Review Article

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Articulators: Past to Present

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ABSTRACT

Background: Articulators vary widely in the accuracy with which they reproduce the movements of the mandible. Some articulators are very simple as they do little more than simulate the hinge motion of the mandible and hold the casts in centric relation. At the other extreme, complicated articulators are also available which require very complex recording apparatus and they aim to simulate all the jaw movements. None of the articulators exactly reproduce the full range of jaw movements, nor is the reproduction of such a range required for fabrication of any kind of prosthesis. Many instruments fall between these two categories as they provide a more or less accurate reproduction of movement. The challenge for the dentist is to choose an articulator that is suitable for the purpose at hand, neither more nor less complicated than necessary. An emerging understanding of the neurophysiology of mandibular movement and the influence of several morphological and behavioral considerations led to the notion that each patient is his or her own best articulator. Therefore the diverse, and frequently subtle, variations required for each individual occlusion could be more easily achieved with an adjustable articulator that accepts a variety of records. The final programming of occlusion can then be done intraorally as required. The new Virtual articulator provides interesting modules for presenting and analyzing the dynamic contacts of the occlusal surfaces of the maxillary and mandibular teeth and the relation to condylar movement. It is a basic tool that deals primarily with the functional aspects of occlusion; however, it also can be regarded as a core tool in many diagnostic and therapeutic procedures and in the CAD/CAM manufacture of dental restorations.

Keywords: Articulator, dentistry, Prosthodontics.

INTRODUCTION

An articulator is neither a mouth of patient nor a chew-in device or a tooth milling machine. It should receive and register craniodental and maxillo-mandibular relations, the paths and axis of mandibular motion and should ideally allow the incorporation of these factors into the prosthesis customized for a patient.[1] According to eighth edition Glossary of Prosthodontics Terms, articulator may be defined as "a mechanical device which represents the temporomandibular joint and jaw member to which maxillary and mandibular casts may be attached to simulate some or all of the mandibular movements".[2] Some of these devices make no attempt to represent the temporomandibular joints (facebow transfer) or their paths of motion (eccentric registrations). Some instruments allow eccentric motion determined by adequate registrations (positional registrations). Some utilize average or equivalent pathways. Some attempt to reproduce the eccentric pathways of the patient from three dimensional registrations. The dentist should understand the differences between these articulating devices, and determine which would be most satisfactory for the

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patient. Recently, Virtual articulator is developed which is a basic tool that deals primarily with the functional aspects of occlusion; however, it is also useful in many diagnostic and therapeutic procedures and in the CAD/CAM manufacture of the restorations. The add-on modules in this virtual concept will change conventional ways of production and communication in dentistry and begin to replace the mechanical tools.[3] Virtual 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.[4] The use of these articulators allows dental technicians to simulate human mandibular movements and correct all possible digitized occlusal surfaces in order to achieve smooth and collision-free movements.[5]

CLASSIFICATION OF ARTICULATORS

The range of articulators with different principles of design is so great that a system of classification is indispensable to using and teaching the theory and practice of articulation.

I. **Gillis (1926) classified the articulators into[6]**

(1) The adaptable or adjustable type

(2) The average or fixed type

II. Boucher classified articulators in year 1934 as nonadjustable or adjustable[7]

He also subdivided the adjustable type into two group

(1) A two dimensional instrument

(2) A three dimensional instrument

III. Kingrey stated in 1942 in Anthony's textbook that for descriptive purposes articulators may be classified into two general groups[8]

(1) Simple articulators or Non adjustable

(2) Adjustable or adaptable articulator

IV. Weinberg (1963) classified the articulators into arbitrary, positional, semi adjustable, and fully adjustable[9]

(1) *Arbitrary* - this type of articulator followed Monson Spherical theory.

(2) *Positional* - this one followed Stanberry tripod concept.

(3) *& (4) Semi adjustable and fully adjustable* - these two classes are based on the amount they mimic the mandibular movements.

Semi adjustable – followed Hanau H concept

Fully adjustable – followed Hanau Kinoscope concept, Gysi Trubyte concept and Mc Collum concept.

V. Boucher classified the articulators based on[10]

(1) The theories of occlusion and

(2) The types of records used for their adjustment.

a) **The Bonwill theory of occlusion** proposed that teeth move in relation to each other as guided by the condylar and incisal guidance. Bonwill theory, a theory of equilateral triangle, states that the distance between the condyles is equal to the distance between the condyle and the midpoint of mandibular incisors; the equilateral tringle formed between the two condyles and the incisal point. Theoretically, the dimension of equilateral tringle is 4 inches. Bonwill's articulator allow lateral movement and permit the movement of the mechanism only in horizontal plane.

b) **The Conical theory of occlusion** proposed that the lower teeth move over the surfaces of the upper teeth as over the surface of a cone, generating an angle of 45 degrees, with the central axis of the cone tipped 45 degrees to the occlusal plane. The Hall Automatic articulator designed *by R.E. Hall* conforms this theory.

c) **The spherical theory of occlusion** *by G.S. Monson* proposed that the lower teeth move over the surface of the upper teeth as over the surface of a sphere with a diameter of 8 inches. The Centre of the sphere was located in the region of the glabella, and the surface of the sphere passed through the glenoid fossa along or concentric with the articulating eminences. The maxillo-mandibular instrument and the Hageman Balancer follow this theory.

CLINICAL SIGNIFICANCE OF ARTICULATOR

The articulators are widely used not only for construction of complete dentures but also to reposition the mandible and for treatment and prevention of temporomandibular joint and periodontal diseases. Often the simplest satisfactory articulator will produce the most consistent result.[11] Properly mounted dental casts allow the operator to better visualize the patients occlusion from all aspects, especially from lingual side. Another advantage of mounted diagnostic casts involve the ease of mandibular movements. On the articulator, a patient's mandibular movements and resultant occlusal contacts can be observed without influence of the neuromuscular system. Often when the patient is examined clinically, the protective reflexes of neuromuscular system avoid damaging contacts. As a result, interferences can go to unnoticed and therefore undiagnosed. When the mounted diagnostic casts are occluded, these contacts become evident. Thus the casts can assist in more thorough occlusal examination in patients with TMJ disorder. Mounted diagnostic casts are often helpful for the patient's education.

Probably the most common use of the dental articulator is in treatment. It can be an indispensable aid in developing dental appliances that will help treat the patient. It can provide the appropriate information regarding mandibular movement that is needed to develop an appliance or restoration for occlusal harmony. Although theoretically this information could be acquired by working directly in mouth, the articulator eliminated many factors (e.g. tongue, cheeks, saliva, and neuromuscular control system) that contribute to errors. In some instances it is necessary to use materials that are not suitable for the oral cavity, then the articulator becomes the only reliable method for developing an appropriate occlusal condition in the dental appliance. It is an intricate part of crown and fixed prosthodontic procedures.

EVOLUTION OF ARTICULATORS

The first articulator was 'Slab Articulator'. It was described by ***Philip Pfaff*** **in 1756.** The distal portion of the casts had plaster extensions with grooves that served as indices.[12]

The "barn door" hinge articulator', also known as the Dayton Dunbar Campbell instrument was another one of the common articulators used and are available from any hardware or general stores. It can be modified by bending each arm 90 degrees to form L-shaped upper and lower members.[12] **The adaptable "barn door" hinge** has an anterior Vertical stop in the form of a bolt. It allows opening and closing hinge movement and with minimal lateral movement if instrument is well manufactured.[12]

The first mechanical articulator was described by J.B. Gariot in **1805**. It was a hinge joint articulator with two metal frames for attaching the casts. The frames were joined by means of a hinge and a setscrew was there to maintain vertical position.

Bonwill, a mathematician, in **1858**, started the ball rolling with his two-dimensional equilateral triangle type articulator that had an opening, a protrusive and lateral component, such as it was, which allowed for some resemblance of balanced relationship with the result that chewing movements were rendered possible and serious interface of cusps could be detected and eliminated. With his innovation, anatomic and balanced occlusion were demonstrated for the first time and dentistry became Trans fixed again for another forty years.[13]

W.E Walker in 1896 said that dentures, which were balanced on Bonwill's articulator, did not balance in the mouth and recognizing many other defects in his work, pointed to the absence of condylar inclination as the dictating factor. His work led to the necessity of making extra oral tracing, which could be recorded and transferred to his adjustable articulator. The articulator was intricately constructed capable of the accepting the variable reading as recorded by his "Facial clinometer" , or recording device, it was a two dimensional gothic arch movement type of instrument , and was revolutionary. As a result of his findings, complex type of articulator began to evolve, and until 1910 every investigator sought to reproduce the individual movements of the patient's mandible. They recognized condylar path varied from person to person and that, even in same person, the condylar path may differ.[13]

Grittman in 1899 designed a typical instrument which permits eccentric motion based on averages and will not accept face bow transfer, called The Grittman articulator. The cast are mounted on this instrument according to the Bonwill triangle theory. The condyles are on the lower member of the articulator and their parts are inclined 15 degree.[2]

The Gysi Adaptable articulator was introduced in **1910**, but apparently it was beyond the technical ability and finances of most dentists. For this reason, Gysi Simplex was introduced as a mean value articulator in 1914. It was competitively priced and did not require great technical ability to operate. The condylar guidance of the Gysi Simplex is fixed at 33 degrees and is shaped like the ogee path. The first articulator to use the ogee path was an English instrument introduced by J. B. Parfitt in 1902-3. The incisal guide is not adjustable.[12]

George Monson in 1918 designed The Maxillomandibular instrument which was based on the spherical theory of occlusion. According to this theory, which evolved from concepts of Monson and a German anatomist, Graf Von Spee, the mandibular teeth move over the maxillary teeth as over the surface of a sphere. The average radius of the sphere is 4 inches, with the center of sphere located in the region of the glabella and the surface of sphere passing through the condyles or centric with condyle path.[12]

Rudolph L. Hanau, an engineer during the time of First World War in 1921 developed a research model called the "Hanau - Model C Articulator" which had provision for controlled movement with more accurate and accessible controls, and its adjustments and operation simplified. Hanau Model H designed by Rudolph Hanau in 1923. This articulator accepts a facebow transfer, and the horizontal condylar inclinations are set by means of a protrusive interocclusal record. The condyles are on the upper member. The Bennett angle (L) was calculated from the horizontal condylar inclination (H) by means of Hanau's equation, L = H/8 +12.

Later in 1923, he devised the 'Hanau Model M Kinoscope Articulator', which provided exact measurement of mandibular movements. It has double condylar posts on each side. The inner posts serve two purpose. They act as the horizontal condylar guides, and are adjusted Medio laterally to produce mechanical equivalents of intercondylar distances. The Bennett angle is adjusted by rotating eccentric cones against the horizontal axis shaft.[12]

Gysi in 1926, introduced a fairly sophisticated articulator called the **Trubyte Articulator**. This instrument accepts a face-bow transfer, protrusive interocclusal records and some lateral interocclusal records. The horizontal condylar inclinations are individually adjustable and individual Bennett adjustments are located near the center of the intercondylar axis. The incisal guide table is adjusted to the patient's Gothic arch angle. The intercondylar distance is fixed. This instrument is able to accept some, but not all lateral interocclusal records.[2]

Bergstorm designed an instrument in **1950** called Arcon , which is similar to the Hanau H expect that the condyles are on the lower member of the instrument, and the condylar guides are curved and on the upper member. Bergstrom's instrument was not the first arcon instrument, but he was the first to use the term Arcon. Bergstrom derived the name ARCON from ARticulator and CONdyle. The term arcon is commonly used to indicate an instrument that has its condyles on the lower member and condylar guides on upper member. Instruments that have condyles on the upper member and condylar guides on the lower member , for example Hanau H Model H are commonly referred to as condylar instruments or as non arcon instruments.[2]

Later, *Granger, Stuart, Ney* and *Guichet* introduced the Pantographic Tracings. **Hanau Model 96H2** was introduced in **1958**. Articulators was an increased distance between the upper and lower members from 95 mm to approximately 110 ram. In addition, the orbital indicator was added to the upper member. It remained a semi adjustable articulator.[12]

The Dentatus ARL articulator was first manufactured by A. B. Dentatus of Stockholm Sweden, in **1958**. The Dentatus ARL articulator is a semi adjustable articulator that is a shaft type of instrument with a straight condylar path and a fixed intercondylar distance. In mechanical principle and design, it is similar to the Hanau H2.[12]

The Whip-Mix articulator is a simplified version of Stuart's fully adjustable articulator. It was designed

for complete dentures, and was intended to be useful as a diagnostic instrument and as a teaching aid. This is a semi adjustable arcon articulator that has three intercondylar adjustments: small, medium, and large. These are selected by means of the accompanying Quick Mount face-bow that uses the external auditory meatus as a posterior landmark. This face-bow has a nasion anterior guide that establishes an anterior point of reference for maxillary cast positioning. The condylar element of the Whip-Mix articulator is adjustable about the vertical and horizontal axes but not the sagittal axis. It therefore cannot be set to all positional records.[12]

Plasterless Articulator Mercer H82-M1 articulator (Smith Dental Products), is a two-dimensional fixed condylar inclination plane line instrument, precision made, sturdily designed, and easy to use. A fixed 25-degree condylar inclination path slot is incorporated into the two vertical posts of the lower bow-formed platform. A horizontal shaft with lateral axle extensions connects the element between the upper and lower bows. The lateral axle extensions of the horizontal shaft pass through the 25-degree condylar path slot on the vertical posts of the lower member. Dental casts are routinely mounted on articulators with plaster of Paris or artificial stone. Dimensional changes that occur on setting of these products could significantly affect the accuracy of the interocclusal relationship of the mounted casts. Although the need for control of this variable exists, it remains a neglected aspect in the cast-mounting procedure. A new articulator that is both practical to use and accurate in relating casts to their correct occlusal relationships has been developed.[14]

Recent advances in electronic and computer technology facilitated the development of electronic techniques to record the motion of the mandible. The main advantage of this technique is that, they could accurately record the dynamic motion of the mandible. Because of their reduced size, these devices provide negligible interferences with the natural motion of the mandible.

The three dimensional kinematic characteristics of the temporomandibular joints during any mandibular activity can be measured analyzed and described using these devices. These devices do not require head fixation, do not alter or interfere with natural occlusion and are light in weight. An electronic, computerized pantograph was compared with mechanical pantograph and was found 93% of immediate side shift measurement within 0.3 mm. 92.5% of progressive side shift within 4º, 87% of protrusive inclination measurement within 6º.Using electronic and computerized pantograph, errors occurring in the transfer of measurement can be minimized. Recently advanced virtual articulator offers the possibility of significantly reducing the limitations of mechanical articulators. Introduction of virtual 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. The equipment's and technologies by which we can interact in a virtual reality are known as virtual reality equipment and virtual reality technologies.[15]

The limitations of mechanical articulators can be reduced by means of Virtual concept of articulators. Decision support for dentists, orthodontists, and dental technicians supplied by a computer tool such as the ''virtual articulator'' could improve the clinical outcome. Owing to non reproduction of exact mandibular motion and its variable dynamics, the mechanical articulators may not simulate the patient's gnathological system including teeth, muscles and Temporomandibular joints.

The mechanical articulators cannot simulate the mobility of the teeth when using plaster casts in it and the distortion and deformation of the mandible during loading conditions (the mandible bends in maximal opening position to the inner side, which entails problems when making impressions of teeth during wide opening). One of the most interesting options offered by the virtual tools is the ability to ''move'' and navigate through enlargeable occlusal surfaces to explore the details of functional occlusion that cannot be visualized using casts alone. To study the impact of joint determinants (e.g., Bennett angle, slope of condylar guidance, side shift) on occlusal movement patterns, the virtual articulator requires virtual tools for joint-constraint adjustment and collision detection, which simulate the stops of static and dynamic occlusion. A mechanical

articulator doesn't record the effect of resilience of soft tissue or muscle engrams. The dynamism of occlusion in mouth can't be analyzed by mounted casts on mechanical articulators. Furthermore, the error in handling the materials (wax or bite registration materials) and techniques employed for various procedures during rehabilitation may decrease the accuracy in achieving the final results. The programming of virtual articulators is done by scanning/digitizing of tooth surface, restoration or complete denture models or centric relation records by means of 3D Laser scanner. The jaw motion analyzer tool is used to record patient specific motion data of TMJs. 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.

CONFLICT OF INTEREST

No potential conflict of interest relevant to this article was reported.

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