# Virtual Articulator in Prosthetic Dentistry: A Review

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## Abstract

Virtual reality is 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 change in the trends from numerous mechanical articulator designs to recently developed virtual articulator is an advance in the development of articulator design. Virtual articulator is one such application in prosthetic and restorative dentistry based on virtual reality that will significantly reduce the limitation of the mechanical articulator, and by simulation of real patients data, allow analysis with regard to static and dynamic occlusion as well as jaw motion. This paper is attempted to highlight the procedure and benefits of using a virtual articulator over the traditional one.

**Keywords:** Virtual Articulator, Engineering, Prosthodontics, Stomatognathic

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## Introduction

Over the last few decades, newly developed technologies have revolutionized the world of dentistry and paved the way for exciting developments. For example, virtual reality's applications in dentistry are still being developed but have already resulted in many advances[1]. 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[2]. Virtual reality is a simulation of actual reality that generates an artificial place to replace the real world. Technologies and equipment that are created in virtual environments but have real-world applications are called virtual reality technologies and equipment. The applications of virtual reality in clinical and laboratory procedures have had an impressive influence on research, development and industrial manufacturing and have provided better education and training to dental students by simulating real word situations through a combination of virtual articulators, computer-aided design, and computer- aided manufacturing (CAD/CAM) technologies, digital face bows, visualizations and virtual dental patients[1].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. 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. 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." 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[3]. Virtual dental articulator provides virtual reality applications to the world of dental practice which is used for occlusal relations. The commonly used semi-adjustable ariticulators have





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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[4]. The virtual articulators require digital 3D presentations of the jaws and patient specific data on jaw movements. It then stimulates jaw movements and provides dynamic visualization of the occlusal contacts[5]. This paper is attempted to highlight the procedure and benefits of using a virtual articulator over the traditional one.

**Methods of Literature Search**

In this modern era of technological advancements, various internet based means are available that can legitimately retrieve biomedical information. Some of the popular internet based popular search engines (Google, Yahoo), scholarly search bibliographic databases (PubMed, PubMed Central, MedlinePlus, Cochrane, Medknow, EBSCO, ScienceDirect, HINARI, WebMD, IndMED, and Embase), and textbooks were searched until December 2022 using MeSH (Medical Subject Headings; PubMed) keywords such as "Virtual Articulators," "Computer Aided Design and Computer Aided Manufacturing," "Recent Advances," "Mechanical Articulator." The search was limited to reviews, systematic researches, and meta‐analyses in different dental journals published over the past 40 years in English and in Spanish. A total of 98 articles were identified; however, after investigating the titles and abstracts, this number was finally reduced to 15 articles.

**Virtual Articulator**

Virtual articulator is also called as "SOFTWARE ARTICULATOR" they only exist as a computer program. Comprise of virtual condylar and incised guide planes. Guide planes measured by Jaw Motion Angular (JMA). Need for virtual articulator has been designed for the exhaustive analysis of static and dynamic occlusion. Reducing the limitation if mechanical articulator. Advantages: full analysis can be made of static and dynamic occlusion of inter maxillary relationships and of the joint conditions. It is also employed for dynamic visualization of mandible and maxilla. Section planes allowing detailed observation of regions of TMJ. Combined with CAD/CAM technology, this tool offers great potential in planning dental implants. To fabricate best fitted occlusal restoration possible. Virtual articulators are of two types; completely adjustable and mathematically adjustable.



**Completely Adjustable**

It records / reproduce exact movements path of the mandible using electronic jaw registration system called JAW MOTION ANALYSER (JMA). The software of the DENT-CAM virtual articulator Developed at the University of Griefewald consists of 3 main windows and a slice window, which show some movement of teeth from different aspects. Rendering window - Shows both jaw during dynamic occlusion.

**MATHEMATICALLY SIMULATED VIRTUAL ARTICULATORS**

Mathematical simulation of the articulator movement by fully



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adjustable 3D virtual articulator is possible. It is capable of reproducing the movements of a mechanical articulator. It offers possibilities not offers by some mechanical dental articulator such as, Curved Bennett Movement, 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 like an average value articulator, and therefore, and it is not possible to obtain easily the individualized movement paths of each patients. Functioning of virtual articulator is the basic system that generates 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 the computer screen by means of some type of code. Virtual Articulator provides best quality of communication between the dentist and dental technician, it simulates real patient specific data and it analyses both static and dynamic occlusions, ganathic and joint conditions, acts as a 3D navigator. Limitations of Virtual Articulator is that it is 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 from scanners, sensors, minor adjustments, incorporating motion parameters etc.

**Development and Designing of Virtual Articulator**

The designing of dental virtual articulator is achieved by means of computer aided design (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.[1] The tools used are: HandyscanREVscan 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 needs to be rectified and redesigned accordingly.

**Strategic 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





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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.[3] 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.

**Programming of Virtual Articulators**

The programming and adjustment methods of the virtual articulator were described by Kordass and Gartner in 1999. Pre requisite for visualization on screen is 3D scanning/digitizing of tooth surface or restorations or denture models using 3D scanner. Scanning/digitising – 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 visualisation and computerised manipulation. 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. Patient Specific Motion Data of Temporo mandibular joints.[3] The Jaw motion analyser (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 digitising 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. Thus simulating the patient specific movement patterns with the attached scanned/digitised virtual models constructed in the virtual articulator. The relative position of the upper or maxillary virtual model in reverse position is digitised using face bow and located directly in the virtual articulator. The lower or mandibular virtual model is then located in centric relation with



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the upper virtual model using an electronic bite. Finally, visualise the occlusion 3D in all planes on the computer screen. The virtual articulator system is now ready to be applied for kinematic simulation analysis. If the jaw motion analyser 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 (radius of the condylar guide, maximum distance of condylar protrusion), retrusion (radius of the condylar guide, maximum distance of retrusion), laterotrusion (maximum protrusion, Bennett angle, radius of the right and left condylar guide, right and left horizontal condylar slope, shift angle, immediate side shift), and opening/ closing movement (maximum opening angle). After defining the motion parameters, collision detection is triggered to recognise 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. 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 head of the patient and generate an image from these signals. Fang and Kuo, presented a new model using this system for assessing mandibular dynamics. They designed customised device for each patient, fixed in the same position in both the plaster models and in the oral cavity. After scanning of models, the patients performed mandibular movements (aperture/closure, protrusion/retrusion, and lateral excursions) for 20min. The data recorded were later processed by mathematical models to reconstruct customised dynamics for each patient for visualization and computer based analysis (table 1).

## Future Scope of 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 and 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.[3]



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Table 1: Pioneer workers and their potential contribution in virtual articulator.[7,6,5,4,3,2,1]

| Author | Types | Design | Limitation | Advantages | Recent Development |
|---|---|---|---|---|---|
| Ozdemir et al 2021 | Completely adjustable mathematicall y adjustable | Szentpetery's VA VA of kordass & gartner | Economical | Designing of occlusal surface in CAD CAM system Detailed 3D visualization of region of interest | Newest version haptic based first touch enabled virtual articulator |
| Kamal Hasan et al 2019 | Completely adjustable mathematicall y adjustable | Szentpetery's VA VA of kordass& Gartner V.A. based on mechanical dental articulator | Cost effective knowledge about CAD/CAM tech Technical skills | Designing of occlusal surface in CAD CAM system Detailed 3D visualization of region of interest Possible to modify. | Newest version haptic based first touch enabled virtual articulator |
| Kalpana et al 2018 | Completely adjustable mathematically adjustable | Szentpetery's Stratos 200 | Cost effective knowledge about CAD/CAM technology | Provides best communication Simulating real patient specific data | Newest vesia haptic based first touch enabled virtual articulator |
| Lahori et al 2017 | Completely adjustable mathematically adjustable | Designszentepetery's virtual articulator V.A of Kordass & Gaertner | Costefficient | Better visualization of details & supports the mechanical tools. Influence the quality of the networking communicatio n between dental practice & laboratory. | |
| Luthra R P et al 2015 | Completely adjustable Mathematically y adjustable | CAD & reverse engineering tools PDL | Cost effective knowledge about CAD/CAM tech Technical skills | Best quality of communication between the dentist & technician Analyses both static and dynamic occlusion Designing of occlusal | 3D virtual articulator system-(zebris company, D-ISNY Newest version Haptic based first touch enabled virtual articulator |

| | | | | | |
|---|---|---|---|---|---|
| Singh N et al 2014 | Completely adjustable mathematically adjustable | Designszentepetery's virtual articulator V.A of Kordass & Gaertner | Economical | Improves design of dental prosthesis Adding kinematic analysis to the design processes | Special orthodontic CAD module |
| Korala Kunte P.R. et al 2014 | Completely adjustable mathematically adjustable | PDL Bilbao | Cost effective Knowledge about CAD/CAM Technical skill | Dynamic visualization of occlusal surface is possible using virtual articulator | Newest version haptic based first touch enabled virtual articulator |



**Discussion**

In this modern world of advanced in information technology, it has greatly improved our standard of living, gaining experience, communicate, and entertain. Much innovative and technological advancement have been introduced in the field of dentistry. Virtual reality is a computer based technology linked with the future of dentistry and dental practice. A virtual articulator is a computer software tool that is capable of reproducing the relationship between the jaws and simulating jaw movement. It has gradually gained research interest in dentistry over the past decade. In prosthodontics, the virtual articulator should be considered as an additional diagnostic and treatment planning tool to the mechanical articulator, especially in complex cases involving alterations to the vertical dimension of occlusion. Numerous authors have reported on the available digital methodologies used for the assembly of virtual arch models in a virtual articulator, focusing their attention on topics such as the virtual facebow and digital occlusal registration. To correctly simulate jaw movement, the jaw models have to be digitalized and properly mounted on the virtual articulator. 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, allows analyses with regard to static and dynamic occlusion as well as to jaw relation. The advent of intra-oral scanners, CAD/CAM and reverse engineering technologies have even further improved the quality and precision of treatment procedures. As tools of digital technology, augmented reality and virtual reality have been adopted in all disciplines of dentistry and dental education. In particular, virtual articulators have allowed for a full analysis of occlusion with dental models that can simulate all mandibular movements in static and dynamic positions. When combined with additional software, virtual articulators can also enhance education and practice, allow for quicker and more precise individualized diagnoses and enable discussions of dental treatment planning options with patients during their first appointment. Virtual articulators are one such tools that



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enables dentist to overcome the limitations and drawbacks of traditional and mechanical articulator.

## Conclusion

The virtual articulator is a precise software tool that deals with the functional aspects of occlusion analog with CAD/CAM systems substituting mechanical articulators and thus avoiding their errors. Developments in digital dental technology, particularly in virtual reality, have resulted in great advances in accurate and precise static and dynamic simulations in all disciplines of dentistry and in dental education. In the future, these systems should be enhanced with 4D technology in dynamic simulations. For these reasons, virtual reality has revolutionized dentistry and will continue to enhance dental practices for the foreseeable future.

## References

1. Koralakunte PR, Aljanakh M. The role of virtual articulator in prosthetic and restorative dentistry: a review. J Clin Diagnostic Res. 2014;8:25-28.
2. Singh N, Dandekeri S, Shenoy K, Bhat V. Digital Articulators:A Promising Technology of the future . Int J Dent Med Res 2014;1:98-102.
3. Luthra RP, Gupta R, Kumar N. Virtual articulators in prosthetic dentistry: a review. J Adv Med and Dent Sci Res. 2015;3:117-121.
4. Lahori M, Siddharth, Chakraborty S. Virtual articulators: changing trends in Prosthodontics.2017
5. Kalapana D, Brunda, Rao SJ,Venktesh P, Bhatt P. Virtual Articulators: Reality in Virtuality L: a review. Int J of Scientific Res 2018;7:1-2.
6. Hasan K, Selvarasu K, Robin PK. Virtual articulators in Prosthodontics: a review. Drug Invention Today. 2019;11:1604-1606.
7. Ozdemir G, Albayrak B, YuzbasiogluE,Olcer Y. Virtual articulators, Virtual Occlusal records and virtual patients in dentistry. J Exp Clin Med. 2021;38:129135.





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