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Review Paper

Articulators in Prosthodontics and Dentofacial Orthopedics

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Abstract:

In modern dentistry, prosthodontists and general dental practitioners can provide accurate prosthodontic treatments to patients as a result of a macroevolution in dental technology field. The aim of this review paper is to provide an overview of articulators in dentistry, particularly in fixed and removable prosthodontics, their different types or classifications, indications, advantages, and limitations.

Keywords: *Articulators; Face-bow Transfer Record; Prosthodontics; Denture; Instrument; Cast; Temporomandibular Joints, Bennett Shift.*

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Introduction:

The dental articulator is an essential instrument and mechanical device used to relate the positions and movements of the mandibular cast to the maxillary cast during certain phases of prosthodontic restorations.

It is absolutely a necessary tool to intensify the quality of delivered work and upgrade patient satisfaction (1). An articulator can be defined as a mechanical device that mimics the temporomandibular joints and jaw components. It is used to affix the maxillary and mandibular casts and replicate various mandibular movements (2). However, some articulators used by prosthodontists do not satisfy this definition. Some do not make any type of hinge motion, while others do not come close to duplicating mandibular movements.

Posselt has classified articulator types into three groups based on their design: plain line or simple hinge types, mean value types with fixed condylar path and incisal inclines, and adjustable types.

An articulator's main functions are to maintain a fixed and predetermined relationship between opposing casts, facilitate opening and closing movements, and generate diagnostic sliding

motions of teeth, which simulate those observed in the oral cavity (3).

The articulatory system is composed of two temporomandibular joints (TMJ) connected at the symphysis, occlusal surfaces of teeth, masticatory muscles and periodontal proprioceptive nerve fibers (4). The basic mandibular movements are rotation, translation and lateral movements. The lower jaw is capable of a 20 mm opening and closing range while the condyles rotate in their final hinge position. As the jaw opens further, the condyles move out of the glenoid fossa and slide down the articular eminence. During lateral movement, the condyle on the working side rotates with little medial displacement, while the condyle on the nonworking side rotates and shifts laterally (immediate side-shift), and then gradually moves forward along the medial wall of the glenoid fossa (progressive side-shift) (5).

According to the findings of Shanahan and Leff's study on mandibular and articulator movements, the **following conclusions were reached:**

The opening and closing movements of the mandible do not match those of hinge-axis articulators (6). Tracings of mandibular movements show differences in the quality of horizontal, lateral, protrusive excursions and vertical masticatory cycles, with no alignment with the opening and closing arcs of hinge-axis articulators or straight-line protrusive movements of adjustable articulators (7, 8). Further, the idea or the concept that the mandible rotates around a translating axis is untenable. The meaning of this concept or belief is simply that the mandible does not change its size or shape during the movements (9). Lastly, the theory that the mandible rotates about vertical axes in the region of the condyles during lateral movements is also un-tenable, and the use of central bearing points in the mouth produces unnatural influences upon the movements of the mandible. Shanahan and Leff's conclusions regarding the movements of the mandible are generally correct. Normal functional movements of the mandible involve both sliding and rotation, resulting in compound motion with both an instantaneous axis of motion and an instantaneous axis of rotation (10).

Advantages and Limitations of Dental Articulators:

Dental articulators offer several advantages, including the ability to visualize the patient's occlusion from a lingual view, not requiring patient cooperation once interocclusal records are obtained, eliminating difficulties in refining complete denture occlusion in the mouth, reducing chair time for the patient, and not being affected by the patient's saliva, tongue, and cheeks.

The limitations of dental articulators include potential errors resulting from tooling (manufacturing), metal fatigue, and wear; the inability to precisely reproduce functional or intra-border movements of the mandible; the inability to replicate exact mandibular movements; and the reproduction of errors resulting from jaw relation procedures (5).

Classification of Dental Articulators:

Dental articulators can be classified based on their capabilities and record acceptance into four classes: Class I, simple hinge or plain line articulators; Class II, mean value or fixed condylar path articulators; Class III, semi-adjustable articulators; and Class IV, fully adjustable articulators. They can also be classified based on their adjustment capacity into non-adjustable, semi-adjustable, and fully adjustable.

Plain Line or Simple Hinge Type of Articulator:

This type of articulator is commonly referred to as the straight-line articulator and is capable of producing opening and closing movements only. While it can accurately record and maintain the centric occlusion and/or maximum intercuspation, it does not provide any information about protrusive, working, and non-working positions.

Despite this limitation, it remains popular among prosthodontics technicians due to its simplicity and lack of control mechanisms that require no jaw relation records from the patient, other than certain types of inter-occlusal centric relation records for opposing occlusal rim orientation.

The simple hinge articulator is made up of upper and lower members attached by a hinge (11) as shown in Figure 1, and is mainly used for the construction of a single unit that conforms to the existing ICP. The main advantage of this type of articulator is its low cost and ease of use (12, 13). However, its primary disadvantages include the lack of personalized information about the spatial relationships between the patient's jaws and the terminal hinge axis. This can result in artificial teeth arrangements for complete dentures that do not resemble the patient's actual jaw movements. Restorations made using these articulators are typically too high when tried in the patient's mouth and require occlusal adjustments before cementation. This problem is exacerbated when the anterior guidance is not steep enough to dis-occlude the posterior teeth quickly (11), which mean the dentist must spend considerable time adjusting and selectively grinding. This articulator cannot adjust elements of protrusive and lateral movements and does not allow accurate vertical dimension changes (12). Only the static ICP can be visualized using this articulator (14), and it does not accept face-bow transfer, limiting its esthetic perspective (12).

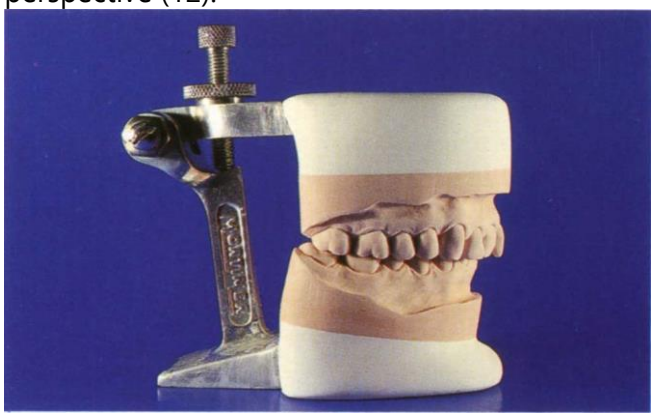

Figure 1. Plain line or simple hinge articulator (11).

Mean Value or Fixed Condylar Path Articulators:

Average or mean-value articulator is a non-adjustable articulator that allows for motion based on three mean mandibular measurements: an intercondylar distance of 10–11 cm, a condylar guidance of 33°, and an incisal guidance of 9–12°, which make this type of articulator superior to simple hinge articulators only if these fixed values coincide with the patient's values (14, 15). These articulators allow for horizontal and vertical movements, while the permitted eccentric movements are based on average values and cannot be altered to accommodate individual patient variations. For many patients, the condylar path ranges from 30-40 degrees from the horizontal, with an average of 32 degrees.

They consist of upper and lower members that are joined by two vertical posterior posts called "condylar post supports" which are fixed to the members. The upper end of each post has an inclined groove that represents the condylar path, through which the condylar shafts extending from the upper member are located and moved, allowing for horizontal movement of the upper member. The two members of these articulators are joined together by two joints that represent the temporomandibular joint.

When the articulator does not accept a face-bow record, the mounting is made according to and based on Bonwill's triangle theory in 1850 states that "the two condyles and a point located between the lower central incisors form an equilateral triangle with sides of 4 inches" (Figure 2) (14). Bonwill discovered that in mandibles, the inter-condyle distance as well as the distance from each condyle to the contact point of the lower central incisors formed an equilateral triangle with sides of four inches (Figure 2). An anterior pointer is attached to the incisal pin of the articulator to locate the tip of the occlusion rim labially and

orient the cast in relation to the Bonwill triangle (14).

The mean-value articulators are used for the fabrication of single-unit anterior or posterior restorations, short-span posterior prostheses for patients with prominent canine guidance, and anterior bridges for patients with minimal overjet and overbite (≤1mm) (14). The primary advantages of these articulators are their affordable cost and the fact that they do not require complicated equipment (13). However, there are also some disadvantages, such as limited protrusive and lateral movements. Additionally, these movements bear little resemblance to actual patient movements because face-bow cannot be used with average value articulators (11). As a result, restorations fabricated on these articulators will require intra-oral adjustments (15).

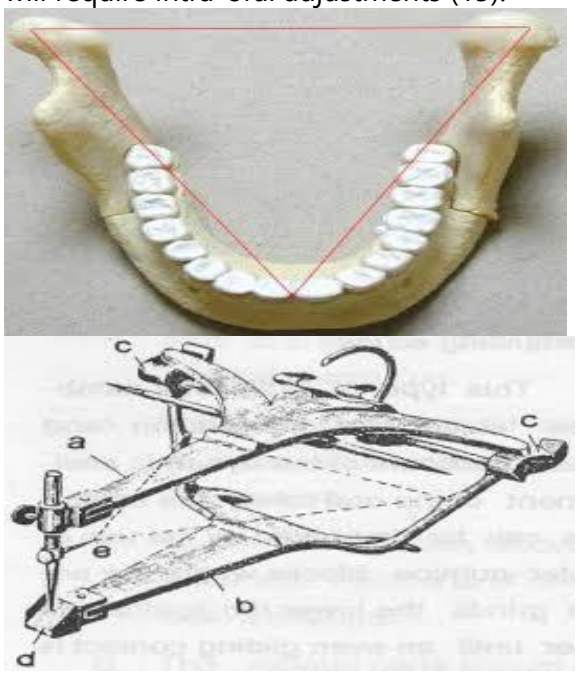

Figure 2. Mounting of maxillary cast according to Bonwill triangle (14).

Adjustable Condylar Path Articulators:

This type of articulator differs from the fixed condylar path type of articulator in that it has adjustable condylar and incisal guidance. These articulators can be adjusted so that the movements of their jaw members closely resemble all movements of the mandible for each individual patient. Furthermore, this type of articulator can accept eccentric records, which are used to adjust the condylar guidance of the articulator so that the movements of its jaw members closely resemble those produced by the patient. In contrast, mean-value articulators cannot accept eccentric records and have a predetermined condylar path that cannot be adjusted.

According to the eccentric records accepted by these types of articulators, they are classified as semi-adjustable condylar path articulators and fully adjustable articulators. Semi-adjustable articulators are the most commonly used for advanced restorative treatments and are satisfactory for most prosthodontic work (16). This type of articulator can accept the face-bow record to mount the upper cast, the centric occluding relation record to mount the lower cast, and the protrusive record to adjust the articulator's horizontal condylar path inclination. Meanwhile, the articulator's lateral condylar guidance is adjusted according to Hanau's formula, which is L = H/8 + 12, where L is the lateral condylar path inclination and H is the horizontal condylar path inclination obtained by using a protrusive record from the patient.

There are two types or designs of semi-adjustable articulators, the arcon type of articulator, in which the fossae are on the upper member, and the non-arcon type, in which the fossae are on the lower member. Arcon articulators usually have a removable upper member and are good teaching instruments since the position of the fossae corresponds to that of the patient. If casts are mounted in a non-arcon articulator with a centric relation record, it may be difficult to position them subsequently in the intercuspal position, as the condyles are restricted by the fossae slots, which

may not permit the correct condylar movement to occur between the CRCP and the ICP. The accuracy of restorations constructed on both types of semi-adjustable articulators is the same. However, some operators believe that the arcon type is better and superior because of the following reasons: firstly, in the non-arcon type, the condyles are restricted in the fossae track, which limits the correct shifting between the retruded contact position and the intercuspal position. However, in the arcon type of articulator, this movement is possible (12). Secondly, the angle between the inclination of the condylar track and the maxillary occlusal plane is fixed in the arcon type on opening and closing, but it is not in the non-arcon type (Figure 3). This may introduce some inaccuracy in the relation of the condylar angle to the maxillary cast upon the removal of the protrusive bite record as they become more parallel to each other, resulting in the fabrication of restorations with reduced cusp height (17).

The great advantage of using a semi-adjustable articulator is that restorations can be made to function in harmony with existing teeth in both centric and eccentric movements without the need for extensive intraoral occlusal adjustments (13). The disadvantages of using a semi-adjustable articulator include the expense and time required for face-bow transfer and eccentric record registration, although it saves time needed for later intraoral adjustments (13).

The fully-adjustable articulator is a sophisticated articulator that can replicate the three-dimensional movements of recorded mandibular motions. It differs from the semi-adjustable articulator in that the lateral condylar path inclinations are adjusted according to records taken from the patient. This type of articulator can accept the following records: a face-bow record to mount the upper cast, a centric occluding relation record to mount the lower cast, a protrusive record to adjust the articulator's horizontal condylar guidance, which corresponds to the patient's horizontal condylar path inclination, a right lateral record to adjust the left lateral condylar guidance, which corresponds to the patient's left lateral condylar path inclination, and a left lateral record to adjust the right lateral condylar guidance, which corresponds to the patient's right lateral condylar path inclination. The possible movements of this type of adjustable articulator are the same as those of semi-adjustable articulators, in addition to having a Bennett movement. The disadvantages of using a fully-adjustable articulator include the need for multiple records, which can introduce the possibility of errors. Therefore, semi-adjustable articulators are usually sufficient for complete denture construction.

The uses of fully adjustable articulators include full mouth rehabilitation, severe tooth surface loss (TSL) or tooth wear (TW) cases, shallow posterior guidance and/or Bennett angle, shallow anterior guidance with mobile guidance teeth, short clinical crowns, balancing side interferences, alteration of the vertical dimension, implant-tooth supported fixed prostheses, and parafunctional habits (12).

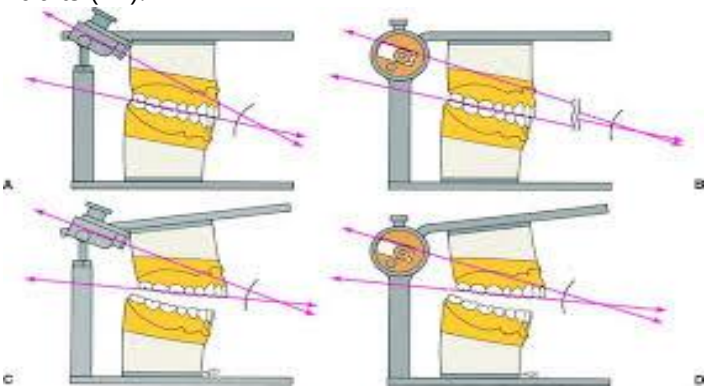

Figure 3. The angle between the condylar track and the maxillary plane is fixed in the arcon articulator (A and C) and varies on the non-arcon semi-adjustable articulator (B and D) on opening and closing (17).

Virtual Articulators:

Virtual articulator is a computer software tool that can reproduce the occlusal relationship between the jaws and simulate the lower jaw's biomechanical movement (18). Virtual articulators were introduced as potential substitutes for conventional mechanical ones to overcome their shortcomings (18). Mechanical articulators cannot precisely simulate masticatory movements, which depend on muscle patterns, soft tissue resilience, and joint disc functioning. The virtual articulator can significantly reduce the limitations of mechanical articulators due to several advantages. It allows for a comprehensive analysis of both static and dynamic occlusion, inter-maxillary relationships, and joint conditions. Additionally, its three-dimensional (3D) visualization enables the selection of specific planes for detailed observation of regions of interest, such as the lower jaw, upper jaw, temporomandibular joint, and more. When combined with CAD/CAM technology, this tool holds great potential for planning aesthetic restorations and dental implant prosthetic restorations, as it offers enhanced precision and reduces treatment duration (18).

Virtual articulators are classified into two types: mathematically simulated articulators and fully adjustable virtual articulators. Mathematically simulated virtual articulators are capable of reproducing the movements of a mechanical articulator. They are simple, adjustment-free articulators and are used similarly to an average value articulator. The second type, which is the fully adjustable virtual articulator, provides all the features of a fully mechanical adjustable articulator in a virtual form (18).

The process of virtual articulation is as follows: after taking an intraoral scan of the teeth and the bite record, an ultrasonic system is attached to the patient's condyles and mandible to analyze jaw movements (19). The patient is instructed to perform all possible mandibular movements. The data obtained is then processed and stored (19). Digital articulators provide a three-dimensional animation of jaw movements with the ability to visualize dynamic maxilla-mandibular relationships without the restraints of the mechanical articulator or the mounting casts. Furthermore, a quantitative analysis of occlusal forces and directions can be provided. This facilitates the provision of tailored treatment for individual patients without overlooking occlusal interferences (20). The data obtained can be saved in the patient's records and transferred to the laboratory for fabrication of prostheses that function in harmony with the opposing teeth. Alternatively, the data can be sent directly to the milling machine if available in the dental office. Thus, the restoration can be prepared and delivered at the same appointment, eliminating extra laboratory steps (21, 22, 23).

Selection of Dental Articulator:

Proper selection of the dental articulator is crucial for the success of the restorative treatment, with key factors including the amount and timing of the Bennett shift, type of anterior guidance, and angle of the condylar path. Difficult cases to treat include those with early Bennett shift or movement, no anterior guidance or flat anterior guidance, and flat early condylar movement. Other factors that impact dental articulator selection include the forms of posterior teeth, concept of occlusion, extension of restorations, and type of support in removable partial denture. There is no one-size-fits-all articulator suitable for all cases (24). For difficult, complicated cases with TMJ disorder or severe malocclusions, a fully adjustable articulator is needed. For 99% of cases, articulators that accept face-bow are sufficient, but selecting an accurate, easy-to-use face-bow system is equally important (1), as proper face-bow transfer accuracy highly impacts the mounting of casts (17).

Conclusion:

A dental articulator is an important instrument in dental practice, particularly in removable and fixed prosthodontics, for constructing complete dentures and long-span bridges. There are many types and designs available, but none can duplicate the patient's physiological and functional mandibular movements exactly. The more adjustments that can be made by the articulator to match the patient's movements, the better the treatment outcome will be, and the fewer intraoral adjustments will be needed. Several factors affect the choice of an articulator, but semi-adjustable articulators are generally suitable for most treatment purposes. On the other hand, virtual articulators offer excellent alternatives to traditional mechanical articulators, addressing their limitations by simulating occlusal relationships and jaw movements. With options ranging from mathematically simulated articulators to fully adjustable virtual articulators, these technological virtual tools provide valuable support for comprehensive analysis and precise planning in the field of dentistry. It is important to note that no matter how simple or complicated an articulator is, if it is not used properly or lacks the necessary features for the intended purpose, the results will be unsatisfactory.

References

1. Cabot LB. Using articulators to enhance clinical practice. British dental journal. 1998; 184(6):272-276.
2. Glossary of prosthodontic terms. The Journal of prosthetic dentistry. 2005; 94(1):10-92.
   Posselt, U: Physiology of occlusion and Rehabilitation, Oxford and Edinburgh, Blackwell Scientific Publications, 1968, pp. 107-114.
3. Posselt, U: Physiology of occlusion and Rehabilitation, Oxford and Edinburgh, Blackwell Scientific Publications, 1968, pp. 107-114. 4.
4. Howat AP, Capp NJ, Barrett NVJ. A color atlas of occlusion & malocclusion. Published online 1991:240.
5. Veeraiyan DN, Ramalingam K, Bhat V. Textbook of Prosthodontics. 2nd edition. New Delhi: Jaypee Brothers. 2017:196-209.
6. Shanahan. T. E. J., and Leff, A.: Mandibular and articulator movements. J. Prosth. Dent., 9:941, 1959.
7. Shanahan. T. E. J., and Leff, A.: Mandibular and articulator movements. Part II. Illusion of mandibular tracings. J. Prosth. Dent., 12:82, 1962.
8. Shanahan. T. E. J., and Leff, A.: Mandibular and articulator movements. Part III. The mandibular axis dilemma. J. Prosth. Dent., 12:292, 1962.
9. Shanahan. T. E. J., and Leff, A.: Mandibular and articulator movements. Part V. Vertical and sagittal axes myths. J. Prosth. Dent., 13:872, 1963
10. Shanahan. T. E. J., and Leff, A.: Mandibular and articulator movements. Part IV. Mandibular three dimensional movements. J. Prosth. Dent., 12:684, 1962
11. McCullock AJ. Making occlusion work: I. Terminology, occlusal assessment and recording. Dental update. 2003; 30(3):150-157.
12. Shillingburg HT, Sather DA, Wilson EL, Cain JR, Mitchell DL, Blanco LJ, Kesslerr JC. Fundamentals of Fixed Prosthodontics.

4th edition. Hanover Park, IL: Quintessence Pub. 2012:27-34.
13. Okeson JP. Management of Temporomandibular Disorders and Occlusion. 8th edition. St. Louis, Mo.: Mosby. 2019:441-454.
14. Myers GE. Status report on articulators. Council on Dental Materials and Devices. Journal of the American Dental Association. 1974; 89(5):1158-1161.
15. Milosevic A. Occlusion: 3. Articulators and related instruments. Dental update. 2003; 30(9):511-515.
16. Azzer SS. Kemper E. The patient-specific anatomical articulator. The journal of prosthetic dentistry. Published online 2021.
17. Rosenstiel SF, Land MF, Fujimoto J. Contemporary Fixed Prosthodontics. 5th edition. St. Louis, Mo.: Mosby Elsevier. 2016:41-68.
18. Lepidi L, Galli M, Mastrangelo F, et al. Virtual Articulators and Virtual Mounting Procedures: Where Do We Stand? Journal of Prosthodontics. 2021; 30(1):24-35.
19. Maestre-Ferrín L, Romero-Millán J, Peñarrocha-Oltra D, Peñarrocha-Diago M. Virtual articulator for the analysis of dental occlusion: an update. Medicina oral, patologia oraly cirugia bucal. 2012; 17(1):160-163.
20. Hayashi T, Saitoh A, Ishioka K, Miyakawa M. A computerized system for analyzing occlusal relations during mandibular movements. The International Journal of Prosthodontics.1994; 7(2):108-114.
21. Kordaß B, Gärtner C. The virtual articulator—concept and development of VR-tools to analyse the dysfunction of dental occlusion. International Congress Series 2001; 1230(C):689-694.
22. Hsu M, Driscoll C, Romberg E, Masri R. Accuracy of Dynamic Virtual Articulation: Trueness and Precision. Journal of prosthodontics: official journal of the American College of Prosthodontists. 2019; 28(4):436-443.
23. Yau HT, Liao SW, Chang CH. Modeling of digital dental articulator and its accuracy verification using optical measurement. Computer methods and programs in biomedicine. 2020; 196.
24. Hobo S, Shillingburg HT, Whitsett LD. Articulator selection for restorative dentistry. The Journal of prosthetic dentistry 1976; 36(1):35-43.