Virtual articulators in prosthodontics - Review

Kamal Hasan¹, Kathiravan Selvarasu*¹, Pon Kirubha Robin²

ABSTRACT

In this modern world of advanced information technology, it greatly improved our standard of living, gaining experience, communicate, and entertain. Many innovative and technological advancements have been introduced in the field of dentistry. The change in trends from numerous mechanical articulator designs to recently developed virtual articulators is an advance in the development of articulator design. Virtual technologies in dentistry are used to provide better education and training by simulating complex recording of mandibular movements and enhancing procedures that are traditionally limited, such as work with the mechanical articulator. The virtual articulator is intended to use as a tool for the analysis of the complex static and dynamic occlusal relations.

KEY WORDS: Articulator, Computer-aided design and computer-aided manufacturing, Virtual articulators

INTRODUCTION

Virtual refers to as “immersive, interactive, multi-sensory, viewer-centered, and three-dimensional (3D) generated environment.”⁶ Virtual dental articulator provides virtual reality applications to the world of dental practice which is used for occlusal relations.⁷ The commonly used semi-adjustable articulators have major limitations such as the movements of the mandible cannot be reproduced exactly or can maximize the record, and also they do not provide time-related information on jaw movement. These problems can be solved by replacing the mechanical articulator by a digital simulation which is called as “Virtual Articulator.”⁵ The virtual articulator has been designed for the detailed analysis of static occlusion and dynamic occlusion. This device incorporates virtual reality applications to the world of dental practice with the purpose of changing the usage of conventional mechanical articulators and thereby avoiding the errors and limitations of the latter. In daily practice, mechanical articulators are used to diagnose and simulate the functional effects of malocclusions and morphological alterations on dental occlusion.

However, this mechanical scenario, so very different from the real-life biological setting, poses a series of problems.³ In effect, the movements reproduced by the mechanical articulator follow the margins of the structures that conform the mechanical joint, which remain invariable over time, and which cannot simulate masticatory movements that are dependent on the muscle patterns and resilience of the soft tissues and joint disc. Moreover, tooth mobility cannot be simulated by plaster models; as a result, the latter are unable to reproduce the real-life dynamic conditions of occlusion. There are also other problems derived from the procedures and materials used for assembling the models in the articulator: Precision in orienting the model, expansion and contraction of the plaster, deformation of the bite-recording material, the stability of the articulator, etc. Due to these factors, dynamic reproduction of the excursive movements appears to be scantily reliable. In this sense, Tamaki et al. reported that only 82% of the teeth reproduce the protrusive contacts, and that 90% reproduce the laterality contacts in the mechanical articulator adjusted by computed axiography. In addition, the mechanical articulator generates new contacts.³⁴

The data obtained from the articulate will be processed by mathematical models to reconstruct the
The virtual articulator offers an animation of the movements of the mandible based on the input data, and calculates the points of occlusion, which, in turn, are shown on-screen by means of some type of code. Ideally, the virtual articulator is equipped with a device for registering the specific mandibular movements of a given patient (such as the Jaw Motion Analyzer (JMA)) and can integrate the movements recorded in the animation. If no device is available for registering the mandibular movements, specific movements must be defined by means of parameters, in a way similar to the practice used with mechanical articulators. Some parameters of interest in these cases would be the following: Protrusion (radius of the condylar guide and maximum distance of condylar protrusion), retrusion (radius of the condylar guide and maximum distance of retrusion), laterotrusion (maximum protrusion, Bennett angle, radius of the right and left condylar guide, right and left horizontal condylar slope, phase angle, and lateral displacement), and aperture/closure slope (maximum angle of aperture). After defining the movement parameters, collision detection is required to identify the movement restrictions. In these cases, it may be of interest to leave a distance corresponding to the thickness of the occlusion paper used in the mechanical articulators, for calculating the points of occlusion on the basis of this distance. As an example, the software of the Dent-CAM® virtual articulator (Comp. KaVo, DLeutkirch) uses three main windows that show the same movement pattern, distinguishing a series of aspects: (a) Interpretation window: This shows both maxillae in dynamic occlusion and allows us to obtain unusual points of view, for example, observation from an occlusal surface of closing of the opposing tooth during mastication; (b) occlusion window: This shows the points of contact that appears on the occlusal surfaces of the upper and lower teeth as a function of time; and (c) section window: This offers different frontal sections along the dental arch. This tool can be used to analyze the degree of intercuspidation, as well as the height and functional angles of the cusps. The latest 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 tool allows us to observe the inter-relationship between the incisal guide and the condylar guide, and the effects of joint mobility on occlusion.

The Need of Virtual Articulator

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 intermaxillary relationships, and of the joint conditions, thanks to dynamic visualization in 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 the temporomandibular joint. Combined with computer-aided design and computer-aided manufacturing (CAD/CAM) technology, this tool offers great potential in planning dental implants, since it affords greater precision and a lesser duration of treatment.

There are two types of virtual articulators which are categorized as follows:

- Completely adjustable virtual articulator
- Mathematically simulated virtual articulator

**COMPLETELY ADJUSTABLE VIRTUAL ARTICULATOR**

It records/reproduces exact movement paths of the mandible using an electronic jaw registration system called JMA.

The ultrasonic measurement system, JMA (Zebris, Germany) is used to record and implement the movement pattern of the mandible. It is an ultrasonic motion capture device that is comprised 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 infraorbital plane and special points of interest (e.g., On the 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 calculates and visualizes both static and kinematic occlusal collisions and are used in designing and correction of occlusal surfaces in CAD systems, for example, Kordass and Gartner virtual articulators.

- Helps to record and produce exact movements of mandible using an electronic jaw registration system called JMA.
- The digitized dental arches move along the movement paths which can be viewed in the computer screen.
- The software helps in calculating and visualizing both static and kinematic occlusal collisions and also used as designing and correction of occlusal surfaces in CAD system.[14]

**MATHEMATICALLY SIMULATED VIRTUAL ARTICULATOR**

It is based on a mathematical simulation of the articulator movements. It is a fully adjustable 3D 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 angle movements or different movements for adjustment in ideal settings. This makes it more versatile than a mechanical dental articulator. On the other hand, since it is a mathematical approach, it behaves like an average value articulator, and therefore, and it is not possible to obtain easily the individualized movement paths of each patient, for example, Stratos 200, Szentpetery’s virtual articulator.[15]

- It records and produces movements of the articulator based on mathematical simulation of articulator movements.
- A fully adjustable 3D virtual articulator capable of producing all articulator movements.
- It allows additional settings such as curved Bennett movement and other movements for adjustment in ideal settings.[7]

**Advantages**

- Dynamic visualization of the occlusal surface is possible using virtual articulator.[3]
- The clinician can visualize the teeth surface occlusion for contact points and prematurities leading to proper information for the diagnosis.[8,2]

**Disadvantage**

- A record has to be made for each patient, which is certainly not practicable for every clinician.[9]

**ARTICULATOR DESIGNS**

**Szentpetery’s Virtual Articulator**

It was introduced by Szentpetery in 1999. The design is based on a mathematical simulation of articulator movements. It is designed as fully adjustable 3D virtual dental articulator which is capable of reproducing the movement of an articulator. This design helps providing possibilities that are not given by some other mechanical articulators such as curved Bennett angle movements by making it more versatile than mechanical articulator. However, in view of mathematical approach, it behaves like an average value articulator and it is not possible to obtain the individualized movement paths of each patient easily.[16]

**Virtual Articulator of Kordass and Gartner**

It was introduced by Kordass and Gartner in 2003. The design is based on the exact record of mandibular movements with the help of jaw movement analyzer. This virtual articulator system requires digital 3D representation of the jaws which the input data capable of generating an animation of the jaw movement and gives a dynamic and detailed visualization of the collision points. There is a device to record the patient specific jaw movements which are known as the Zebra JMA in which the recorded jaw motion can be integrated into animation. JMA is a device used for the acquisition of mandibular movements.[3,11]

**Virtual Articulator Based on Mechanical Dental Articulator**

It was introduced by graphic design and engineering project development from University of Basque Country in 2009. The project was refined on developing a different virtual articulator based on the mechanical dental articulator in which the setting parameters can be registered and transferred to the patient. The problems or the limitations of the previous designs to develop virtual dental articulator were considered in this project. This design is much more in a simple form than the virtual articulator developed by Kordass and Gartner and at the same time has a more accurate result which can be obtained than the Szentpetery’s virtual articulator. The main advantage of this design is that the user can decide and choose the most suitable articulator to be used in the simulation.[14]

**DENTAL CAD/CAM SYSTEM**

CAD/CAM was first introduced to dentistry in the mid-1980s. Both chairside and chairside laboratory integrated procedures are available for CAD/CAM restoration fabrication. In selecting which procedure to follow, consideration should be given to esthetic demands, chairside time, laboratory costs, number of visits, and convenience and return on investment associated with CAD/CAM equipment. Depending
The virtual articulator in dentistry: Concept and application

The virtual reality technology has opened the door for all the dentists toward successful diagnosis and treatment planning and also for students to understand the advanced technology which is used in dentistry with virtual articulators. The virtual articulator is a precise software tool dealing with the functional aspects of occlusion along with CAD/CAM systems which substitutes mechanical articulators and hence avoiding errors and minimizing corrections. The concept of virtual articulator will change conventional ways of production and communication in dentistry and begin to replace the mechanical tools.

REFERENCES


Source of support: Nil; Conflict of interest: None Declared