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Review Article

Virtual articulator: An emerging tool in treatment planning in prosthodontics

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Abstract

Virtual articulator is a remarkable tool that transforming the way dental professionals analyse, plan, and execute various procedures, resulting in more precise treatments and improved patient outcomes. In this article, we will delve into the world of virtual articulators, exploring their benefits, applications, and the potential they hold for the future of dentistry. This article aims to introduce the ideas and tactics for potentially replacing mechanical articulators with virtual counterparts. Additionally, it provides a concise overview of the virtual reality haptic system and emphasizes the emergence of touch-enabled virtual articulators.

Keywords: CAD/CAM, Mechanical articulator, Touch enabled virtual articulator, Virtual articulator, Virtual reality.

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1. Introduction

Since its inception, mechanical articulator has been used as an important tool not only in prosthodontics but also in orthodontics, orthognathics etc.[1] A mechanical articulator is a tangible tool designed to replicate the interaction between the jaws and the skull base, along with mandibular articulation, with respect to all three spatial planes.[2] With the digital era, this mechanical articulator is replaced by virtual articulator (VA). It simply means using a software for articulation.[3]

To understand the virtual articulator, it is necessary to understand about virtual reality. Virtual reality replicates the physical reality by generating a virtual environment. The tools and technologies that facilitate interaction within this virtual realm are referred to as virtual reality equipment and virtual reality technologies.[4] In prosthodontics, VA incorporates the analysis of occlusion either static or dynamic.

With the advent of CAD/CAM technologies, single visit dentistry has become a norm. However, the dynamics of occlusion cannot be completely simulated in a mechanical articulator.[5] Most often the prosthesis has to be corrected in the mouth. These shortcomings can be overcome by means of a virtual articulator.[6] This article aims to provide an overview on the concept of virtual articulator.

1.1. History and evolution of articulators

The first record of use of an articulator dates back to 1756. It was a simple hinge articulator. The mechanical articulators aim to simulate the masticatory system i.e. the mandible and the temporomandibular joint.[7] These articulators could only simulate the static occlusion. Occlusion is a dynamic process. The time-dependent muscle guided movement, action of soft tissues and real border of mechanical joint cannot be replicated.[8,9] Virtual articulator use a programme known as 'software articulator'. The prosthetic needs like treatment planning for single crown to complex full mouth rehabilitation cases can be done with the aid of VA. **Figure 1**

1.2. Types of virtual articulators

Broadly the types of Virtual articulators can be divided as:

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Completely adjustable and mathematically simulated articulator.

1.3. Completely adjustable virtual articulator

It uses an electronic jaw registration system known as Jaw motion analyser (JMA) that replicates the mandibular movements.[10] The digital JMA then can be viewed on three different windows. The software then measures the static and kinematic occlusal relations and is then used in corrections in the CAD software.[11]

1. **Rendering window:** This window displays both dental arches during dynamic occlusion and can visualize unique perspectives within dynamic occlusal patterns. For example, it offers a view from the occlusal cusps while observing the approaching movement of antagonistic teeth towards the intercuspation position during chewing movements.

2. **Occlusion window:** This window showcases static and dynamic occlusal contacts as they slide over the surfaces of the upper and lower jaws over time.

3. **Compact window:** Temporomandibular joint movements are depicted in sagittal and transversal views within this smaller window, enabling the analysis and diagnosis of correlations between tooth contacts and temporomandibular joint movements.

4. **Slice window:** This window presents frontal cross-sectional views across the dental arch. It aids in analyzing the extent of intercuspidation, as well as the height and functional angles of the cusps. The analysis of guidance and balancing is facilitated through this window.[6]

1.4. Mathematically simulated Virtual articulator

It captures and replicates articulator motions through a mathematical simulation of their movements. These digital articulators offer the option for extra configurations, like curved Bennett movement or other adjustments within optimal conditions. However, a notable drawback is their tendency to function as general average articulators, lacking the capability to derive personalized movement paths for each patient.[12] Some examples of mathematically simulated Virtual articulator are Stratos 200, Szentpetery's virtual articulators.

1.5. Selection of Virtual articulator

CAD systems aid in designing the virtual articulators. The development takes place within the Product Design Laboratory (PDL) situated in the Faculty of Engineering at Bilbao, a part of The University of the Basque Country. This partnership includes collaboration with the Department of Prosthetics at Martin-Luther University of Halle, and the process unfolds as follows:

Initially, a range of mechanical articulators are selected for preliminary modeling using CAD systems (Solid Edge and CATIA). Subsequently, the design process is executed using the available measurement and reverse engineering tools at the PDL. The tools utilized include the Handyscan REVscan 3D scanner, along with its software (VXscan), reverse engineering and computer-aided inspection software (Geomagic Studio and Qualify), Rapidform XOR, and the ATOS I rev.[2] GOM 3D scanner.

1.6. Functioning of Virtual articulator

After constructing the virtual articulator, all measurements undergo a process of verification and thorough examination. Should any issues arise during this phase, they are promptly addressed, requiring subsequent rectification and redesign.[13] If the mandible functions not merely as a simple hinge but rather demonstrates the capacity to rotate around axes in three planes, the occlusal morphology of any oral restoration must account for unhindered movement of antagonist teeth, while also accommodating mandibular motion. As a result, the selection of a suitable articulator becomes a crucial step in designing the virtual articulator using this approach. Ultimately, the impact of the chosen articulator directly extends to the effectiveness of both fixed and removable prosthetic restorations.[14]

The programming of a virtual articulator can be explained as following steps:

1. **Scanning/digitising**: to capture images of teeth, tooth surfaces, restorations, complete denture models, or centric relation, a 3D Laser scanner is utilized. This scanner projects a vertical laser beam onto the surface of the object. A digital camera, equipped with a charge-coupled device (CCD), records the reflection of the laser beam from the object and transmits the resulting digital signals to an electronic processing system. The processed image data is stored as digital matrix brightness values, readily accessible for use by the scanner software and for visualization and manipulation on a computer screen. Scanning can be done as direct digitising and indirect digitising.

2. **Patient specific motion data of temporo mandibular joints (TMJ)** – The Jaw Motion Analyzer (JMA) device employs fixed reference points on the patient's mandible. This system measures ultrasonic impulses emitted by three transmitters affixed to a lower sensor on the mandible's labial surface. Four receivers on a face bow opposite these transmitters detect rotational and translational components. A specialized digitizing sensor establishes the hinge axis-infraorbital plane reference, including key points like the occlusal surface. Ultrasonics pinpoint spatial positions, outlining the patient's masticatory movement. The system reproduces patient-specific patterns using digitized

virtual models within the virtual articulator. The upper model's reverse position is digitized via a face bow, placed directly in the articulator. Lower model alignment is achieved with an electronic bite for centric relation. Finally, 3D occlusion is visualized on-screen, priming the system for kinematic simulation analysis.[15,16]

1.7. Recent advances in Virtual articulator

The latest iterations of the software include an orthodontic component that enables the generation of a virtual treatment plan. Additionally, the program now features the visualization of condylar paths in both the sagittal and horizontal planes. This software utility enables the examination of how the incisal guide and condylar guide interact, as well as the impact of joint mobility on occlusion.[17] In conclusion, virtual articulators are reshaping dental practice, enhancing precision, and ushering in new possibilities. Their transformative potential holds promise for optimizing dental treatments and patient experiences.

2. Limitations of Virtual Articulators

It is expensive since it involves digital scanners, sensors, software, and diverse virtual articulator models tailored to individual patient requirements. Proficiency in CAD/CAM technology, mechanical articulators, virtual articulator design and modelling, as well as technical expertise in interpreting scanner and sensor data, making minor adjustments, and integrating motion parameters, is essential.

3. Conclusion

Virtual articulators represent a significant advancement in prosthodontic diagnosis and treatment planning by enabling precise analysis of both static and dynamic occlusion in a digital environment. By integrating patient-specific jaw movements, temporomandibular joint dynamics, and CAD/CAM technology, virtual articulators overcome many of the inherent limitations of conventional mechanical articulators. Although challenges such as high cost, technical complexity, and the need for specialized training remain, ongoing technological advancements are steadily improving their accessibility and clinical applicability. As digital dentistry continues to evolve, virtual articulators are poised to play an increasingly important role in enhancing treatment accuracy, efficiency, and patient outcomes, particularly in complex restorative and full-mouth rehabilitation cases.

4. Author Contributions

All authors contributed significantly to the conception and design of the study. Literature review, data collection, and manuscript drafting were performed by the authors. All authors critically reviewed the manuscript, approved the final version.

4.1. Data availability

No new data were created or analyzed; all sources are cited.

4.2. Consent to participate.

Not applicable.

5. Conflict of Interest

The authors report no conflicts of interest.

6. Source of Funding

No funding was received for this study.

7. Ethical Approval

Not required, as no human or animal subjects were involved.

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