Validation procedures in computerized dentistry

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CHAPTER 4

Computer modelling of occlusal surfaces of posterior teeth after application of an axiographic registration (Condylocomp) system

Keywords: CAD/CAM, virtual articulation, electronic axiographic registration, occlusion
4.1 Abstract

Statement of problem: Static and dynamic occlusal interferences frequently need to be corrected by selective grinding of the occlusal surface of conventional cast and ceramic-fused-to-metal restorations. CAD/CAM techniques allow control of the dimensional contours of these restorations. However, the parameters responsible for the occlusal form need to be determined. These parameters can be given as default values or can be individually determined after jaw movement registration. Both types of values can be introduced into the CYRTINA® CAD/CAM system. The question is if after application of this procedure the correction for occlusal interferences in restorations can be omitted.

Purpose: This study investigated the possibility of data-transfer derived from an optoelectronic registrationsystem (String-Condylocomp, KAVO)** into the CYRTINA system to fabricate full ceramic restorations consisting of a zirconia substructure veneered with a layer of porcelain. Furthermore the differences of these crowns were compared to crowns designed by using default settings as well as selection of a static occlusal position.

Material and methods: The preparation of a first mandibular molar (46) as well as the other teeth of the lower and upper jaw were digitized with a fast laser-stripe surface scanner. Then a digitized anatomical design of the 46 was adapted to give optimal positions for the cusp tips and fossae with the opposing teeth in static (STA) occlusion using the computersoftware (CyrtinaCAD). Disturbances in the dynamic occlusion were eliminated using two settings of the software to adjust the computer design: 1. the default (DEF) and 2. the condylocomp (COND) setting.

Results: The clinical features of the occlusal morphology of the crown types fulfilled the esthetic and morphological criteria of restorations in clinical dentistry. Differences in the morphology of the CON crown as compared to the STA and DEF crown were small and existed especially in the disto-buccal part of the occlusal surface. Sufficient occlusal contacts existed in the imitated functional movements.

Conclusion: Functional occlusion without occlusal interferences in a CYRTINA crown for the first mandibular molar can be obtained using data from the Condylocomp-KAVO registration, which were incorporated in the CYRTINA CAD/CAM system.

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4.2 Introduction

Clinical experience has shown that factors determining occlusion in the conventional indirect restorative crown fabrication techniques are difficult to control. Even after applying careful impression techniques, registration of jaw movements and optimal technical procedures in the dental laboratory, occlusal disturbances are common. Therefore frequently selective grinding is indicated at the insertion of the restorations. These corrections will affect the material qualities in particular when porcelain is used in the occlusal surface of dental restorations. Many types of articulators have been developed to copy the individual 3-D mandibular movements to improve dental restorative procedures. In this way cuspal placement and ridge-groove alignment of opposing teeth have been determined to avoid occlusal disturbances. In dental practise mostly the angles of the right and left sagittal condylar path, the Bennett movement and the incisal guide are set in half adjustable articulators to simulate the individual movement patterns of opposing occlusal tooth surfaces. However, when using these averaged settings, occlusion that is harmonious with an individual dynamic movement pattern, which is the major prerequisite for successful restoration of the occlusal surface of posterior teeth, cannot be expected. This may also be said for the CAD/CAM crowns made after the implementation of default values.

The design of a restoration with the CAD/CAM system has the advantage that numerous parameters can be set in the computer software to simulate the 3-D maxillo-mandibular movement patterns. The implementation of the individual data of jaw registration of the protrusive, laterotrusive and mediotrusive pathways of the interocclusal contact movements can be expected to give the most appropriate settings. After application of these values the individual locations of the supporting cusp tips can be computed using the CAD software. The implication for practical dentistry will be great if tooth morphology can be designed, without introduction of interferences in dynamic occlusion. Several registration methods have been proposed to determine a complete description in 3-D of the position of the lower jaw with respect to the upper jaw. Therefore the recording of six independent coordinates corresponding to the six degrees of freedom is required. The six degrees of freedom of the lower jaw should be established in a head related coordinate system, because movements of the head are normal phenomena observed during registration procedures. For clinical situations head related 3-D registration systems are very laborious and patient-unfriendly. Recently a new optoelectronic registration apparatus (String Condylocomp-KAVO) has been developed for clinical practice, in which the origin of the coordinate system is attached to the
moving head, so that the coordinates of the mandibular intercondylar axis are relative to the position of the head.

After transfer of the registration data obtained from the String-condylocomp to the CYRTINA system for simulation of the recorded mandibular movements, we investigated the following questions:

1. Can a CYRTINA CAD/CAM crown be designed using the information concerning the interocclusal relationship from the String-condylocomp registration?
2. Which morphological differences are detectable in porcelain crown restorations based upon Condylocomp registration as compared to crowns produced with default values for the sagittal and medial condyle angles as well as crowns only designed for static occlusion.

4.3 Material and methods

In a model of a human head (Patient Simulator, KAVO EWL), manufactured for educational purposes, a set of 14 acrylic elements has been placed in both upper and lower jaw. The jaw relation can be classified as an Angle Class 1 relation with a sagittal overjet of 1mm. The dental archs are fixated in the head and connected via a mechanical temporo-mandibular joint (TMJ). The condylar head moves opposite a sigmoid „temporal” surface under cranially directed forces of springs. The condylar path inclination of the TMJ has been pre-set by the manufacturer. The intended movements of the lower jaw are manually performed by the operator. The mandibular movement patterns are limited in accordance to the mechanical constraints of the artificial TMJ, the elements and the tension of the springs.

The String Condylocomp LR3 is a computerized jaw movement registration apparatus developed for diagnostics and therapy in functional disorders of the stomathognathic system. Rotational and translational movements of a reflector connected to the mandible and positioned laterally of the right and left TMJ, are measured in a head-related device (photo String-Condylocomp). The connection to the mandible is achieved via a clutch fixated on the labial surfaces of the lower front elements. The head related frame is positioned according to a intercondylar hinge axis and the Camper plane. After defining this axis, the centric occlusion position as well as the protrusive and the left and right lateral guided contact movements were registrated. These data can be used for the determination of data for the development of CAD/CAM crowns. Additionally they can be used for the individual
adjustments of most commercially available articulators or the analysis of individual jaw motion parameters.

In our study the movement registrations were executed using the KAVO model after preparation of the 46 for the restoration with a CYRTINA porcelain crown. Rounded types of diamond burs were used and silicone-rubber impressions were made of the preparation and the other elements of the lower jaw. The impression of the antagonist was incorporated in the check bite. The gypsum cast of the prepared tooth and adjacent teeth and the antagonistic teeth in the check bite were digitized as described in the section CSD\textsuperscript{5}.

Essentially the individual movement is determined by registration of the X, Y and Z coordinates of the left and right end points near the condyle of the axis and the rotation around this axis. Six channels were used for the description of the movements of both condyles in the medial, proal and caudal direction. The rotational values from the plane determined by the left and right condyle and the inferior incisivus and the rotational intercondylar axis are additionally arranged in another channel. The data from the condylocomp registration in three directions have been referred to a Cartesian axis system (Fig.4.1). These data were introduced in the CYRTINA system and transformed to the position of the 46 for the design and manufacturing of the CYRTINA crown.

After running the CYRTINA CAD procedure, the Condylocomp crown (CON) could be manufactured\textsuperscript{5}.

The morphology of the occlusal surface of the CON crown of the 46 was compared to two other types of CAD/CAM crowns; the static (STA) and the default (DEF) crown. The STA

\begin{figure}[h]
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\caption{Denton-Condylocomp registration apparatus: Six channels are used for the movement description of the right and left condyle; three channels for the movements of each condyle. The rotational values from the plane determined by the left and right condyle and the inferior incisive point with respect to the rotational intercondylar axis are additionally arranged in another channel. The position of both condyles and lower incisive point have been referred to a cartesian axis system.}
\end{figure}
crown is the crown design which was chosen from a library of generic anatomical forms and afterwards adapted to the adjacent molars and the antagonist. In the DEF crown the occlusal form was adapted according the default settings in the CYRTINA CAD system. The angles for the sagittal condyle, the lateral Bennett and the incisal path have respectively been chosen as default values of 30, 20 and 30 degree. These values are commonly used by dental technicians for the adjustments in dental articulators.

For discrimination and illustration of the differences in occlusal surface design of the three crowns, i.e. the CON, the DEF and the STA crown, three possibilities were chosen.

Firstly by comparing bucco-lingual sections of the opposing 16 and 46 of the three design types: CON, DEF and STA.

Secondly, by comparing the graphic designs of the morphology of the three crown types in the CYRTINA system.

Thirdly by comparing the frequency of the interocclusal distances in an interocclusal range of 1mm, measured from the occlusal surface of the crown in intervals of .05 mm.

Interocclusal markings of the contactpoints after manipulation of the opposing jaws in the KAVO head have been registrated to indicate the functional contacts in centric occlusion.

4.4 Results

The detailed description of the manufactoring of the CYRTINA crowns is published in part 1.
In Fig. 4.2 three types of movements in medio-, latero- and protrusive direction are shown in a projection of the crown design in respectively the occlusal, the bucco-lingual and the mesio-distal view (Fig. 4.2a, 4.2b and 4.2c).

To compare the settings of the CYRTINA software the registration data using the KAVO-condylocomp have been transformed to values for the sagittal, lateral and incisal angles using the String-Condyllocomp software.

These have been calculated respectively as 45, 5.5 and 64 degrees. The immediate side shift was calculated as .5 mm.

**Figure 4.3: Bucco-lingually sections of the 16 and 46 at the same mesio-distal position for the STA (left), CON (middle) and DEF (right) crown design respectively. The amount of interference in this section is indicated by the amount of overlap of both antagonistic teeth.**

In the present study the generated designs of the occlusal morphology were visualized in two options which can be chosen out of a great variety of possibilities from the CYRTINA system. 1. the illustration of the contacts of antagonistic molars in a bucco-lingually section (Fig. 4.3), 2. the perspective view of modelled occusal designs (Fig.4.4) and 3. The illustration and determination of the frequency of contactpoints within a range from 0-1 mm (Fig. 4.5).
The part of the occlusal surface of the 46, interfering with the antagonistic teeth during the registrated individual contact movement, was defined and indicated in the CYRTINA system. In bucco-lingually sections of the 16 and 46 at the same mesio-distal position, the amount of interference can be determined for the CON, DEF and STA crowns (Fig. 4.3a, 4.3b and 4.3c).

The areas of the occlusal surface of the STA crown design, which need to be corrected in the CYRTINA system according to the CON and DEF settings so that the crown will function without disruption of the harmonious movements of the stomatognathic system are indicated by overlapping contours of the opposing CON and DEF designs. In the section of Fig. 4.3 most correction is needed in the DEF configuration whereas the outline of the form using the CON registration values hardly needs correction.

Figure 4.4: Perspective views of the STA, the CON and the DEF crown of the 46. Most striking differences exist in the disto- buccal parts.
In Fig. 4.4 the perspective illustrations of the CON, DEF and STA crowns show differences in the disto-buccal parts of the occlusal form for the CON and DEF crown as compared to the STA crown. This difference indicates the potential incidence of disturbances in the dynamic occlusion occurring when no change in the occlusal morphology would be applied.

Figure 4.3: The frequency of intervals (.05 mm) determined in a range from 0 (contact with the crown surface) to 1 mm (left). In the first .2 mm the number of intervals for the CON and STA crown exceeded that of the DEF crown (right). Differences may be explained by the performance of jaw movements in the KAVO-head imitating the border movements with the KAVO-Condylocomp. The STA and DEF crowns reveal a comparable number of intervals in the first .2 mm, whereas after about .3 mm hardly any differences exist in the number of contacts for the three types of crowns.
Table 4.1: The frequency of intervals (.05 mm) determined in a range from 0 (contact with the crown surface) to 1 mm (Fig 4.5a). In the first .2 mm the number of intervals for the CON and STA crown exceeded that of the DEF crown (Fig 4.5b). Differences may be explained by the performance of jaw movements in the KAVO-head imitating the border movements with the KAVO-Condylocomp. The STA and DEF crowns reveal a comparable number of intervals in the first .2 mm, whereas after about .3 mm hardly any differences exist in the number of contacts for the three types of crowns.

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By comparing the frequency of the interocclusal distances within an interocclusal range of 1 mm it appeared that the number of contact points for the designs of the CON and STA crown exceeded that of the DEF crown (Fig 4.5a, 4.5b). The STA and CON crowns reveal a comparable number of points with an interocclusal distance up to .1 mm. In the central part at the centric point of the STA and CON designs Fig. 4.5a reveals contact which does not exist in the DEF design). Because of the contact in centric occlusion no elongation of the CON crown will occur in the functioning dentition. After an interocclusal distance of about .3 mm
hardly any differences exist in the interocclusal distances of the occlusal surfaces of the three
types of crowns (Fig. 4.5b).
After positioning of the STA, CON and DEF crowns on the cast in the KAVO-head the
marginal gap and functional contacts were determined. The transition of the crown to the
margin of the preparation was not detectable using a dental probe.

4.5 Discussion

In this study the application of the CYRTINA CAD/CAM procedure was used for the
fabrication of a crown in static contact (STA). Although this design fulfils the aesthetical
demands of a dental restoration in function it deranges normal functional movements.
Therefore CYRTINA CAD/CAM crowns were designed, which additionally have been
corrected for disturbances during dynamic contact movements. Two types of settings
were chosen for the fabrication of these crowns: 1. Using the default values mostly used in
articulators and 2. Using the data obtained after registration of the individual contact
movements.
The application of an optoelectronic 3-D registration apparatus in the CYRTINA CAD/CAM
system was tested for the production of metal-ceramic crowns. It appeared to be possible to
implement the data from the String-Condylocomp in the CYRTINA system.
The strength and the esthetic demands of dental restorations can be met with the automated
production system 5,9. This procedure is less time consuming and will help to reduce the
expenses of dental treatment. However, in dental practice the functional properties will
determine the overall quality of the restorations. Therefore manufacturing of crowns without
interferences in dynamic occlusion and optimal contact in centric occlusion using the
CYRTINA software is of great value.
The String condylocomp registration apparatus is designed for use in dental practice.
However for routine restorative procedures, the application of this opto-electronic device will
mostly be unproportionally time consuming and may burden the patient. In pilot studies the
registration procedure has been tested in patients and produced crowns without dynamic
disturbances. Also the contacts in centric occlusion garantee an optimal restoration. However,
in clinical trials with greater patient groups, the practical aspects should be evaluated further.
The CYRTINA system till now is the first system where data files from the Condylocomp
could be directly implemented for crown modelling and reconstruction. In this way
conventional methods, where articulators are used for the construction of the occlusal design
of the crowns can be omitted. Furthermore, the difficulty to visualize in 2-D projections the contact situation of spatial movements of the antagonistic teeth during function and contact movements of opposing jaws in the articulator is substituted by evaluation of the designs on the CAD/CAM screens. These designs may be studied in every plane or in 3-D perspective images if wanted.

From Fig. 4.3 can be depicted that in the STA design the opposing teeth have contact in occlusion. During articulation, using this design, occlusal disturbances will be generated. In the CON and DEF designs the overlapping contours demonstrated in the bucco-lingually sections of the crowns indicate the amount of tooth structure from the STA crown which is needed to be corrected to make the CON and DEF crowns functioning without dynamic disturbances. The small differences shown in these sections may be taken as an indication of the sensitivity of the system.

In the perspective illustrations of Fig. 4.4 these differences are not easily detected but can also be demonstrated, mainly in the disto-buccal part of the occlusal surface.

It is well known that the arcs of movement produced by cusp tips against the occlusal surfaces of opposing tooth surfaces should be considered in three dimensions. Most studies however focussed on these movements projected onto the horizontal plane. In this plane the variation of ridge and groove direction and cuspal position have been studied mostly. From these studies it is known that increase of the angular alteration of the medial condylar path (Bennett angle) will drastically change ridge and groove direction. With increase of the Bennett angle on the nonworking side, the path of movement of the maxillar tip projected on the horizontal plane will be directed more medially. Furthermore this increase will permit a smaller cuspal height \(^{10,3,4}\). The perspective view of the CON crown surface as compared to the DEF surface indicates that in the CON setting apparently the Bennett angle was smaller as compared to the DEF setting. However also the immediate side shift of the CON setting may have influenced the small differences in the disto-occlusal cusp form.

From these examples it can be seen that the CYRTINA CAD/CAM system is well equipped to demonstrate the influence of various articulator setting on the 3-D configuration of occlusal surfaces. A study to demonstrate systematically the influence of these parameters is in preparation.

Functional restorations can, when the proper software has been applied, be produced with the CYRTINA design and fabrication system.
4.6 Acknowledgement

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4.7 References


