REVIEW ARTICLE

VIRTUAL ARTICULATORS IN PROSTHETIC DENTISTRY: A REVIEW

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ABSTRACT:
Virtual reality is a computer based technology that allows us to navigate and view a world of three dimensions in real life. In dentistry, the use of computer aided design (CAD) systems and reverse engineering tools permit the introduction of kinematic analysis in virtual design process. The virtual articulator is one such application in prosthetic and restorative dentistry based on virtual reality that will significantly reduce the limitations of the mechanical articulator, and by simulation of real patient data, allow analysis with regard to static and dynamic occlusion as well as to jaw relation. This article reviews the need of virtual articulators, designing, development and programming of virtual articulators, advantages and limitations of virtual articulators, and a brief note on haptic based touch enabled virtual articulator.
Key words**:** CAD, Jaw motion analyzer, Virtual articulator, Virtual reality

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This article may be cited as: Luthra RP, Gupta R, Kumar N, Mehta S, Sirohi R. Virtual articulators in prosthetic dentistry: A review. J Adv Med Dent Scie Res 2015;3(4):117-121.

INTRODUCTION

Research work in the recent decades quoted many innovative and technological advancements introduced in the field of dentistry. Computer technology seems to form the future of dentistry. Virtual reality (VR) technologies have a strong impact on research, development, and industrial production. VR technologies in dentistry will be used to provide better education and training by simulating complex contexts and enhancing procedures that are traditionally limited, such as work with mechanical articulator.[1]

Innovative research has also invaded the field of prosthodontics with several articulator designs which are used for fabrication of restorations compatible with stomatognathic system. The transition from numerous mechanical articulator designs to recently developed virtual articulators is a major breakthrough in the development of the articulator design.[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]

There are several articulators available in market today, some are very complex and some are very simple in their use and adjustments. The articulator to be used depends on preference of dentists. The late Carl O. Boucher stated "it must be recognized that the person operating the instrument is more important than the instrument itself. If dentists understand articulators and their deficiencies, they can compensate for their inherent inadequacies." [4]

DRAWBACKS OF MECHANICAL ARTICULATORS

The mechanical articulators are used in routine practice to diagnose and simulate the functional effects of malocclusions and morphological alterations upon dental occlusion. However, this mechanical scenario is different from the real life biological setting and poses a series of problems. 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 dynamic conditions of the

occlusion in the mouth. The accuracy of reproduction gets hampered by many other problems regarding the technical procedure and dental materials as:

- The deformation of bite registration material (e.g. wax is susceptible to heat)
- Repositioning the cast into the bite impressions without leaving any space
- The stability of the articulator itself
- The correct orientation of the cast
- The use of rigid and expanded plaster material
- Maintainance of the mechanical articulator.

Because of these basic errors, the reproduction of dynamic, excursive contacts seems to lower the reliability of mechanical articulator. [1, 5-9]

VIRTUAL ARTICULATORS

Virtual Articulators are also called as "software articulators" as they are not concrete but exist only as a computer program. They comprise of virtual condylar and incisal guide planes. Guide planes can be measured precisely using jaw motion analyser or average values are set in the program like average value articulator. The Virtual Articulators are able to design prostheses kinematically. They are capable of simulating human mandibular movements, by moving digitalized occlusal surfaces against each other and enabling correction of digitalized occlusal surfaces to produce smooth and collision-free movements.[2,7]

NEED FOR VIRTUAL ARTICULATORS

The virtual articulator has been designed for the exhaustive analysis of static and dynamic occlusion. This tool incorporates virtual reality applications to the world of dental practice with the purpose of replacing mechanical articulators. The virtual articulator offers the possibility of significantly reducing the limitations of mechanical articulators, due to a series of advantages: full analysis can be made of static and dynamic occlusion, of the inter-maxillary relationships, and of the joint conditions, thanks to dynamic visualization in three dimensions (3D) of the mandible, the maxilla or both, and to the possibility of selecting section planes allowing detailed observation of regions of interest such as for example the temporomandibular joint. Combined with CAD/CAM technology, this tool offers great potential in planning dental implants, since it affords greater precision and a lesser duration of treatment.[6]

The prosthodontic applications of virtual articulators are to fabricate the best fitted occlusal restoration possible, to help students to understand the function of dental articulator, different excursive movement and their influence on the occlusal surface and to improve the quality of communication between the dentist and dental technician.[3]

TYPES OF VIRTUAL ARTICULATORS

There are two types of virtual articulators namely:

- Completely adjustable
- Mathematically simulated

Completely Adjustable Virtual Articulator:

It records /reproduces exact movement paths of the mandible using an electronic jaw registration system called Jaw Motion Analyser (JMA).

The ultrasonic measurement system, Jaw Motion Analyzer (Zebris, Germany) is used to record and implement the movement pattern of the mandible. 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 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).[2,7]

The digitised dental arches then move along these movement paths that can be viewed in the computer screen consisting of three main windows showing the same movement of the arches from different planes.

The software calculates and visualises both static and kinematic occlusal collisions and is used in designing and correction of occlusal surfaces in computer aided designing (CAD) systems. Eg: Kordass and Gartner virtual articulators.

The software of the DentCAM virtual articulator developed at the University of Griefswald consists of three main windows and a slice window, which show the same movement of teeth from different aspects:

Rendering window: Shows both jaws during dynamic occlusion and can visualise unusual views throughout dynamic patterns of occlusion i.e.: the view from the occlusal cusps while watching the antagonistic teeth coming close to the intercuspidation position during chewing movements.

Occlusion window: Shows the static and dynamic occlusal contacts sliding over the surfaces of the upper and lower jaw as a function of time.

Smaller window: The movements of the temporomandibular joint are represented in a sagittal and transversal view which allows the

analysis and diagnosis of interdependencies between tooth contacts and movements of the temporomandibular joint.

Slice window: Shows any frontal slice throughout the dental arch. This tool helps to analyse the degree of intercuspidation, and the height and functional angles of the cusps. With this window, the analysis of guidance and balancing becomes easy.[1,7]

The recent software versions incorporate an orthodontic module allowing the creation of a virtual setup. The program has also been equipped with the representation of the condylar trajectories in the sagittal and horizontal planes. This software tool allows us to observe the inter relationship between the incisal guide and the condylar guide, and the effects of joint mobility upon occlusion.[7]

Mathematically Simulated Virtual Articulator:

It is based on a mathematical simulation of the articulator movements. It is a fully adjustable three dimensional virtual articulator capable of reproducing the movements of a mechanical articulator. In addition, mathematical simulation contributes to offering possibilities not offered by some mechanical dental articulators, such as 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. Eg: Stratos 200, Szentpetery's virtual articulator.[8,10]

DEVELOPMENT AND DESIGNING OF VIRTUAL ARTICULATOR

The designing of dental virtual articulator is achieved by means of computer aided desigm (CAD) systems and reverse engineering tools. The development is made at the product design laboratory (PDL) in the faculty of Engineering of Bilbao (The University of the Basque Country) in collaboration with the department of prosthetics of the Martin-Luther University of Halle as follows:

- Different mechanical articulators are selected first to be modeled through CAD systems (Solid Edge and CATIA).
- The design process will then be carried out using measuring tools and reverse engineering tools that are available at the PDL. The tools used are: Handyscan REVscan 3D scanner and its software (VXscan), Reverse engineering and computer-aided inspection software (Geomagic Studio and Qualify), Rapidform XOR, ATOS I rev.2 GOM 3D scanner.

After the virtual articulator is constructed, all the measurements are verified and checked.

If any problem exists, that need to be rectified and redesigned accordingly [8, 11- 13]

SELECTION OF THE ARTICULATOR

The selected articulator and even more importantly, the skill and care, with which it is used, have a direct effect/impact on the success of fixed or removable restorations. If the dentist's only concern is the relationship of the antagonist teeth at the point of maximum intercuspation, the design and the use of an articulator will be greatly simplified. Since the intercuspation position is static, the articulator will need to act only as a rigid hinge, which is little more than a handle for the model.

The mandible however does not act as a simple hinge. Rather than this, it is capable of rotating around axes in three planes. The occlusal morphology of any restoration for the mouth must accommodate the free passage of the antagonist teeth without interfering with the movement of the mandible.

Because of their potential to produce pathologies, occlusal interferences must not be incorporated into restorations placed by the dentist. One way of preventing this problem is the use of fully adjustable articulators which simulate mandibular movements with a high degree of precision. Treatments using these articulators are time consuming and demand a great skill from both dentist and technician. As a result, the cost of such treatments does not make it feasible for minor routine treatment plans. [2,5,8,13]

PROGRAMMING OF VIRTUAL ARTICULATORS

The programming and adjustment methods of the virtual articulator were described by Kordass and Gartner in 1999.[7] Pre requisite for visualization on screen is 3D scanning/digitizing of tooth surface or restorations or denture models using 3D scanner.

The scanning can be done in 2 ways:

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

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

The scanned data helps to obtain the real geometry of the mouth and its relative location are reconstructed in a CAD system using the face bow. In the second phase, the type of articulator is selected depending on the required accuracy and/or on the patient's setting data available in each case. Once the dental prosthesis is modelled, the functional simulation is performed in order to obtain the interfering collision points which could

produce a disease in the temporomandibular joints, which may end up producing a disease in the temporomadibular joints. Excursive movements, such as protrusion and laterotrusion are simulated using a CAD system, analyzing possible occlusal collisions so that the design can be adequately modified. Finally, the dental prosthesis is milled and tested on the mouth of the patient.[9]

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 analysed including force at the points of contact and the frequency of contacts in relation to time.[8]

ADVANTAGES OF VIRTUAL ARTICULATOR:

- Provides best quality of communication between the dentist and dental technician.
- Analyses both static and dynamic occlusions.
- Designing of occlusal surface in CAD CAM system.
- Analyses gnathic and joint conditions.
- Offers a detailed 3-D visualization of region of interest.
- Possible to modify or introduce new setting according to the patient and helpful for patient's education.

LIMITATIONS OF VIRTUAL ARTICULATOR

- Cost effective as it requires the digital scanners, digital sensors, software's, and different types of virtual articulator models mimicking the mechanical ones according to the patient need.
- Knowledge about the CAD/CAM technology, mechanical articulators, designing and modeling of virtual articulators etc and technical skills regarding the interpretation of data recorded scanners, sensors, minor adjustments, incorporating motion parameters etc.[2]

FUTURE WORK:

In future, there is a need to develop virtual articulator software that integrates the correcting software for CAD/CAM system directly into the process of construction of crowns and bridges. A digital face-bow transfer is not possible. At present, the face bow has to be mounted on the patient and then brought to the dental mechanical articulator. Finally, it is important to remark that several improvements should be made up when obtaining the patient's data. This is a main shortcoming which generates difficulties on the next step, this is, the use of the articulator and the design process. Therefore, a progress in this sense will bring important improvements on the whole process.[14]

HAPTIC BASED FIRST TOUCH ENABLED VIRTUAL ARTICULATOR

Sensable Dental Technologies has developed the newest version of its Intellifit™ TE (Touch-Enabled) Digital Restoration System that offers dental labs even more choice, performance and flexibility in digitally designing and fabricating a wide range of dental restorations. The system's support for both fixed and removable restorations including full ceramic monolithic crowns, bridges and prepped veneers, produced faster and with heightened precision though its unique touch-enabled technology, allows dental labs of all sizes to gain a competitive advantage. [15]

Also, Intellifit's unique 3D 'Virtual Touch' interface and integrated touch-enabled articulator allow lab technicians to actually feel how the teeth – including the new restoration they are producing – will fit together in the patient's mouth. Articulators are essential to testing the occlusion of almost every type of dental restoration and lab technicians have long used them, as well as their sense of touch, to assess whether a restoration will allow the patient to function with the correct amount of contact and excursive movements. Intellifit's virtual articulator mimics the feel and function of a physical articulator, yet allows dynamic settings to meet patient specifications and freedom of movement in three dimensions. Touch-enabled, virtual articulator allows technicians to test occlusion of restoration – before it is produced and enabling them to actually feel the fit.[8,16]

CONCLUSION

The virtual reality technology has opened door for dental professionals towards successful diagnosis and treatment planning with virtual articulator in day to day clinical practice. The virtual articulator is a precise software tool that deals with the functional aspects of occlusion along with CAD/CAM systems substituting mechanical articulators and thus avoiding their errors. Haptic

based virtual reality system's touch enabled virtual articulators allow lab technicians to actually feel how the teeth, including the new restorations produced will fit together in the patient's mouth. The concept of virtual articulator will change conventional ways of production and communication in dentistry, and will replace the mechanical tools.

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