The journal of
PROSTHETIC AND IMPLANT DENTISTRY
Official Publication of Indian Prosthodontic Society
Kerala State Branch

ROLE OF VIRTUAL REALITY IN PROSTHODONTICS

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Abstract:

The future of dentistry is heading towards customized dental treatment of each patient. This can be easily accomplished through the computer based technology and the virtual reality which helps a dentist to simulate the real life condition. This is very effective through virtual articulator, face-bow transfer and mandibular movement which analyse the static as well as dynamic occlusion and eliminates unwanted occlusal problem prior to designing of the prosthesis. With the advent of these tools, dentistry has become accurate, easier and effective.

KEYWORDS: articulator, face-bow, virtual Prosthodontics, CAD CAM

In the recent era, a lot of advancements are seen in the field of dentistry, especially in materials and manufacturing techniques. With the advent of computers, the life of a dentist has become easier and less complicated. The cumbersome laboratory procedures and extensive casting method have become simple and easy to do with the introduction of digital technology in dentistry. The credit to this goes to Duret et al who were the first to express computer-assisted crowns and Mormann et al who developed the CEREC System. Correspondingly, Anderson and Oden developed the PROCERA System and worked on nickel-chromium alloys. Whatever be the system followed, the process is almost the same. The computer aided process is broadly divided into three phases namely; (1) the scanning phase, (2) the designing phase (CAD software) and (3) the machining phase. The scanning phase is undergoing development with different type and forms of scanner while the machining sector is also presently going through lot of changes. However the design software has undergone a drastic change with the creation of virtual articulators which simulates the mandibular movement and generates the dynamic occlusal surface.

INDICATION

Need for virtual articulator can be explained in two ways, First of all problems related to the mechanical articulator can be reduced, secondly, is the problems related to dental materials. The difficulty in proper orientation of cast, the stability of articulator, the difficulty in repositioning of cast, difficulty in the bite registration without leaving space, the deformation of registration material and the use of rigid expanded plaster materials which leads to reduced reliability in reproduction of dynamic, excursive contacts can be avoided. Moreover, it is possible to visualize three dimensional TMJ movements and the path followed by condyle. It helps in detailed analysis of static and dynamic occlusion. It is also applied for orthodontic treatment plan and also for positioning implant with a virtual set-up of suprastructure[1].

ADVANTAGES AND DISADVANTAGES

The main advantage of virtual articulators is that it helps in accurate repositioning of master cast without use of interocclusal material, to quantify the effect of resilience of the soft tissue on time dependant basis during mastication, for better communication between dentist and dental technician, and to help dental students understand the functional dynamics of dental articulator. However, it does not simulate the biologic system like complexity of movement, changes in TMJ during loading and mobility of teeth.

TYPES

Virtual articulator (software articulator) is an articulator which exist as computer program with virtual condylar and incisal guide plane. They simulate mandibular movement by moving digitalized occlusal surface against each other providing a smooth movement. There are 2 types of virtual articulator 1) Completely adjustable virtual articulator and 2) Mathematically simulated virtual articulator[1]. Completely adjustable virtual articulator was designed by Kordass and Gaertner of Greifswaid University of Germany in 2003. This articulators records the mandibular movements using an ultrasonic measurement system called zebra jaw motion analyser (Zebris, Germany) which is comprised of many ultrasound emitters attached to labial surface of mandibular teeth using an autopolymerising jig and sensor located on a head frame. The two condylar points and an infraorbital point are used to locate a plane to which jaw movements are related and is saved as ASCH file.

To program this articulator, it is necessary to digitalize the tooth surface. This done by either through a direct digitalization where tooth surface is scanned intraorally or indirect digitalization where the cast is scanned. To visualize the image the University of Greifwald, Germany developed virtual reality rent CAM which operates on four windows on the computer screen[2]. (1) The rendering window displays both jaw during dynamic occlusion like chewing (2) the occlusion window which display static and dynamic contacts with sliding movements during function and (3) the smalled window which displays the movement of TMJ in sagital and horizontal view (4) the slice window which displays frontal slice throughout the dental arch which helps to analyse the degree of intercuspidation, and the height as well as functional angles of the cusps. It helps to analyse the guidance and to balance easily. It is used in complex static and dynamic occlusal evaluations, to improve the design of virtual prosthesis, adding Kinematic analysis to design process, for occlusal construction in CAD, CAM by kinematic method, and dynamic visualization of occlusal surface. Virtual articulator requires a virtual facebow to transfer the planes. Hence a virtual face bow recording is done.

A mathematically simulator virtual articulator[3,4] by Szentoetery of Martin Luther University of Halle in 1999 is a fully adjustable 3 D virtual articulator which reproduces movements similar to a mechanical articulator. It has a curved Bennett movement but behaves as an average value articulator, hence it is difficult to obtain individualized condylar path. At the sametime, there are different movements possible in identical setting, making it a very versatile instrument. Eg-stratos 200, Szentpetery's articulator.

VIRTUAL FACEBOW RECORDING AND TRANSFER

Although virtual articulators are of good use, one problem which exists is the transfer of the digitized cast to this virtual articulator. This is solved by the introduction of digital facebow which locates the maxillary cast to the cranial coordinate system

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thereby making the transfer of the exact position of the maxillary cast to the articulator. This is done in two steps. The horizontal reference plane is scanned first followed by scanning the dental arches of the patient to obtain digital casts using an extraoral or intraoral dental scanner. To obtain horizontal reference point, place 3 skin –adhesive targets on the head; one on the infraorbital point and two next to TMJ (Point 1,2 and 3). Now the scanner is attached the fixed part secured on the head. These three points are scanned as point A,B,C by touching the tip of the scanner to the 3 adhesive targets placed on the head. This gives horizontal reference plane of the patient. Further, maxillary occlusal plane should be related to this horizontal reference plane. This done by identifying 3 most prominent cusps on the occlusal surface of the maxillary arch. To do this, first place the articulating paper in a flat metal facebow fork and introduce the facebow fork into the patient's mouth. Position the facebow fork against the maxillary cast and determine the 3 most prominent cusps on the occlusal surface which is marked three points (points 4, 5, and 6). These three points when joined together determine the occlusal plane. Place the pointer on these three points and transfer the position of the pointer into the same coordinate system with the COM professional software, which coincides with the fixed part of each scan. With reverse engineering software, blending these 6 points create patients co-ordinate system from the first three points and occlusal plane form the last three point. Now with rapid form software, align the virtual model of maxillary cast to the cranial co-ordinate system by applying the method of least squares. It further transfers the maxillary cast to the virtual articulator software and align in such a way that the cranial co-ordinate system coincides with the virtual articulator's co-ordinate system. Scan the mandibular arch and further both arches scanned together with an intraoral scanner in centric occlusion from 3 directions. This is further transferred to the virtual articulator software[5].

VIRTUAL RECORDING OF MANDIBULAR MOVEMENT

Further advancement occurred in this field with the ability to record mandibular movement and transfer this to the articulator. This is done in a sequential manner.

First step is to construct the mechanical articulator. Hanau H2 was the first articulator that has been modeled as it has simple geometrical bodies. This is done by taking measurements of this articulator followed by scanning the parts. The scanning is done using ATOS 1 3D Scanner which is followed by designing[3].

In the second step of design process, the drafts are located on the correct position in space. Hence the sections of the scanned point cloud are fused using a Rapid form XOR software to get the parts of the articulator. The whole articulator has been constructed combining both measured and scanned parts. Once the Virtual Articulator is constructed, all the measures are verified.

The third step is to record the dental arches and bite registration using a 3D scanner "scan BD" by Willy tech. It scan's 8000 to 14,000 points per second with a reproducibility of 2 μm and accuracy of matching of 10μm.

The fourth step deals with locating the models on the articulator. For this purpose, the relative position of the upper model is scanned using facebow. The location of the lower model is made using an electronic bite which was taken in centric Relation.

The fifth step is to use the CATIA CAD system for kinematic simulation on a virtual articulator[6].

Similarly, Stratos 200 and the lvoclar stators 200 have been modeled using a solid Edge CAD system. Some parts were modeled directly after measuring the mechanical dental articulator. However, the Handyscan 3D scanner has been used, due to its mobility and versatility as almost all the articulator can be scanned. Using Geomagic point cloud edition software, the useful data has been taken from the millions of points that has been scanned. The parts of the articulator modeled in the CAD system and the scanned points are converted to solid by means of the Rapid form software. Further, they are assembled adding the necessary constraints. Mechanical joints will have to be created either by automatically converting the existing assembly constraints or by manually selecting different joints between parts. Then, after adding the commands on articulators, the user will be able to control the DOFs.

Each CAD system has different possibilities and capacities for simulation. The project started using the solid EDGE V18, Modelling the lvoclar stratus 200 mechanical dental articulator. There were problem to import digitalized models using STL-files. This problem was solved by using the V20 of Solid Edge, so the virtual articulator was able to simulate excursive movements correctly. The SolidEdge CAD system is not able to calculate laterotrusion movements due to the contact surface change that occurs at the same time with these movements. These limitations were corrected using the Dynamic Designer software, based on the MSC, ADAMS simulation engine. Hence the CATA DMU-Kinematics module has been used for the following work. This module offers more options than solidEDGE CAD system. Hence the movements of the Hanau H2 and Denar MarkII have been simulated more accurately. On the hand, the movement of protrusion has been simulated and the trajectory of the first lower left molar has been analysed. On the other hand, the lateral movement has been simulated using different values of the Bennett.

The final step is to record mandibular movement which is accomplished by using the jaw motion analyzer. Three skin adhesive targets are placed, one on skin of TMJ, infraorbital point to obtain a hinge- axis infra-orbital plane and a special digitizing sensor analysis this plane. The ultrasonic measurement system jaw Motion Analyzer (Comp Zebris Isny, Germany) is used to record and implement the sonic impulses emitted from three transmitters attached to the lower sensor which analyses the mandibular movement. Four receivers are attached to a face bow opposite them. This positioning enables the detection of all rotation and translation components in all degrees of freedom. Movement data finally can be calculated in relation to the digitized points. Silicon-based jaw relation registrations are used to reproduce the occlusion and this remain attached to the upper teeth during opening. This registration is stabilized with impression plaster on a metal carrier plate. The digitizing sensor is attached to detect three main reference points on the rear of this metal plate. These three points are used to combine movement data and the digitized dental arches. First, the impression of the upper teeth is digitized and then the record material and the plaster of the lower teeth are scanned. Both dental arches are correctly related to each other. The digitized impressions of the lower and upper jaw can be combined with the scanned data from casts without losing the predefined jaw relationship. By defining and calculating the same reference, both data sets, were matched and presented in the virtual articulator.

For the detection of tooth wear, there is another model that semi-auto-matically analyzes the teeth for signs of wear or bruxism. The algorithm searches for facets and separates them from the surrounding surface using special segmentation algorithms. A CAD module allows the improvement of the functional occlusion by manipulating the occlusal surface. The occlusal profile of the teeth can be designed with increased or decreased cusps to eliminate occlusal interferences in the dynamic pattern and optimize the occlusion. The data set of newly designed and improved occlusal surface can be transferred to a milling machine, producing real crowns and fixed restorations with that particular optimized functional occlusion[7].

To produce the VR articulator as a marketable software tool University, of Greifswald, Kettenbach GmbH Co KG, and the Fraunhofer Institute for computer Graphics (IGD) cooperated to establish the virtual articulator software system. If the jaw motions analyzer tool is available, the patient –specific jaw motion can be recorded. The data can be loaded into the virtual articulator software and the three dimensional movements of the jaws are simulated. If the jaw motion analyzer tool is not available, different jaw motions can be defined via parameters, just as with the mechanical articulator protrusion (parameters: radius of the condylar pathways, maximal protrusion distance, horizontal condylar slope).

Retrusion (parameters:radius of the condylar pathways, maximal retrusion distance), laterotrusion (parameters: maximal protrusion value, Bennett Angle, radius of condylar pathways (left, right) horizontal condylar slope (left, right), shift angle, immediate side shift), opening/closing movement (parameter: maximal opening angle parameters are entered). The occlusion detection engine is triggered. For occlusion detection, a distance can be chosen corresponding to the thickness of the occlusion paper used in the mechanical articulator. The occlusion points are calculated according to this defined distance.

Virtual dentistry is raised to a higher level by the introduction of virtual articulators. Added to it the digital facebow recording along with the recording of mandibular movement has made life of a dentist very simple and provide a high quality of treatment and care. The designing process using all these tools will revolutionize dentistry and replace the mechanical instrument soon.

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