Review Article

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Virtual Articulators: A Changing Phase of Modern Prosthodontics

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ABSTRACT

Background Virtual reality is a computer based technology using special software that simulates a user's physical presence in a virtual or imaginary environment. In dental virtual designing, kinematic analysis can be done by using reverse engineering and computer aided design (CAD) systems. By using virtual articulator, we can analyse both static and dynamic occlusion using real patient data at the same time overcoming the limitation of mechanical articulator. In this article, we will discuss the need for virtual articulator, designing, development and programming, advantages and limitations of virtual articulator. In addition, a brief discussion about haptic based touch-enabled virtual articulator is done.

Keywords: Virtual Articulators; CAD/CAM; Mechanical Articulator.

INTRODUCTION

Digital advancement continues to reshape the field of dentistry and becoming part and parcel of the contemporary prosthodontics. The probability of most of the procedures being based on the digital techniques in near future and endless scope of digitisation and technology in clinical and lab procedures like use of CAD-CAM technology, stereolithography, rapid prototyping, use of virtual articulators and digital face bows, digital radiographs, or in the field of training, education and research by the use of virtual patient programs, dental softwares, optoelectronic recording of jaw motion, digital instron machine, retention testing device, audiovisual aids… and so on, has open door to the world of virtual dentistry.[1]

There are various different diagnostic and reconstructive procedures that require visualization and analysis of mandibular movements, dental arch relationship and teeth contact outside the patient's mouth. Therefore, there is an indispensable need for a mechanical device in diagnostic and reconstructive procedures. According to GPT 9, 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".[2]

There is a large variety of articulators available today each of them having different ease of usability. Every dentist has his/her own preference of articulator. 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".[3]

Researchers have provided several articulator designs, which are used for fabrication of restorations compatible with stomatognathic system. In the changing phase of prosthodontics, virtual articulators are a major breakthrough in the field of articulators.

Virtual Articulators

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These are also known as "**Software Articulators**" as they are software based on virtual reality technology rather than mechanical articulators. They comprise of virtual condylar and incisal guide planes. Using jaw motion analyzer (JMA), we can accurately measure the guide planes or use average values in setting the program. A harmonious interrelationship between the TMJs, mandibular movements and digitized occluding surfaces of the teeth can be established by kinematically designed prosthesis.[4]

Need of Virtual Articulators

Digital technology is a step forward from the conventional mechanical articulators. This mechanical scenario is different from real life biological setting as it cannot simulate the masticatory movements that are dependent upon muscle patterns. No machine is capable of reproducing muscle synergy, proprioception, resilience of soft tissues and joint disc. Articulators can be adjusted to the positional records as secured from the patient, but they can only approximate mandibular movements. The virtual articulator offers the possibility of significantly reducing the limitations of mechanical articulators due to its series of advantages in visualization of static and dynamic occlusion, sectional planes of the area of interest and joint conditions. Using CAD in conjunction with VR technologies can further provide a great help in developing dental implants as CAD offers greater precision in lesser time. Modification or introduction of new settings according to the patient can be done during the procedure.

At the same time, it has the limitation of process being costly, as it requires many type of tools and technical skills to digitalize the information and modeling the dental prosthesis. In addition, knowledge about the CAD software is required to work with virtual articulators.

Types of Virtual Articulators

There are two types of virtual articulators:

- Completely adjustable
- Mathematically simulated

Completely adjustable virtual articulator: In this virtual articulator, we can record and reproduce the movement of mandible with the help of an electronic jaw registration system known as Jaw Motion Analyzer (JMA). It is ultrasonic measurement system, used to trace the movements of mandible. It has grid of ultrasonic emitters, which is joined securely to labial surfaces of mandibular teeth using jig of cold cure acrylic. There are four ultrasonic receivers attached to the arm opposite to emitters, which records the motions in all degrees of freedom. Digitalized sensor dictates the reference plane such as hinge axis, infra orbital plane and occlusal surface. The digitized 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 then accesses the static and dynamic occlusal collisions, which is used to design the occlusal surface in CAD software. Eg: Kordass and Gartner virtual articulators.

DentCAM software designed and developed at University of Greifswald consists of three major 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 visualize unusual views throughout dynamic patterns of occlusion i.e. the view from the occlusal cusps while watching the antagonistic teeth coming close to the inter-cuspidation 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 analyze the degree of inter-cuspidation and the height and functional angles of the cusps. With

this window, the analysis of guidance and balancing becomes easy.

The latest version of the software has orthodontic module that allows us to develop virtual setup. Condylar trajectories can be viewed in sagittal and horizontal planes. Inter connection between the incisal guide and the condylar guide and the effects of joint mobility upon occlusion can be analysed.[5]

Mathematically Simulated Virtual Articulator:This articulator records and reproduce movements based on mathematical simulation. It also provides some extra features like curved Bennett movement or other movements for adjustment in ideal settings. Mathematical approach of this articulator limits the possibility to analyze individualized movement paths of each patient. Eg: Stratos 200,Szentpetery's virtual articulator.[6]

Designing and Development of Virtual Articulator

CAD system and Reverse engineering tools together is used to design dental virtual articulators. Reverse engineering can be viewed as a process of analyzing a system to identify the systems components and their interrelationships. In the collaboration with department of prosthetics of the Martin-Luther University, product design laboratory (PDL) in the faculty of Engineering of Bilbao (The University of the Basque Country) has developed the virtual articulators. They are following the process as follows:

Mechanical articulators are selected to make its digital design in CAD software. Most commonly used CAD softwares are CATIA and Solid Edge.

The design process will then be carried out using measuring 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), Rapid form XOR, ATOS I rev.2 GOM 3D scanner.

At the final stage, they cross check every measurement. If they can find any issue in design, they fix it as per requirements.[7] (Fig-1)

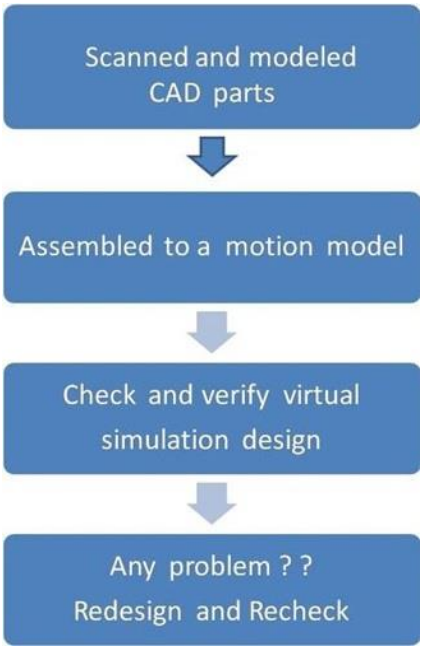

Fig 1: Virtual articulator designing method

Selection of the Articulator

Numerous articulators are available for the restoration of occlusion. The challenge for the dentist is to choose an articulator that is suitable for the purpose at hand, neither more nor less complicated than necessary. The goal is to make restoration with occlusal morphology compatible with the movements of mandible. The more closely the articulator matches the patient's anatomy, usually outcome is better and less adjustments are required at chair-side on fitting prosthesis. Mandibular movements occur around the temporomandibular joint which is capable of making complex movements. Any restoration provided should not interfere with mandibular function in mastication, speech, and swallowing nor should they transmit excessive force to the attachment apparatus or the temporomandibular joint either in the intercuspal or eccentric jaw positions as well as during movement. 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.[8]

Programming of Virtual Articulators

The method of programming and adjustment is defined by Kordass and Gartner in 1999. To visualize the virtual articulator, 3D scanning of tooth surface/ restorations or 3D denture models is required. We can perform scanning using two ways:

Direct Digitizing - done directly from the patient's mouth using intraoral scanner.

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

In CAD software, with the help of scanned data, we can create actual geometry of patient's mouth and its relative location. Depending upon the required accuracy and the patient's setting data available; we choose the type of articulator required for the scenario. Once the dental prosthesis is modeled, the functional simulation is performed in order to obtain the interfering collision points. Every movement is then closely observed in CAD system to avoid collisions and designs are modified adequately. In the last step, we prepare the dental prosthesis and tried in patient's mouth. (Fig-2).

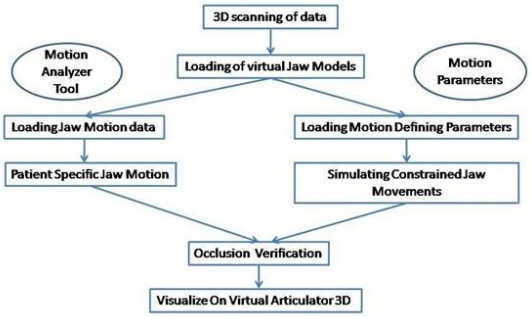

Fig 2: Virtual articulator functioning method

Recent Developments in Virtual articulator

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

- An input device in form of 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.

Haptic Based Touch Enabled Virtual Articulator

Haptics technology also known as kinaesthetic communication or 3D touch. The word haptics originates from the Greek verb "haptesthai" which relates to the ability to touch and manipulate objects. While active touch is referred to as bidirectional flow of energy and information between the real, virtual environment and the human sensory modality. The interaction of objects or environment could be made by humans, machines or combination of both and the object and environments can be real, virtual or combination of both too. **Haptic technology has invaded the field of** medicine and dentistry. This technology has enabled the development of telepresence surgery, allowing expert surgeons to operate on patients from a distance. As the surgeon makes an incision, they feel tactile and resistance feedback as if working directly on the patient. Haptic interfaces for medical simulation are being developed for training in minimally invasive procedures such as laparoscopy and interventional radiology and for training dental students. The Haptic technology along with visual display can be used to train people for tasks which require hand-eye coordination such as a dental surgeon makes an incision, drilling into a carious lesion, etc. Repetitive procedures such as proper hand and instrument usage and placement are primary targets which have to be learned on dental simulators.

VirDenT is a dental medicine e-learning system with a haptic interface that allows students in dental schools to practice tooth preparations in fixed prosthetics in a virtual environment. The advantages of VirDentT system over earlier systems used in prosthetic and restorative dentistry such as DentSim, Virtual Reality Dental Training System

(VRDTS), Iowa Dental Surgical Simulator, HapTEL system etc are that VirDentT system does not require simulation, plastic models, dental parts, turbines, dental drills and more, so costs are much reduced.[10]

Sensible 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. This system support fabrication of fixed and removable restorations including full ceramic monolithic crowns, bridges and veneers produced in less time and precision through its unique touch-enabled technology, allowing dental labs to gain a competitive advantage. In addition, Intellifit's unique 3D 'Virtual Touch' interface and integrated touch-enabled articulator allow lab technicians to use their sense of proprioception to assess whether a restoration will allow the patient to function with the correct amount of contact and excursive movements.[11] 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. Actual feel and fit of occlusion in the restoration can be envisioned by Touch-enabled virtual articulator.

CONCLUSION

The virtual reality technology has already made a significant strides in the field of dentistry. It has opened door towards transformation from routine conventional methods used in dentistry into a virtual reality dental world. Virtual articulator is precise tool for the full analysis of occlusion in real patient and helps the dental professional in establishing a diagnosis and in planning the best treatment option. It is fueling a new era of people and machines working together with data-driven insights and highly strategic and outcome – focused processes.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

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