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Evaluation of dental restorations with occlusal surfaces - A new approach -

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Introduction/Aim of the study

Mainly, the occlusal fit of prosthodontic restorations is evaluated qualitatively by visual control of color-marked contact points. A large loss of data and information is immanent in conventional methods for the exploration of internal, marginal and occlusal fit of fixed restorations.
Aim of this study was to develop a procedure for the three-dimensional analysis of internal and occlusal precision of fit.

Material and Method

A test model was developed by reverse engineering. Every single step in the manufacturing of fixed prosthodontic restorations concerning the influence on the achievable precision has to be evaluated. The test model is based on a real and an identical virtual model of upper and lower teeth in static occlusion.

Starting point were full arch master-casts of the upper and lower jaw (teeth 14, 16 and 36 prepared with a chamfer, tooth 15 missing). The master-casts were optically digitized with a measuring error of ± 10 µm (ODKM, IVB GmbH, Jena, Germany; Fraunhofer Institut für angewandte Optik und Feinmechanik, Jena, Germany).

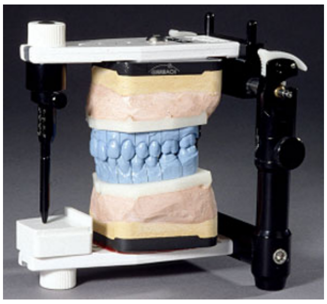

Fig. 1: Starting point of the reverse-engineering process.

Data Processing
To avoid undercuts, point clouds were reduced manually, then filtered and exported in ASCII-format (Argus, IOF, Jena, Germany). With Surfacer® (Version 10.6, Imageware Inc., Ann Arbor, Michigan, USA) points differing more than 10 µm from a plane respectively a sphere were removed from the data sets.

CAD
Based on the point clouds, surfaces as smooth as possible were created with Surfacer® for each tooth (curve mesh with 240 control points). With maximum smoothness, influences of roughness or surface structure on the results within the single steps of manufacturing were avoided.

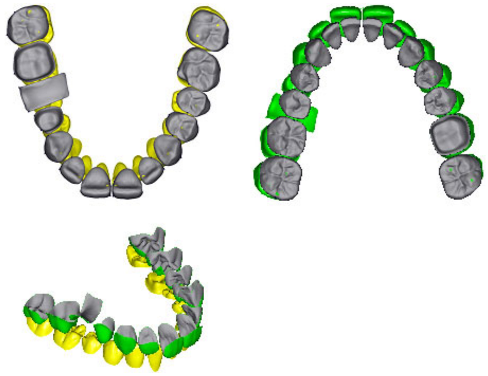

Fig. 2: Virtual Model optimized for CAD/CAM purpose.

Minimizing the deviation between virtual model and real model, areas which caused difficulties in fabrication were specifically modified.

Reverse-Engineering/Optimization

The processing error had to be determined. For this reason, impressions were taken of the real model's metal teeth (Dimension Penta H, Dimension Garant L, Pentamix-machine, 3M Espe AG, Germany) and master cast dies were made (esthetic rock 285, dentona, Germany). The dies were digitized again. The error of impression-taking and die-making averaged 8 µm. Data sets were aligned to the reference surfaces of the virtual model. Surface-Cloud-Differences between point cloud and respective surface of each tooth were analyzed qualitatively and quantitatively.

Fig. 3a+b: Prototype of maxillary and mandibulary metal Real Model.

The real model was manufactured from high-grade aluminium by the Institute for Production Automatisation and Control Technologies, Technical University Dresden with a 5-axis milling machine (Maho MH 800 C, Firma Deckel Maho, Pfronten, Germany).

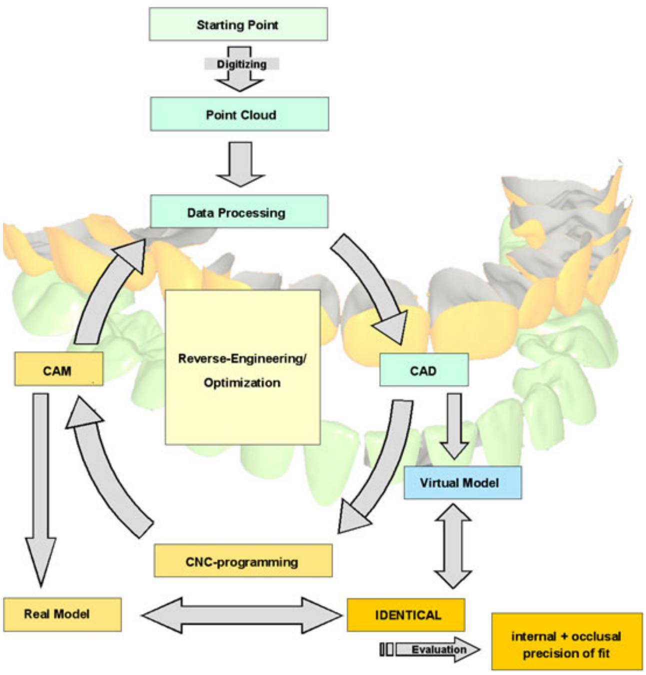

Fig. 4: Optimization cycle and functional principle for the evaluation of internal and occlusal precision of fit.

Results

By multi-step optimization, manufacturing a real model in static occlusion, which is identical to a virtual model is considered to be possible within a processing error of <= 5 µm for each single tooth respectively an error of <= 40 µm concerning the whole model. In a workpiece, the finest structures possible to be CAD/CAM fabricated are dependent on the kind and size of the tool chosen. A qualified combination of milling and finishing cycles results in a workpiece surface quality that matches the surface smoothness of the virtual model.

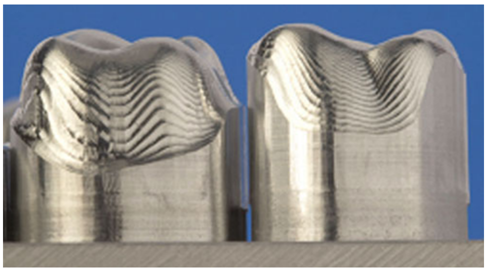

Fig. 5: Necessary adjustment of the milling paths.

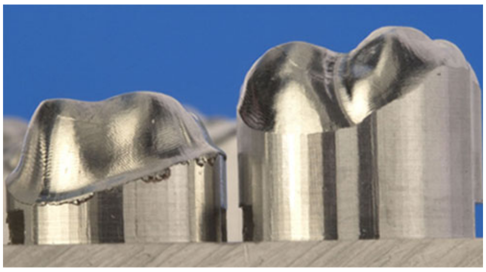

Fig. 6: Necessary adjustment of the feed velocity.

Deep and narrow fissures on occlusal, vestibular or oral surfaces result in processing errors lying not within the defined tolerance. Before manufacturing is started the processability of the workpiece has necessarily to be checked with the chosen milling tool (Tool-radius-plot). The interpenetration of upper and lower tooth surfaces may be evaluated qualitatively analogous to the analysis of occlusal contacts in conventional methods. On top of this, a quantitative evaluation of the size of the occlusal contacts is possible.

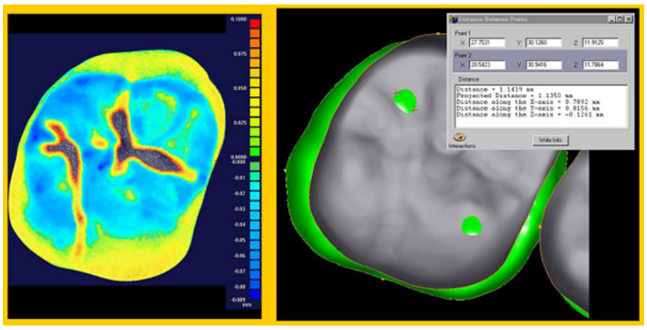

Fig. 7: Qualitative and quantitative analysis of the congruence between Virtual and Real Model by color-coded 3D-analysis (surface-cloud-difference) and 2-dimensional measurement of the occlusal contacts.

Conclusion

The precision in manufacturing aimed for in the test model can be reached when qualified optimization of the reverse-engineering process is performed. Obtained results of the specific demands in CAD/CAM-fabrication can be transferred to the processing of fixed prosthodontic restorations.

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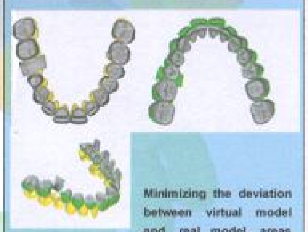

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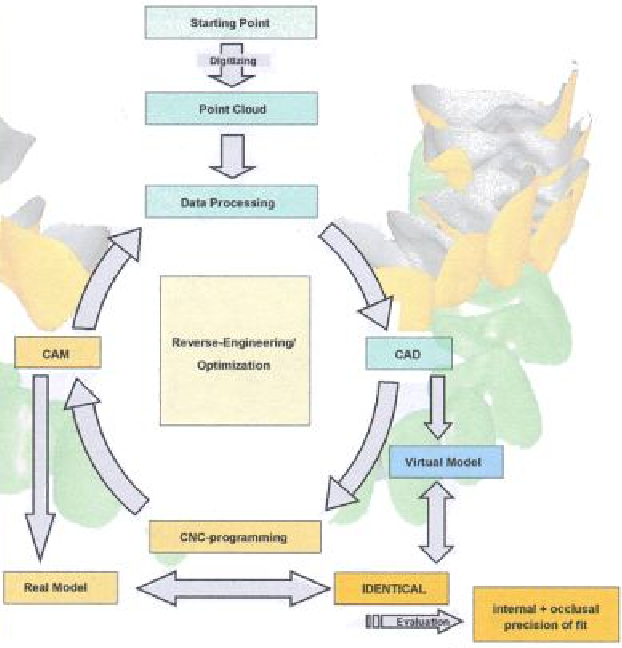

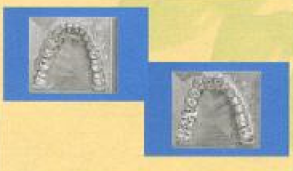

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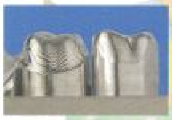

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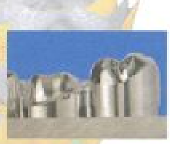

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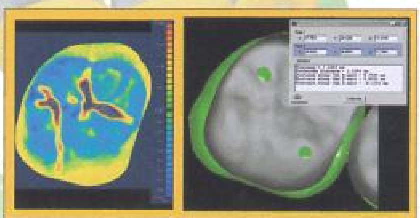

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