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Virtual Articular –A Myth or Reality

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ABSTRACT:
A virtual articulator is a computer software tool which reproduces the relationship between the jaws and simulating jaw movement. In dentistry over the past decade it has gradually gained research interest. The virtual articulator should be considered as an additional diagnostic and treatment planning tool to the mechanical articulator in prosthodontics, especially in complex cases involving alterations to the vertical dimension of occlusion. Numerous researchers 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. The jaw models have to be digitalized and properly mounted on the virtual articulator to correctly simulate jaw movement. The aim of this review was to discuss the current knowledge surrounding the various techniques and methodologies related to virtual mounting in dentistry, and whether virtual articulators can be used routinely in day-to-day clinical practice in future. This review also depicts the history of the virtual articulator up to its current state and discusses recently developed approaches and workflows for virtual mounting based on current knowledge and technical devices.

1. Introduction

The mechanical articulator (MA) has long been used as an essential tool in laboratory procedures to aid in both diagnosis and treatment planning in different fields of dentistry, such as orthodontics, prosthodontics, and orthognathics.[1] Mechanical articulator is a physical instrument that facilitates reproduction of the relationship between the jaws and the skull base, as well as mandibular articulation, in relation to each of the three spatial planes.[2]In the fields of articulator there is a shift from a mechanical device to its digital alternative, the virtual articulator (VA) with advancements in technology.[3] The virtual articulator reproduces the relationship between the jaws in a virtual environment.[4] In the early 2000s, clinicians began to verify the rationality of digitally designing prostheses using a virtual articulator. The aim of the present narrative review was to assess the present scenario of virtual articulators in the literature and to understand the current status regarding the various steps involved in virtual mounting procedures. The relation to the virtual facebow and the virtual articulators is also discussed in this review. Finally, the use of virtual articulators into clinical practice in future is highlighted in this review.

History of the virtual articulator

Historically, Szentpetery in the late 1990s first introduced virtual articulators software in dentistry. Bisler and his team from the University of Greifswald, Germany in 2002 introduced the first virtual articulator.[5,6-8] Bisler et al. stated that the virtual

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articulator as “a tool for the analysis of the complex static and dynamic occlusal relations”. The use of virtual articulators has been applied to computer-aided design and computer-aided manufacturing (CAD-CAM) dentistry since then. Virtual articulators are mainly used for individualized diagnostics and avoidance of the common problems encountered with mechanical articulators, such as creation of new occlusal contacts, material deformation, errors during orientation and positioning of dental casts, and difficulties simulating patient data in three dimensions (3D). It can be utilized as an educational tool to display treatment options to patients. Dent Cam (Kavo; Hamburg, Germany) was the first software including virtual articulator functionally. The things required for the digital acquisition of tooth data (single tooth or dental arches and occlusal registration) is the 3D laser scan.[9] Bisler et al. proposed the use of a "Scan 3D" scanner (Willytec; Munich, Germany), allows direct scanning of the arches and occlusal registration, making the data available for virtual presentation, manipulation, and navigation. Dent Cam software was also used for recording mandibular movements and playing them back as an animation. Clinicians can visualize and analyze the static and dynamic occlusal contacts during mandibular movement using patient-specific data into DentCam software. A Jaw Motion Analyzer (JMA) (Zebris Company; Isny, Germany) which measures the speed of ultrasonic pulses emitted by transmitters and sensors to record mandibular movements and also capture the dynamic elements of occlusion and masticatory function. This tool helps mandibular movements to be analyzed in all their spatial, rotational, and translational components. Special sensors are not only used to determine the anterior and posterior reference points, but also occlusal contacts. A silicone occlusal registration key is attached to the upper arch during opening and closing movements. It is stabilized through a metal carrier-plate to which sensors are attached. Finally, the movement data is combined with data from the arches as follows: upper teeth and material for occlusal registration of lower teeth are scanned; both dental arches are correctly oriented relative to each other; the digitized impressions of the upper and lower jaws are combined with the data scanned from the casts while preserving a desirable jaw relationship; and both sets of data from the 3D scanner and mandibular motion records are imported into the virtual articulators. A color scale (yellow, red, and blue) is then used to visualize contact points. The program also allows selection of different thicknesses of articulation paper, same as with a mechanical articulators. After describing the possibility of using a virtual articulators, the authors hypothesized future versions with potential to facilitate its use in orthodontic, implant, and prosthetic fields. In the past, a major disadvantage regarding the use of JMA in daily clinical practice was its higher cost, but recently, but now- a- days it becomes a more affordable tool.

DRAWBACKS OF MECHANICAL ARTICULATORS

The mechanical articulators are used in routine practice for diagnosis and simulate the functional effects of malocclusions and morphological alterations upon dental occlusion. However, this mechanical scenario is not same as the real life biological setting. The mobility of the teeth cannot be simulated in Mechanical articulators while using plaster casts in it, the distortion and deformation of the mandible during loading conditions and the complexity of movement patterns because the movements of the mechanical articulator follow border structures of the mechanical joint. The real dynamic conditions of the occlusion in the mouth cannot be represented in mounted or articulated casts. The accuracy also gets hampered by many other problems regarding the technical procedure and dental materials as: The deformation of bite registration material (e.g. wax is susceptible to heat), repositioning the cast into the bite impressions without leaving any space, the stability of the articulator itself, the correct orientation of the cast, the use of rigid and expanded plaster material and maintenance of the mechanical articulator. The reproduction of dynamic, excursive contacts seems to lower the reliability of mechanical articulator because of these basic errors. [1, 5-9]

VIRTUAL ARTICULATORS

Virtual Articulators are also called as “software articulators”. They comprise of virtual condylar and incisal guide planes. Guide planes can be measured precisely using jaw motion analyzer or average values are set in the program like average value articulator. The Virtual Articulators are able to design prostheses kinematically. They are capable of simulating human mandibular movements, by moving digitalized occlusal

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surfaces against each other and enabling correction of digitalized occlusal surfaces to produce smooth and collision-free movements.

NEED FOR VIRTUAL 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, dynamic visualization in three dimensions (3D) of the mandible can be possible, the maxilla or both, and to the possibility of selecting section planes allowing detailed observation of partial 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.[6] The prosthodontic applications of virtual articulators are to fabricate the best fitted occlusal restoration possible, to help students to understand the function of dental articulator, different excursive movement and their influence on the occlusal surface and to improve the better communication between the dentist and dental technician.

TYPES OF VIRTUAL ARTICULATORS

There are two types of virtual articulators namely:

a) Completely adjustable

b) Mathematically simulated

Completely Adjustable Virtual Articulator: It records exact movement paths of the mandible using an electronic jaw registration system called Jaw Motion Analyzer (JMA).

The ultrasonic measurement system, Jaw Motion Analyzer (Zebris, Germany) is used to record and implement the movement pattern of the mandible. It is an ultrasonic motion capture device that is comprised of 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 infra orbital plane and special points of interest (eg: on the occlusal surface).[2,7] 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 is used in designing and correction of occlusal surfaces in computer aided designing (CAD) systems. Eg: Kordass (FIG 1) and Gartner virtual articulators. The software of the DentCAM virtual articulator developed at the University of Greifswald consists of three main 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 intercuspation 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 intercuspation, and the height and functional angles of the cusps. With this window, the analysis of guidance and balancing becomes easy [1,7] The recent 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 software tool allows us to observe the inter relationship between the incisal guide and the condylar guide, and the effects of joint mobility upon occlusion.

Mathematically Simulated Virtual Articulator: It is based on a mathematical simulation of the articulator movements. It is a fully adjustable three-dimensional 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 movement or different movements in identical settings. This makes it more versatile than a mechanical dental

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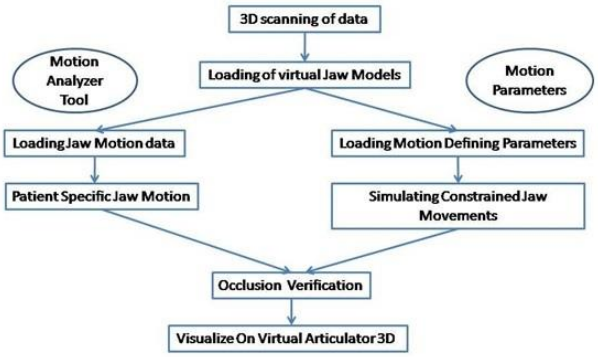
articulator. On the other hand, since it is a mathematical approach, it behaves as an average value articulator, and therefore, is not possible to obtain easily the individualized movement paths of each patient. Eg: Stratos 200, Szentpetery's virtual articulator [8] (FIG 2).



DEVELOPMENT AND DESIGNING OF VIRTUAL ARTICULATOR

The designing of dental virtual articulator is achieved by means of computer aided desigm
(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:

1)Different mechanical articulators are selected first to be modeled through CAD systems (Solid Edge and CATIA).

2) The design process will then be carried out using measuring tools and reverse engineering tools that are available at the PDL. The tools used are: Handyscan REV scan 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 need to be rectified and redesigned accordingly [8, 11- 13] (FIG 3).

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 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. 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. [2,5,8,13]

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. The scanning can be done in 2 ways:

Direct digitizing – It is done directly from the patient's mouth using an intra oral scanner.

Indirect digitizing – It is done outside on the patient's master cast obtained after making final impression. The scanned data helps to obtain the real geometry of the mouth and its relative location are reconstructed in a CAD system using the face bow. In the second phase, the type of articulator is selected depending on the required accuracy and/or on the patient's setting data available in each case. Once the dental prosthesis is modelled, the functional simulation is performed in order to obtain the interfering collision points which could produce a disease in the temporomandibular joints, which may end up producing a disease in the temporomandibular joints. Excursive movements, such as protrusion and laterotrusion are simulated using a CAD system, analyzing possible occlusal collisions so that the design

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can be adequately modified. Finally, the dental prosthesis is milled and tested on the mouth of the patient.

RECENT DEVELOPMENTS IN THE VIRTUAL ARTICULATOR

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

a) An input device in form of a 3D scanner.

b) 3D virtual articulator software for prosthesis modeling with collision detection.

C) 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.[8]

Advantages of Virtual Articulator

The advantages of the virtual articulators are dynamic visualization of the occlusal surface is possible with the virtual articulator, whereas mechanical articulator offers only static presentation, offers a detailed 3-D visualization of region of interest, possible to modify or introduce new setting according to the patient. The clinician can visualize the teeth surface occlusion for contact points and prematurity leading to proper information for the diagnosis [8,9] Virtual articulators are also helpful in-patient education and improves the compliance for the treatment.

Limitations of Virtual Articulator- It is costly 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 are required and technical skills needed regarding the interpretation of data recorded from scanners, sensors, minor adjustments, incorporating motion parameters etc.

Future Modules of Virtual Articulator- In future, there is a need to develop virtual articulator software that integrates the correcting software for CAD/CAM system directly into the process of construction of crowns and bridges. Presently a digital face-bow transfer is not possible. At present, the face bow has to be mounted on the patient and then brought to the dental mechanical articulator. Finally, it is important to remark that several improvements should be made up when obtaining the patient's data. This is a main shortcoming which generates difficulties on the next step, this is, the use of the articulator and the design process. Therefore, a progress in this sense will bring important improvements on the whole process.

HAPTIC BASED FIRST TOUCH ENABLED VIRTUAL ARTICULATOR

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. The system's support for both fixed and removable restorations including full ceramic monolithic crowns, bridges and prepped veneers, produced faster and with heightened precision though its unique touch enabled technology, allows dental laboratories of all sizes to gain a competitive advantage. 15 Also, Intellifit's unique 3D 'Virtual Touch' interface and integrated touch-enabled articulator allow lab technicians to actually feel how the teeth and including the new restoration they are producing and it will fit together in the patient's mouth. Articulators are essential to testing the occlusion of almost every type of dental restoration and lab technicians have long used them, as well as their sense of touch, to assess whether a restoration will allow the patient to function with the correct amount of contact and excursive movements. 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. Touch enabled, virtual articulator allows technicians to test occlusion of restoration – before it is produced and enabling them to actually feel the fit.

Conclusion-The virtual articulator technology has opened a new era for dental professionals towards successful diagnosis and treatment planning in day-to-day clinical practice. The virtual articulator is a precise software tool dealing with the static as well as dynamic state of occlusion along with CAD/CAM systems

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substituting mechanical articulators and thus avoiding their errors. Haptic based virtual reality system's is a touch enabled virtual articulators allow lab technicians to actually feel how the teeth, including the new restorations produced will fit together in the patient's mouth. In near future routine conventional methods used in dentistry will be replaced totally into a virtual world.

FIG 1: Kordass' Virtual Articulators

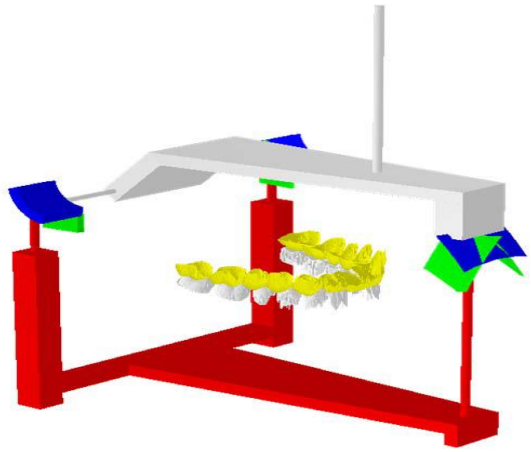

FIG 2: Szentpétery's Virtual Articulators

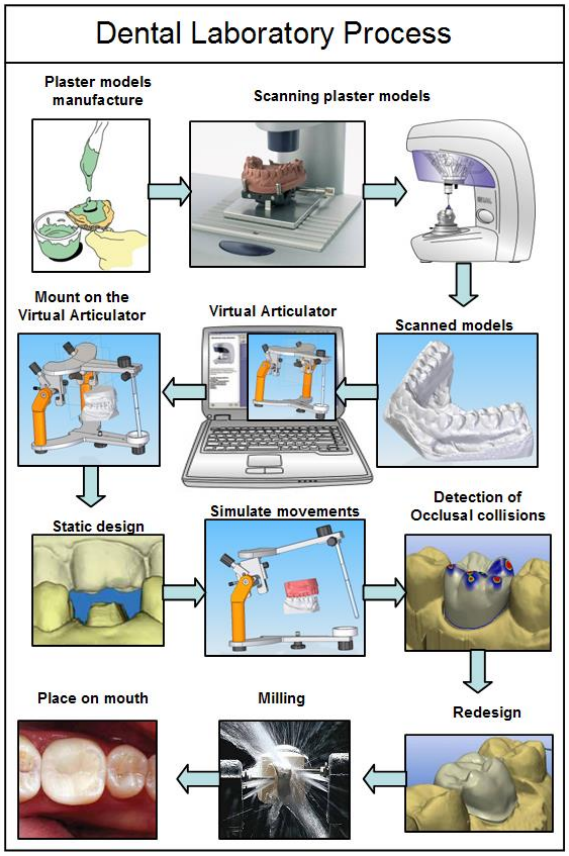

FIG 3: Development and designing of virtual articulator.

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