Review Article

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Augmentation Reality to Virtual Reality: Virtual Articulator

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ABSTRACT

Background: Continuous research for an ideal articulator, which can simulate the masticatory movements of the jaws extra orally, has always been the requirement of the dentists. With the advent of recent technologies and techniques in dentistry, it is amazing to visualize the virtual articulators. Virtual articulators are computer softwares which design the prosthesis kinematically. To overcome the drawbacks of conventionally used articulators, virtual articulators have arrived which involves the use of CAD/CAM systems and hence avoids errors. This enables the dentist to directly visualize the occlusal surfaces and analyze both static and dynamic occlusion.

Keywords: Virtual articulator, dental occlusion, CAD /CAM.

INTRODUCTION

In prosthetic dentistry articulators are the basic tool for designing and fabrication of a denture.[1] Advancements in technologies in the field of dentistry has led to better and improved education and practice by converting complex procedures into simpler and effortless techniques.[2] According to GPT-8 "an articulator is defined as a mechanical instrument that represents the temporomandibular joints and jaws, to which maxillary and mandibular casts may be attached to simulate some or all mandibular movements" [3]

Various types of articulators are available, based on the dentist's ease of use and it is the choice of the dentist to select the type of articulator for his work. The late Carl O. Boucher stated "it must be recognized that the person operating the instrument is more important than the instrument itself. The drawbacks of mechanical articulator have led to the development of virtual reality to fulfill the expectations of the dentists. Virtual articulators are computer aided software programs that consists of virtual condylar and incisal guide planes. In this, the prosthesis is designed kinematically. This software is able to replicate mandibular movements of the patient.[4] A virtual articulator involves 3D representations of the jaws and its movements and hence establishes a dynamic visualization of occlusal contacts of teeth. It gives a 3 dimensional view with six degrees of freedom. Till date, the mechanical articulator has been used to replicate the dysmorphology and dysocclusion functionally.[5]

HISTORY OF ARTICULATORS

The history of articulators parallels that of the varying concepts of occlusion. Attempts were made to record anatomic relationships or reproduce functional movements of the mandible and transfer this to the mechanical devices to simulate the conception of natural movements. In18th century the first plaster articulator devised

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by **Philip Pfaff** in 1756 consisted of plaster extension on the distal portion of the maxillary and mandibular casts grooved to each other. This was commonly known as 'slab articulator' it is first mechanical articulator.[1]. Under the concept of adjustments in various parameters, awni rihani proposed a new classification.

NEW CLASSIFICATION SYSTEM: [6]

To make any classification easy to visualize and to avoid confusion because of these sophisticated adjustments, the requirements of any acceptable articulator must be known. In prosthetic dentistry, the necessity of registering the following records is generally accepted:

1) Face bow record
2) Centric jaw relation record
3) Protrusive record
4) Lateral records
5) Intercondylar distance records

[1] **Fully adjustable articulator** - can accept all of the above five records.

Examples: Hanau Kinoscope, 1923; McCollum-Gnathoscope 1935; Granger Gnatholator 1950; Stuarticulator 1955; Ney-Depietro 1962; Hanau 130-21,1953; Simulator 1968; Denau D4-A, 1968.

[2] **Semi-adjustable articulators**: can accept all the following records.

(i) Face bow record
(ii) Centric jaw relation record
(iii) Protrusive record

Examples: Snow Acme 1910; Gysi Adaptable 1910; Hanau H, 1922; Wadsworth 1924;Gysi Tribyte,1926; House 1927; Dentatus 1944; Bergstrom Aron 1950; Hanau 130-28,1963; Whip Mix 1968.

[3] **Non-adjustable articulators**: can accept one or two of the following three records.

(i) Face bow record
(ii) Centric jaw relation record
(iii) Protrusive record

Examples: Gariot 1805; Ewan 1840; Barn Door Hinge,1958; Bonwill 1858; Walker 1896; Gritman 1899; Snow 1906, Gysi Simplex, 1912; Monson1918; Stansbery 1929; Philips Occlusoscope, 1931; Kile Dentograph, 1946; Transograph 1952; Pankey Mann, 1955.

DRAWBACKS OF MECHANICAL ARTICULATORS:

Presently, the mechanical articulator is used for the functional simulation of the effects of dysmorphology and dysocclusion. For instance, mechanical articulators cannot simulate; the mobility of the teeth when using plaster casts in it, the distortion and deformation of the mandible during loading conditions and the complexity of movement patterns because the movements of the mechanical articulator follow border structures of the mechanical joint. Mounted or articulated casts cannot represent the real conditions of the occlusion in the mouth.

For precise reproduction many problems hinder regarding the technical procedures and dental materials,

1. The deformation of bite registration material (eg. wax is susceptible to heat)
2. Repositioning the cast into the bite impressions without leaving any space.
3. The stability of the articulator itself.
4. The correct orientation of the cast
5. The use of rigid and expanded plaster material.
6. Maintenance of the mechanical articulator because of these basic errors, the reproduction of dynamic, excursive contacts seems to lower the reliability of mechanical articulator .The main disadvantage is that it behaves as an average value articulator and it is not possible to obtain individualized movement paths of each patient.(eg.stratos200).[1]

VIRTUAL ARTICULATORS:

Virtual Articulators are also called as "software articulators" as they are not concrete but exist only as a computer program with components of virtual condylar and incisal guide planes. Like average value articulator Guide planes can be measured using jaw motion analyzer or average values are set in the program. Presently Virtual Articulator is supporting mechanical articulator in better visualization of the occlusion and hence they will replace mechanical articulators in the upcoming years.

There are two types of Virtual Articulators-:

A. Completely adjustable virtual articulator
B. Mathematically simulated virtual articulator.

A) Completely Adjustable Virtual Articulator:

Kordass and Gaertner from the Greifswald University in Germany had designed virtual articulator. It reproduces the movement paths of the mandible with the help of jaw recording system known as Jaw Motion Analyzer (Zebris, Germany). It is an ultrasonic motion capture device that is comprised of an ultrasound emitter array that is bonded to the labial surfaces of the mandibular teeth using a jig customized with cold cure acrylic and a sensor array located on a head frame secured to the patient's head. Both static and kinematic occlusion is used in designing occlusal surfaces in computer aided designing (CAD) systems. The spatial coordinates of the two condylar points and an infraorbital point are pre-selected to define a plane. Movements are then recorded. The three points are: two condylar points and the base center of the T-attachment pointer attached to the jig.

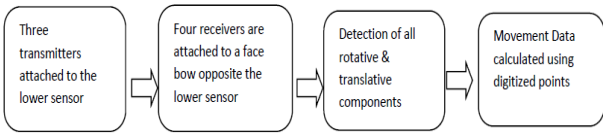

Fig 1: Recording of jaw motion Using Jaw Motion Analyzer.

The same movement of teeth can be seen from different aspects:

1. RENDERING WINDOW: Gives the view of both the jaws during dynamic occlusion.

2. OCCLUSION WINDOW: Gives the view of both static and dynamic occlusal contacts of both upper and lower jaw.

3. SMALLER WINDOW: Gives a view of the temporomandibular joints in sagittal and transverse plane which shows interdependencies between tooth contacts and TMJ movements.

4. SLICE WINDOW: Gives a view of the frontal aspect of the dental arch, the degree of intercuspation, functional angles of the cusps and height.

B) Mathematically Simulated Virtual Articulator:

Szentpétery's virtual dental articulator from the Martin- Luther University of Halle is based on a mathematical simulation of the articulator movements. It is a fully adjustable three dimensional virtual articulator modeled for reproducing all articulator movements. In addition, mathematical simulation contributes to offer possibilities not offered by some mechanical dental articulators, like curved Bennett movement or different movements in identical settings. This makes it more versatile than a mechanical dental articulator. On the other hand, since it is a mathematical approach, it behaves as an average value articulator, and therefore, is not possible to obtain easily the individualized movement paths of each patient .[4]

PROGRAMMING AND FUNCTIONING OF VIRTUAL ARTICULATORS [7]

The programming and adjustment methods of virtual articulator were described by Kordass and Gartner in 1999.

a) Scanning/digitizing – of a tooth or tooth surface or restoration or complete denture models or centric relation, 3D Laser scanner (Willytec, Munich, Germany) is used. This scanner projects a vertical laser beam onto the surface of the object. A digital camera equipped with a charge coupled device (CCD) registers the beam reflected from the object and transmits the digital signals to an electronic processing system. The processed image data are stored as digital matrix brightness values, ready for use by the scanner software and for on screen visualization and computerized manipulation.

b) The scanning can be done in 2 ways:

• Direct digitizing - done directly from the patient's mouth using an intra oral scanner.

• Indirect digitizing - done outside on the patient's master cast obtained after making final impression.

c) Patient Specific Motion Data of Temporo mandibular joints (TMJ) –

i) The Jaw motion analyzer (JMA) tool (Comp Zebris, Isny, Germany) has reference points fixed on the patient mandible.

• This system is based on measuring the velocity of ultrasonic impulses emitted from three transmitters attached to the lower sensor bound to labial surface of mandible and four receivers attached to a face bow opposite to them for detecting all rotative and translative components in all degrees of freedom.

• A special digitizing sensor is used to determine the reference plane, composed of the hinge axis- infra orbital plane and special points of interest (eg: on the occlusal surface).

• An ultra sound is then used to measure the position of these points in space describing physiological masticatory motion of the patient.

• The relative position of the upper or maxillary virtual model in reverse position is digitized using face bow and located directly in the virtual articulator.

• The lower or mandibular virtual model is then located in centric relation with the upper virtual model using an electronic bite. The virtual articulator system is now ready to be applied for kinematic simulation analysis.

ii) If the jaw motion analyzer tool is not available, different jaw motions can be defined via parameters as used with the mechanical articulators (Protar 7, KaVo).

• The following movement parameters selected are: protrusion, retrusion, laterotrusion and opening/ closing movement.

• After defining the motion parameters, collision detection is triggered to recognize the motion constraints, which results in the upper and lower jaws gliding on each other.

• For collision detection, a ray based algorithm is used that is executed in a preprocessing step. For occlusion detection, a distance corresponding to the thickness of the occlusion paper used in the mechanical articulator is chosen, for calculating the occlusion points according to this defined distance.

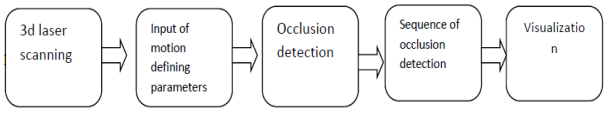

Fig 2: programming of virtual articulator

ADVANTAGES AND USES OF VIRTUAL ARICULATORS

1) The clinician can visualize the teeth surface occlusion for contact points and prematurities leading to proper information for the diagnosis.
2) Visualization of contact points dynamically during jaw movement.
3) Provides best quality of communication between the dentist and dental technician.
4) Analyses both static and dynamic occlusions.
5) Designing of occlusal surface in CAD CAM system.
6) Analyses gnathic and joint conditions.
7) Offers a detailed 3-D visualization of region of interest.
8) Possible to modify or introduce new setting according to the patient and helpful for patient's education.
9) To correct and modify completed restoration.

DISADVANTAGES OF VIRTUAL ARTICULATORS

Proper record has to be made for each patient, which is certainly not practicable for every clinician. Future Modules of Virtual Articulator:-

1) For the detection of tooth wear or bruxism. A module that semi-automatically analyzes the teeth for signs of wear or bruxism is available. The algorithm searches for wear facets and separates them from the surrounding surface using special segmentation algorithms.

2) Fixed crown and bridge work with CAD/ CAM module. Virtual articulators can be integrated with CAD/CAM technology in the precise preparation of crown and bridges, there by produces interference free prosthesis in occlusion when placed in patient's mouth. For Orthodontic Virtual Set up The latest version of DentCAM software, a special orthodontic CAD module was added to simulate the therapeutic result by repositioning single teeth and reforming the dental arch (virtual set-up). Separating single teeth from the complete data set of the upper and lower jaw is a prerequisite to the virtual setup.

3) DentCAM includes a pointer for makes it possible to find .The tooth-crown margin automatically when positioned in the middle of the occlusal table of molars or premolars or incisal rim or canine top. Continuing tooth by tooth, the procedure results in single-tooth–based data sets that are prepared for

special software operations, such as simulation of orthodontic movements.

4) In a case with relative retrusion of maxillary and mandibular anterior teeth, the author used DentCAM to shift the maxillary anterior teeth to their correct anterior position and design them to produce optimal canine guidance Based on the images from the virtual setup tool; an active protrusion splint is included in the treatment plan.[4]

RECENT DEVELOPMENTS IN THE VIRTUAL ARTICULATOR:

The development of 3D virtual articulator system (Zebris Company, D-Isny) requires three main unit devices namely:

 An input device in form of a 3D scanner.

 3D virtual articulator software for prosthesis modeling with collision detection.

 An output device in the form of "rapid prototyping system" with stereoscopic inkjet

Technology. The advantage with this 3D virtual articulator system is that in addition to analysis of Mandibular movements, even masticatory movements can be analyzed including force at the points of contact and the frequency of contacts in relation to time.[8]

APPLICATIONS OF VIRTUAL REALITY HAPTIC SYSTEM IN PROSTHETIC AND RESTORATIVE DENTISTRY

3D haptic technology of virtual reality has introduced dental simulators that provide an efficient means to quickly teach preclinical dental students about dental procedures, while increasing their

• For occlusion detection, a distance corresponding to the thickness of the occlusion paper used in the mechanical articulator is chosen, for calculating the occlusion points according to this defined distance

• Other systems for the detection of mandibular movements available newly are based on other technologies such as optoelectronic devices that use CCD cameras to register the emissions of light emitting diodes (LED's) positioned over the hand-skills considerably.[7]

CONCLUSION

The virtual reality technology has opened doors for dental professionals towards successful diagnosis and treatment planning with virtual articulator in day to day clinical practice. All in all, the virtual articulator is a basic tool that deals primarily with the functional aspects of occlusion. However, it also can be regarded as a core tool in many diagnostic and therapeutic procedures and in the cad/cam manufacture of dental restorations. The add-on modules will change conventional ways of production and communication in dentistry and begin to replace the mechanical tools.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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