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Review Article

Virtual articulator and virtual facebow an aid in complete digital workflow: A review article

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ABSTRACT

Digital dentistry has been at the forefront of modernisation in dental practises. The aim of current dental practises is to provide an aesthetically pleasing and fast treatment options for improved patient satisfaction. Integration of CAD-CAM in dental prosthesis designing has helped achieve these goals. But a big drawback of unwanted occlusal discrepancies has been ignored for long. The development of the Virtual Articulator software has helped solve this problem by allowing the visualisation of occlusal contacts in static as well as dynamic conditions in the CAD software. Newer techniques of setting up Virtual Articulators leading to complete digitization of designing process have been discussed along with the future potential of integrating 3D and 4D haptic based technologies in the software for better dental education.

1. Introduction

Digitization has been at the helm of modern dental practise. With the advent of CAD-CAM technology and intra-oral scanning techniques there has been a boost to single visit dentistry with faster, more precise and more aesthetic computer designed final prosthesis delivery. But, the use of mechanical articulators restricts clinicians to deliver an ideal prosthesis in functional loading conditions of the mandible. These mechanical articulators replicate the maxillomandibular relationship in a static condition without considering the envelope of motion of the mandible in real time. This leads to inaccuracy in locating dynamic occlusal contacts along with development of certain new unwanted occlusal interferences which have to be corrected in the patient increasing the chairside time.[1] Hence the purpose of single visit dentistry is not fulfilled.

These problems can be resolved by replacing the conventional mechanical articulators with the newly developed Virtual Articulator software. This software is based on the virtual reality technology which provides an immersive, interactive, multisensory, viewer centered, 3D computer generated environment to replicate patient data.[2] It adds the ability of performing kinematic analysis during the design process by incorporating patient specific jaw motion data and helping clinicians get rid of the unwanted occlusal interferences during the designing phase itself. This software along with the Virtual facebow forms a completely digital workflow for prosthesis design improving the accuracy and precision of the final restoration and reducing the chairside time of the patient during final cementation.

2. Discussion

The virtual articulator has been defined as a software tool used for improved clinical outcomes and is based on the virtual reality technology The use of this software in dentistry was first described by Szentpetery in 1999.[3] The first commercially available software was developed by Kordass and Bisler in 2000.[4] Since then multiple approaches have been made to develop more user-friendly

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versions of the virtual articulator software. Currently two main types of virtual articulators are in practise, the completely adjustable and the mathematically simulated.

2.1. Mathematically simulated articulator

It was the first approach made at developing the virtual articulator software. Introduced by Szentpetrey in 1999, it is capable of reproducing mandibular movements such as retrusion, protrusion and laterotrusion on the basis of mathematical values of condylar angle and bennett angle. This provides the articulator an edge over the conventional mechanical articulators but it fails to reproduce the individualised movements of each patient as it based on a mathematical approach. Hence a more precise and adjustable software was desired.

2.2. Completely adjustable articulators

This approach was given by Kordass and Gaertner in the year 2000. It has the ability of recording and reproducing the precise movements of the mandible in static and functional conditions. The software is commercially available as DentCAM and is largely built around a Jaw motion Analyser. (JMA) This is an ultrasonic motion capture device used to record the movement of jaws during functional conditions. It is a 2-part system with the ultrasound emitter array bonded to the labial surfaces of the mandibular teeth via a customized cold cure acrylic jig and the counterpart, a sensor array, positioned on a head frame secured to the patient's head. The recorded data is visualized in different windows.[5]

1. Rendering window: offers a comprehensive view of occlusal dynamics as it showcases the unusual occlusal dynamic contacts by real-time visualisation of both the jaws during function.
2. Occlusion window: complements the rendering window by giving a detailed analysis of the occlusal surfaces in static as well as dynamic motion all as a function in time. Helps identify harmful occlusal discrepancies
3. Smaller window: helps co-relate temporomandibular joint problems with harmful occlusal discrepancies. Shows the comprehensive movement of the joint in sagittal and transverse views.
4. Slice window: useful in planning the site of occlusal adjustments as the frontal slice of the dental arch is viewed, showing the height and functional angles of the cusps along with the degree of intercuspation.

While the DentCAM system represents a significant advancement in dental occlusal analysis, it does have 2 notable drawbacks. Firstly, the dependency of the system on specialized motion tracking devices like the JMA making it complex and costly to use in regular day to day practise. Secondly, the lack of standardization to save the jaw motion data in a universal digital format poses a challenge in integrating the DentCAM data with other digital tools or platforms. Additionally, it restricts the interoperability of DentCAM with virtual articulator software, as the usage of the Jaw Motion Analyzer (JMA) may be limited to specific proprietary systems.

These problems were resolved by the introduction of VA software that is based on the type of mechanical articulator to be used. The selection of the articulator is an important step which allows the clinician to visualise the final outcome. Once selected, the articulator is scanned through a scanner and reverse engineering software to obtain data in CAD system. This is then transferred to the Virtual articulator software. This approach allows the clinician to choose the articulator as well as the setting parameters on case-to-case basis thereby providing a more comfortable and user-friendly software to work on.[6]

The steps followed in integrating the virtual articulator to prosthesis designing can be summarised in the flowchart given in the flowchart below.

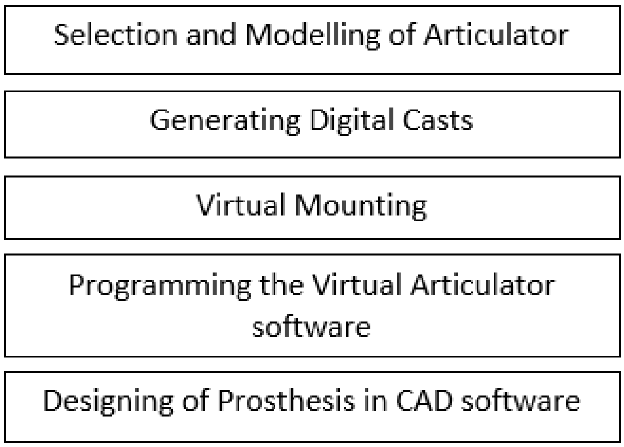

Figure 1: Integration of VA data to prosthesis designing

Once the scanning and modelling of the desired articulator is completed, the digital casts are generated by intraoral or extraoral scanning methods. Studies have reported extraoral scanning to have higher accuracy for full mouth arch scans. The digital casts generated are mounted on the virtual articulator by transferring the facebow record for the maxilla and the centric relation record for the mandibular arch. The articulator is then programmed by inputting custom values for bennett angle, condylar inclination, incisal guidance, etc for mathematically simulated models whereas jaw motion records are taken and transferred in case of completely adjustable articulators. The software is then integrated with the designing tools and the prosthesis design is finalised.

The main steps which define the success of these articulators are the articulation of the maxillary cast with facebow records followed by mandibular mounting via centric relation record and the recording of jaw motion in real time.

2.3. Virtual Facebow

It acts as the virtual analogue of the mechanical facebow thereby allowing the articulation of the digital casts in the virtual environment. Like the conventional facebows, the virtual facebow can also be either average value or kinematic. The method of digital facebow transfer is quite similar to conventional facebow transfer as both require the identification of a reference plane. This plane has 2 posterior points and 1 anterior point. The posterior landmarks are pivotal in locating the terminal transverse hinge axis, an imaginary line around which the mandible revolves in the centric position. Thus, identifying the posterior landmarks through anatomical markings is superior to arbitrary method.

Kinematic facebows represent a more precise subset of virtual facebow systems, as they rely on cutaneous landmarks to pinpoint anatomical condylar projections. By accurately locating the rotational hinge axis through these landmarks, kinematic facebows offer enhanced precision in articulating mandibular movements digitally.

Through the years, several different techniques of virtual facebow have been developed thereby leading to a completely digital workflow for prosthesis fabrication.[7]

2.3.1. Cephalometric images

Developed by Noguchi et al in 2007 primarily for the purpose of bone position change analysis following orthognathic surgeries. Acquisition of the intraoral and extraoral facial structures via frontal and lateral cephalograms is the first step. This is then converted into an integrated data by using superimposition of various points and coordinates on the cephalogram, and the data is used to simulate the orthognathic system in a 3D-shape analysis programme. Occlusal analysis is done in the Maximal Intercuspal Position (MIP). The drawback of this virtual facebow transfer method was the lack of utilization of any real reference plane leading to questionable accuracy of transfer.[8]

Building on the above concept, Ghanai et al in 2010 described another technique to create a virtual patient for surgical planning in dysgnathia cases. They made use of a fixed reference plane in the form of Campers plane and kept the occlusal plane parallel to this fixed refence plane. Campers plane was identified via cephalometric landmarks from 2D projections like lateral cephalograms. This allowed a more accurate mandibular rotational axis transfer thus creating a virtual 3D environment for digital jaw movement. Utilization of 2D imaging systems remained a drawback of the technique.[9]

2.3.2. Position marker scanning with 3D optical scanner method

One of the early acceptable techniques to perform virtual facebow transfer. Explained by Solaberrieta et al in 2103 it eliminates the need of physical mounting of casts and facebow transfer. Extra-oral facial markers are placed on the TMJ and infraorbital notch which orient the maxilla to the cranium and 3 points are chosen intraorally on the most prominent cusp tips to act as intraoral markers for orientation of the occlusion plane of the maxillary cast. Once selected, these markers are then scanned by the extraoral scanner and the cast are digitally mounted on the software.[10]

2.3.3. Facial photographs aided virtual mounting

Another technique given by Solaberrieta et al in 2015. They described the use of cutaneous landmarks in order to identify the posterior condylar projections. This allowed the creation of an arbitrary terminal hinge axis. According to this technique, adhesive targets are placed on the posterior cutaneous landmarks to identify the facial reference planes. Along with this the maxillary plane is recorded by putting the facebow fork with elastomeric impression material into the patient's mouth. With this armamentarium in place, a series of 8-10 high-definition facial photographs of the patient are taken. These are then superimposed and reverse engineered to obtain the spatial relationship between the head and adhesive targets which is utilized to build a 3D virtual model of the patient's face onto which the casts are digitally aligned. Due to lower armamentarium cost, this technique is commonly used and forms the basis of modern-day practise.[11]

2.3.4. Virtual axis technqiue

Introduced by Solaberrieta et al in 2015. Offers an indirect approach to constructing a virtual kinematic facebow, which is significant in dentistry for various procedures, especially in orthodontics. Traditionally, determining the intercondylar hinge axis (ICHA) involved using a physical axiograph, which could be cumbersome and less accurate. Solaberrieta et al utilized scanned computer-generated arches and positioned them relative to the coordinates of the skull. This approach allowed for a more precise determination of the ICHA without the need for physical instrumentation. It gave higher accuracy specially when compared to the conventional maxillary transfer methods. This procedure had applications in orthodontic purposes but not for orthognathic or restorative procedures.[11]

2.3.5. Stereophotogrammetry

Stereophotogrammetry involves capturing three-dimensional images of the patient's head and facial structures using multiple cameras from different angles. By calibrating these images, precise measurements can be obtained, allowing for accurate virtual articulator mounting. The use of calibrated stereophotogrammetry leads to improved accuracy, efficiency, and patient comfort. It allows for a more realistic representation of the patient's occlusal relationships, leading to better outcomes in prosthodontic treatment. According to Lam et al, this system can be easily replicated by the clinician by utilizing lego bricks to stabilize the 2 impression trays and using wax as occlusal registration material to transfer position of maxilla.[12]

2.3.6. Standardized extra-oral photographs

The technique involves using standardized background images to capture the patient's head position. By employing these standardized images, clinicians can ensure consistency and accuracy in capturing the patient's natural head position, which is essential for precise articulation of dental models. Given by Petre et al, it relies on precise marking of the cutaneous landmarks corresponding to the hinge axis by the operator. This is followed by taking standardized 2D facial photographs and superimposing the same onto the CAD software by using reverse engineering. The drawback of this technique is the operator-dependent step of marking the cutaneous landmarks, and hence it is an arbitrary virtual facebow transfer.[13]

2.4. Jaw motion recording

The next important step after articulation of the digital casts is programming the virtual articulator software with real time jaw motion data of the patient. This step is of prime importance in completely adjustable VA software. Kordass and Gartner VA software utilized the jaw motion analyzer for recording the jaw motion wherein the mandibular movement is recorded by ultrasonographic emissions and calculated as the pulse travel time between the emitters and the sensors. This device had the disadvantage of being bulky and expensive for daily practices. Newer jaw motion recording devices are now available to integrate the data with the virtual articulator software.

2.4.1. Modjaw

Helps record real-time jaw motion of patient and create a digital dynamic twin. It has the unique ability of merging all patient data including 3D models, 4D movements and CBCT. It records the markers on the lower facebow utlising high-definition cameras along with scan of certain facial areas to deliver the computer stereo version and record real time jaw movement. The advantage it possess over the conventional techniques includes, no continuous radiation exposure to the patient, lightweight of the device and the ability to constantly upgrade itself.

2.4.2. Freecorder bluefox

Introduced by Dentron, GmBH it is a device that utilizes an optoelectronic registration method or 4D video recording system to record all jaw movements and individual mandible position. Recordings are done in coded patterns, mapped, recognized and decoded by several special cameras and high-performance computers at a rate of 100 times per second. The bow used is ultralight and made of carbon, is attached only to the root of nose and outer auditory canal. The device has the advantage of not utilizing harmful radiations for recording position transfer and also providing a precise model transfer to an articulator without separate use of a face-bow.

2.4.3. ARCUS digma

Introduced by KAVO, by using ultrasound transmission along with microphones and pingers, it captures a comprehensive range of data related to mandibular movement, occlusal positions, temporomandibular joint health, and even muscle activity through EMG analysis. This level of detail can be invaluable for diagnosing issues related to bite alignment, jaw function, and overall oral health. It is a significant advancement in dental technology, offering practitioners a more precise understanding of their patients oral dynamics.

2.4.4. Planmeca 4D jaw motion

A sophisticated system for capturing and analyzing jaw movements in 3D integrating Cone Beam Computed Tomography (CBCT) technology with software that can record, track, visualize, and analyze jaw movements. The use of Planmeca ProFace camera adds another dimension by tracking mandibular movements relative to the maxilla, providing comprehensive data for diagnosis and treatment planning. The recording of eight spheres, half integrated into glasses and half into a bow, allows for precise tracking of jaw movements. By correlating the movement of these spheres with the position of the glasses (representing skull movement) and the bow (attached to the lower arch for detecting relative distances), the software can accurately replicate mandibular movements.

3. Advantages and Disadvantages of Virtual Articulator

3.1. Advantages

1. By providing comprehensive data on jaw movements and occlusal conditions, the system facilitates better communication between the dentist, dental technician, and patient, ensuring alignment in treatment goals and outcomes.
2. Integration with CAD/CAM systems enables the design of precise occlusal surfaces, enhancing the accuracy and fit of restorations and prosthetics.

3. It enables detailed analysis of gnathic (jaw) and joint conditions, aiding in the diagnosis and treatment planning of temporomandibular joint disorders (TMDs) and other related issues.
4. The system goes beyond static occlusal assessment, allowing for dynamic occlusion analysis, which is crucial for understanding how the patient's bite functions during various movements.
5. By providing accurate 3D visualization and data, the system helps eliminate manufacturing problems associated with traditional methods, leading to better-fitting restorations and prosthetics.
6. The system is more time-efficient compared to traditional methods, allowing for quicker diagnosis, treatment planning, and fabrication of dental restorations.
7. By simulating the real patient's occlusal dynamics, the system facilitates modifications to restorations as needed and educates patients about their treatment options and expected outcomes.
8. The data generated by the system can be directly used for 3D printing, enabling the fabrication of patient-specific dental appliances and prosthetics with high precision.[14]

3.2. Disadvantages

1. Expensive, requiring investment in specialized hardware, software, and training for dental professionals.
2. The technology may have a steep learning curve for dental professionals
3. Virtual articulator systems rely on accurate data acquisition and software algorithms to simulate jaw movements. However, technical limitations such as hardware calibration errors or software bugs can affect the accuracy of the simulations, leading to potential inaccuracies in treatment planning.
4. Access to virtual articulator technology may be limited in certain regions or dental practices, particularly in less-developed areas or smaller clinics with budget constraints.
5. As with any digital technology in healthcare, there are ethical considerations regarding patient privacy, data security, and informed consent.
6. Integrating virtual articulator systems with existing dental practice management software or electronic health record systems can pose challenges due to differences in data formats and interoperability standards.

4. Future of VA

4.1. 3D VA system

The development of a 3D software has made it possible to analyse the mandibular movements in real time. This has led to examining the occlusal contacts of a patient during the masticatory movements of the mandible, giving the value of force at the points of contact and the frequency of contacts in relation to time. Therefore, occlusal discrepancies can be kept to a minimum by utilizing the 3D articulating software.[15]

An input device in the form of a 3D scanner is used for digitizing the casts. The output device is in the form of a rapid prototyping system with stereoscopic inkjet technology that helps manufacture the final prosthesis. The designing is done via the help of 3D VA software. It has been useful in planning implant placement locations specially in cases of pterygoid or zygomatic implants.[16] Occlusal examination can also be incorporated.[17]

4.2. Haptic based first touch enable VA

The newest iteration of the IntellifitTM TE (Touch Enabled) Digital Restoration System from Sensable Dental Technologies gives dental labs even more options, performance, and flexibility when digitally designing and fabricating a variety of dental restorations. Dental labs of various sizes can benefit from the system's support for both fixed and removable restorations, including entire ceramic monolithic crowns, bridges, and prepared veneers, which are produced more quickly and precisely because of its innovative touch enabled technology.

Additionally, lab technicians can really feel how the teeth, including the new restoration they are creating, will fit together in the patient's mouth thanks to Intellifit's innovative 3D "Virtual Touch" interface and integrated touch-enabled articulator.

Lab technicians have long employed articulators, as well as their sense of touch, to determine whether a restoration will let the patient to function with the right amount of contact and excursive movements. Articulators are vital to examining the occlusion of practically every form of dental restoration. However, Intellifit's VA enables for dynamic settings to fulfil patient requirements while simulating the feel and functionality of a physical articulator.

5. Conclusion

The virtual articulator represents a significant advancement in dental technology, revolutionizing the way clinicians approach diagnosis, treatment planning, and fabrication of dental restorations. This innovative system enhances communication between dentists, dental technicians, and patients by providing detailed data on occlusal dynamics and jaw function. Its compatibility with CAD/CAM systems allows for the design of precise occlusal surfaces, while dynamic occlusion analysis enables a deeper understanding of how a patient's bite functions during various movements. With its ability to simulate real patient scenarios and aid in 3D printing, the virtual articulator empowers clinicians to deliver personalized treatment plans and patient-specific restorations with unprecedented accuracy. Overall, the virtual articulator represents a transformative tool in modern dentistry, promising enhanced outcomes, improved patient satisfaction, and continued advancements in dental care.

6. Source of Funding

None.

7. Conflict of Interest

None.

References

1. Tamaki K, Čelar AG, Beyrer S, Aoki H. Reproduction of excursive tooth contact in an articulator with computerized axiography data. *J Prosthet Dent*. 1997;78(4):373–8.
2. Koralakunte PR, Aljanakh M. The role of virtual articulator in prosthetic and restorative dentistry. *J Clin Diagn Res*. 2014;8(7):25–8.
3. Szentpetery A. Computer-aided Dynamic correction of digitized occlusal surfaces. *J Gnathol*. 1997;16(1):53–60.
4. Kordas B, Gartner C, Sohnel A, Bisler A, Vos G, Bockholt U, et al. The virtual articulator in dentistry: concept and development. *Dent Clin N Am*. 2002;46(3):493–506.
5. Ferrin LM, Millan JR, Oltra DP, Diago MP. Virtual articulator for the analysis of dental occlusion: An update. *Med Oral Patol Oral Cir Bucal*. 2012;17(1):160–3.
6. Solaberrieta E, Etxaniz O, Minguez R, Muniozguren J, Arias A. Design of a virtual articulator for the simulation and analysis of mandibular movements in dental CAD/CAM. *Procedia CIRP*. 2009;19(3):323–31.
7. Lepidi L, Galli M, Mastrangelo F, Venezia P, Joda T, Wang HL, et al. Virtual articulators and virtual mounting procedures: where do we stand? *J Prosthodont*. 2021;30(1):24–35.
8. Noguchi N, Tsuji M, Shigematsu M, Goto M. An orthognathic simulation system integrating teeth, jaw and face data using 3D cephalometry. *Int J Oral Maxillofac Surg*. 2007;36(7):640–5.
9. Ghanai S, Marmulla R, Wiechnik J, Muehling J, Kotrikova B. Computer-assisted three-dimensional surgical planning: 3D virtual articulator: technical note. *Int J Oral Maxillofac Surg*. 2010;39(1):75–82.
10. Solaberrieta E, Minguez R, Barrenetxea L, Etxaniz O. Direct transfer of the position of digitized casts to a virtual articulator. *J Prosthet Dent*. 2013;109(6):411–4.
11. Solaberrieta E, Garmendia A, Minguez R, Brizuela A, Pradies G. Virtual facebow technique. *J Prosthet Dent* . 2015;114(6):751–5.
12. Lam WY, Hsung RT, Choi WW, Luk HW, Cheng LY, Pow EH, et al. A clinical technique for virtual articulator mounting with natural head position by using calibrated stereophotogrammetry. *J Prosthet Dent*. 2018;119(6):902–8.
13. Petre A, Drafta S, Stefanescu C, Oancea L. Virtual facebow technique using standardized background images. *J Prosthet Dent*. 2019;121(5):724–8.
14. Dadoo A, Jain S, Mowar A, Bansal V, Trivedi A. 3D Printing Using CAD Technology or 3D Scanners, A Paradigm Shift in Dentistry-A Review. *Int J Med Dent Res*. 2021;1:35–40.
15. Aggarwal S, Bali Y, Bhardwaj M, Goswami R. Applications of 3D Printing In Dentistry. *J Res Administration*. 2023;5(2):9218–25.
16. Trivedi A. Rehabilitation of mandibular defects using customized implants. *J Indian Prosthodont Soc*. 1920;20(Suppl 1):29. doi:10.4103/0972-4052.306390.
17. Sharma AR, Kumar N, Singh K, Gupta RK, Sirana P. Occlusal Indicators: It's not always Red and Blue. *J Prostho Dent*. 2020;15(2):11–21.

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