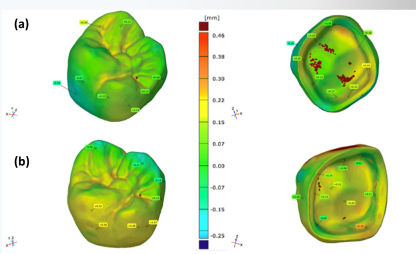
Fig. 5: State-of-the-art and future possibilities in CAD/CAM for digital dentistry.

CAD/CAM technologies are widely used in digital dentistry. Also, completely digital ways by having the digital patient data after scanning, processing them in a matching software and using CNC-milling machines are already state of the art. The goal of this study is, however, a completely automatic production with an AM technology directly producing the dental restorations with minor to no manual postprocessing. With further implementing a selective coloring possibility, the need of finishing the restorations by hand can be omitted[2].

Ⅴ Precision of 3D-printed Restorations

In order to ensure the required resolution for dental restorations, printed parts were compared with milled crowns and the original CAD-model. Both were scanned with an intraoral scanner (Trios®) and overlayed in an inspection software (GOM Inspect®). With the printed part as reference, the deviations to the original STL-file and the milled crown are shown in Fig. 6a and 6b respectively.

Material residues and scanning artefacts lead to misalignment in some spots. The overall matching, however, is promising. With high precision printing and adjusting the shrinkage and distortion during the postprocessing the deviations of 200 µm can be further reduced.



(c)

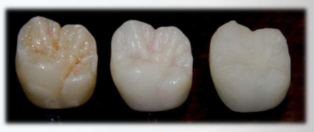


Fig. 6: Comparison of the printed crown to the original STL-file (a) and the milled restoration (b). A milled, pressed and printed molar crown (from left to right), partly glazed (c).

Ⅵ Conclusion

It can be shown that with our stereolithography based system, printed restorations of high quality and resolution can be produced and AM has a high chance to find its way into the dental CAD/CAM process. The overall precision of the final parts is comparable with that of conventionally produced crowns. For other dental restorations like multi-unit bridges this still has to be verified. Therefore we need strong partners with competence in this field, like the University Clinic of dentistry.

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