

## Dental Articulators

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### Abstract

Advancements in dental materials and techniques enabled dentists to provide complex prosthetic treatments to patients. Dental articulator is an indispensable tool to enhance the quality of the delivered work and increase patient satisfaction<sup>1</sup>.

It is the purpose of this paper to present an overview of dental articulators, their different types, indications, advantages and limitations. A practical guide for selecting the right articulator for individual clinical situations is provided.

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### Introduction

The glossary of prosthodontic terms defines the dental articulator as a mechanical instrument that represents the temporomandibular joints and jaws, to which maxillary and mandibular casts may be attached to simulate some or all mandibular movements<sup>2</sup>.

The idea of copying the relationship between upper and lower teeth is not new; it goes back to Phillip Pfaff (1756) who introduced the concept of taking impressions of teeth, pouring them in plaster and relating teeth using wax bite registration. Gariot (1805) was the first to use the term "articulator" referring to plaster casts with posterior extensions indexed in a plaster board (Fig 1)<sup>3</sup>.

It is the purpose of this paper to present an overview of dental articulators, their different types, indications, advantages and limitations. A practical guide for selecting the right articulator for individual clinical situations is provided.

### Requirements of a dental articulator<sup>4</sup>:

1. Maintain the inter-maxillary relationship accurately
  2. It should have an incisal pin and table that allow adjustment of the vertical relationship
  3. Allow free rotational movement
  4. It should have adjustable anterior and posterior guides and accept facebow record
  5. It should be made of strong, corrosion, light-weight and wear-resistant material
  6. The upper and lower members should be sufficiently separated to allow evaluation of occlusion posteriorly
- It should allow protrusive and laterotrusive movements

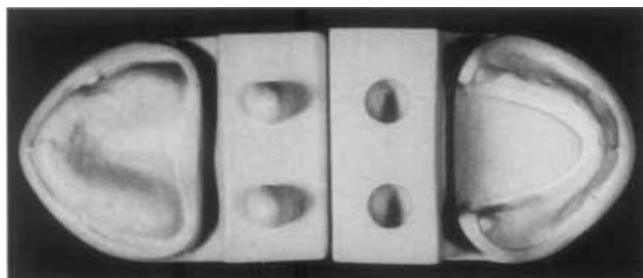


Figure1. Gariot's articulator.<sup>3</sup>

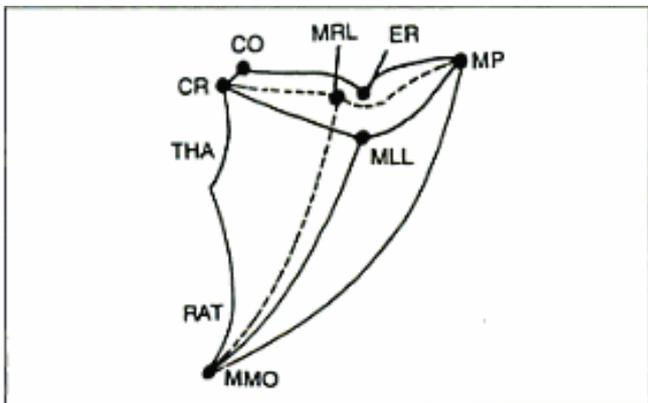
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### The mandibular movements

The articulatory system is composed of two temporomandibular joints (TMJ) connected at the symphysis, occlusal surfaces of teeth, masticatory muscles and periodontal proprioceptive nerve fibres<sup>5</sup>.

Functional mandibular movements are highly repeatable as they are limited by the mandibular ligaments. Posselt (1957) represented the mandibular border movements in a three-dimensional envelope (Fig 2).



**Figure 2.** Posselt's envelope of motion (CR: centric relation, CO: centric occlusion, MRL: maximum right lateral position, MLL: maximum left lateral position, MP: maximum protrusion, ER: edge-edge relationship, MMO: maximum mouth opening, THA: true hinge axis, RAT: rotation after translation).

The basic mandibular movements are rotation, translation and lateral movements. The mandible can open and close up to 20 mm while the condyles are rotating in their terminal hinge position, further opening the condyles leave the glenoid fossa and translate down the articular eminence.

On lateral movement the working side condyle rotates with minimal medial shift while the nonworking side condyle rotates, shifts laterally (immediate side-shift) and then descends gradually forward along the medial wall of the glenoid fossa (progressive side-shift)<sup>6</sup>.

#### Limitations of a dental articulator<sup>6</sup>:

1. Articulators are machined devices that are subject to manufacturing inaccuracy, metal fatigue and wear
2. The movements they reproduce are not the functional movements (they reproduce empty mouth border movements)
3. None of the available articulators can reproduce the exact mandibular movements

#### Uses of the dental articulator

1. Occlusal analysis:
  - Depending on the bite records taken and the type of articulator used, mounted casts are useful to analyse occlusion at centric relation

(CR), centric relation-inter-cuspal position (ICP) slide as well as protrusive and laterotrusive contacts<sup>7</sup>.

- Mounted casts are adjuncts to clinical examination, as it enhances visualization and evaluation of occlusion in the molar region without the hindrance of the tongue and cheeks<sup>8</sup>
  - If the casts are accurately mounted on a semi-adjustable articulator, mandibular movements can be simulated as purely guided by the occlusal anatomy without the influence of the protective neuromuscular reflexes that camouflage occlusal interferences<sup>8</sup>
2. Treatment planning for :
    - Restorative procedures: diagnostic wax-up to envisage the planned treatment outcome prior to executing it<sup>7</sup>.
    - Orthodontic treatment<sup>9</sup>
    - Orthognathic surgery<sup>10</sup>
  3. Fabrication of occlusal splints, custom trays<sup>5</sup> and prostheses with the desired occlusion and aesthetics<sup>11</sup>.

#### Classification of dental articulators

Different types of articulators have been developed over the years:

##### 1. Hand-held casts

After pouring the impressions in stone, casts are trimmed to occlude in the ICP<sup>10</sup>.

Advantage:

- No need for expensive equipment to relate the casts<sup>7</sup>

Disadvantages:

- Once the bite record removed, the centric relation cannot be reproduced.
- The ICP can be reproduced only if enough positive occlusal contacts are present
- Restorations fabricated on hand-held casts will be high in the mouth
- Eccentric movements cannot be reproduced
- Not suitable for restoring multiple units or distal extension edentulous spaces

Uses:

- Assuming that the casts are accurately related, evaluation of the ICP is possible<sup>7</sup>
- If properly trimmed, casts can be used for orthodontic treatment planning<sup>9</sup>

##### 2. Cast relaters

a. Simple hinge articulator

Consists of upper and lower members that are attached together by a hinge (Fig 3)<sup>12</sup>.



Figure 3. Simple hinge articulator.<sup>12</sup>

- It does not accept facebow transfer. So, the aesthetic perspective is limited<sup>7</sup>
- It allows opening and closure around a horizontal axis whose distance from the attached casts is less than the distance between patient's teeth and TMJs (Fig 4)<sup>14</sup>
- Prostheses fabricated on these articulators are usually high when tried in the mouth and require occlusal adjustments on excursions prior to cementation. This effect is exaggerated when the anterior guidance is not steep enough to disocclude the posterior teeth rapidly<sup>12</sup>. Therefore the dentist is expected to spend considerable time on selective grinding.

Uses:

Hinge articulators have limited diagnostic value and may be used for the construction of a single unit that conforms to the existing ICP. A functionally-generated bite record could be used to reduce interferences on lateral and protrusive movements<sup>7</sup>

b. Verticulators

Consists of lower and upper members. The latter glides vertically on metallic rods which brings the mounted casts into ICP (Fig 5)<sup>5</sup>.

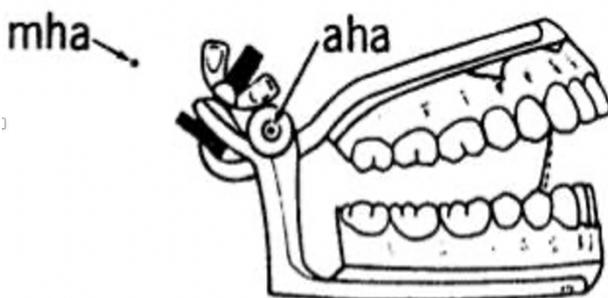


Figure 4. Difference between articulator hinge axis (aha) and mandibular hinge axis (mha).<sup>11</sup>

Advantage:

- Hinge articulators are inexpensive and do not demand much time and skill to use<sup>8</sup>.

Disadvantages:

The disadvantages of hinge articulator outweigh its advantages:

- Only the static ICP could be visualised using this articulator<sup>13</sup>
- It does not permit adjustments of elements of protrusive and laterotrusive movements and no facility to change the vertical dimension accurately<sup>7</sup>



Figure 5. Verticator.<sup>5</sup>

Advantage:

- Very easy to use and allow more accurate positioning of the casts compared with the hinge articulator<sup>5</sup>.

Disadvantage:

- It is incapable of simulating any occlusal

relationship apart from the ICP. No excursive movements are allowed<sup>5</sup>.

Uses:

- Occasionally, it can be used to fabricate single intra-coronal restoration<sup>5</sup>

### 3. Average value (fixed condylar path) articulators

These articulators, as their name indicates, have fixed condylar and incisal angles (30° and 15° respectively) and a fixed inter-condylar distance (110 mm)<sup>14</sup>, which makes them superior to simple hinge articulators only if these fixed values coincide with patient's values (Fig 6)<sup>13</sup>.



**Figure 6.** Average value articulator (Ivoclar Vivadent Corporate, 2012).

These articulators are based on Bonwill's equilateral triangle theory (1850) "the two condyles and a point located between the lower central incisors form an equilateral triangle with sides of 4 inches".

Advantages<sup>8</sup>:

- Does not require complicated equipment and user friendly
- Affordable cost

Disadvantage:

- Limited protrusive and laterotrusive movements are possible on these articulators. These movements bear little resemblance to actual patient's movements as facebow cannot be used with average value articulators<sup>12</sup>
- Restorations fabricated on these articulators

will need intra-oral adjustments on excursions<sup>14</sup>

Uses<sup>13</sup>:

- Fabrication of single-unit anterior or posterior restorations.
- Fabrication of short span posterior prostheses for patients having prominent canine guidance.

Fabrication of anterior bridges for patients with minimal overjet and overbite ( $\leq 1$ mm).

### 4. Semi-adjustable articulators

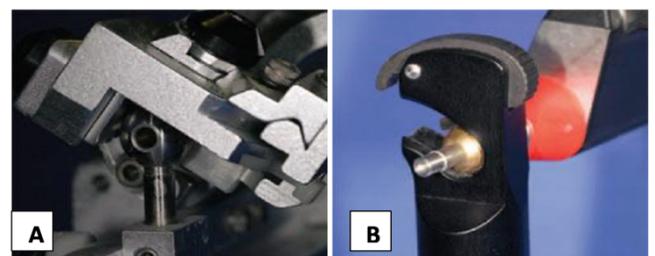
Semi-adjustable articulators are the most commonly used for advanced restorative treatments and are satisfactory for most prosthetic work<sup>15</sup>.

They are manufactured to match the anatomical size of the structures they simulate and can accept facebow record which permits transferring the relation between a patient's hinge access and maxillary teeth to the articulator<sup>5</sup>.

Broadly speaking, semi-adjustable articulators come in two main designs: Arcon and nonarcon (Table 1).

Arcon (Articulating-CONDyle)	Nonarcon
The condylar path is located in the upper member, thus they bear more resemblance to the temporomandibular joint anatomy, making it easy to understand mandibular movements <sup>12</sup>	The mechanical fossa is located in the lower member <sup>12</sup>
Denar@MK II, Sam and Whip Mix are examples <sup>16</sup>	Dentatus and Hanau are examples <sup>16</sup>
The upper member of Arcon articulators is detachable which facilitates waxing restoration as well as occlusal analysis <sup>5</sup>	The upper member of this type of articulators is locked to the mechanical condylar path. This is helpful in setting complete denture teeth but not in fixed restorative work <sup>5</sup>

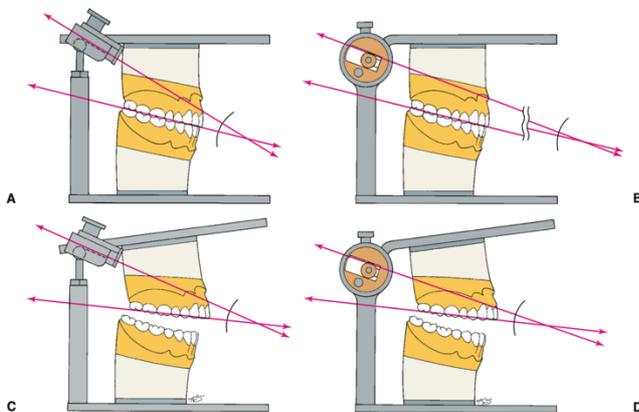
**Table 1.** Comparison between the Arcon and the Nonarcon articulator.



**Figure 7.** The mechanical condyle of A: Arcon, B: Nonarcon articulators (Lee Culp, 2005).

It was shown that there is no difference in the accuracy of restorations fabricated on either type 11. However, some believe that the arcon type is superior for the following reasons:

- In the nonarcon type, the condyles are restricted in the fossae tracks which limits the correct shifting between the retruded contact position and the intercuspal position. However in the arcon type, this movement is possible (Fig 7).<sup>7</sup>
- 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 nonarcon type (Fig 8). 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 fabrication of restorations with reduced cuspal height.<sup>17</sup>



**Figure 8.** The angle between the condylar track and the maxillary plane is fixed in the arcon articulator (A and C) and varies on the nonarcon articulator (B and D) on opening and closing.<sup>17</sup>

### Adjustments

Five main adjustments are possible on these articulators<sup>8,13</sup>

#### 1. The condylar angle (set using protrusive and lateral inter-occlusal records)

The **steepness** of the track along which the condyle descends on protrusion and laterotrusion has a great influence on fossa depth and cusp height of the fabricated restorations<sup>8</sup>.

The steeper the condylar angle, the steeper the cusp inclines will be. Setting the articulator condylar incline at a steeper angle than that of the patient results in a positive occlusal error on the fabricated restoration (high cusps) during excursive jaw movements. While setting the condylar incline of the articulator at a shallower angle than that of the patient results in a negative occlusal error (wide fossae or flat cusp inclines) on eccentric movements<sup>11</sup>.

## 2. The Bennett angle

It is the angle between the advancing condyle path and the sagittal plane. Adjustment of this angle affects the width of the central fossae of fabricated posterior restorations; the larger the angle, the wider the fossae should be to allow freedom of jaw movement without nonworking side interferences<sup>8</sup>.

Bennett angle can be measured by the following methods<sup>1</sup>:

1. Lateral occlusal records
2. Calculated from Hanau's formula:  $H/8+12$  (H is the protrusive angle). The validity of this formula is questionable
3. Alternatively, it can be set arbitrarily at 15° (most commonly used method)

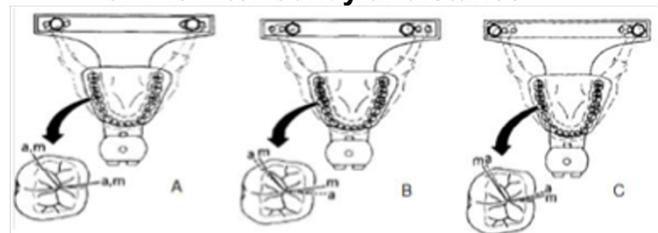
The immediate side-shift is the sideways shift of the mandible at the beginning of lateral excursions and the progressive side-shift is the gradual mediotrusive movement of the mandible occurring at a rate proportional to the forward movement of the advancing condyle. Bennett angle represents both components as a straight line with a start point at the centric position and an endpoint at the maximum lateral excursion<sup>8</sup>. However, some semi-adjustable articulators allow adjustment of these elements separately. This is especially valuable in treating patients with considerable side-shift<sup>16</sup>.

This variable is not adjustable. It is fixed at 110mm in some designs (Denar®MK II) and can be adjusted to small, medium or large patterns in others (Whipmix).

Adjustments of the condylar width on the articulator to match that of the patient allow more accurate duplication of the laterotrusive movements (Fig 9)<sup>11</sup>.

Additionally, measuring and duplicating the inter-condylar width can be a useful guide for setting the canines and the molars in complete dentures<sup>18</sup>.

## 3. The inter-condylar distance



**Figure 9.** The effect of the inter-condylar width on the occlusal anatomy of fabricated restorations (Hobo et al., 1976)

**A:** The paths of lateral movements traced in the

mouth (m) are exactly reproduced on the articulator (a) when the intercondylar width of the articulator equal to that of the mandible.

**B:** The lateral movement paths of the articulator are mesial to those of the patient when the intercondylar width of the articulator is less than that of the mandible.

**C:** The lateral movement paths of the articulator are distal to those of the patient when the intercondylar width of the articulator is greater than that of the mandible.

#### 4. Incisal angle

The incisal guidance is determined by the steepness of the palatal surface of the upper anterior teeth. It has two components: the horizontal and the vertical overlap between the upper and the lower anterior teeth. Adjustment of the incisal guidance table influences the protrusive and laterotrusive movements of the mandible and can be done by raising the lateral wings of the incisal table. Alternatively, a customized incisal guide table can be fabricated using mouldable auto polymerizing resin that is carved according to the patient's jaw movements (Fig 10)<sup>16</sup>.

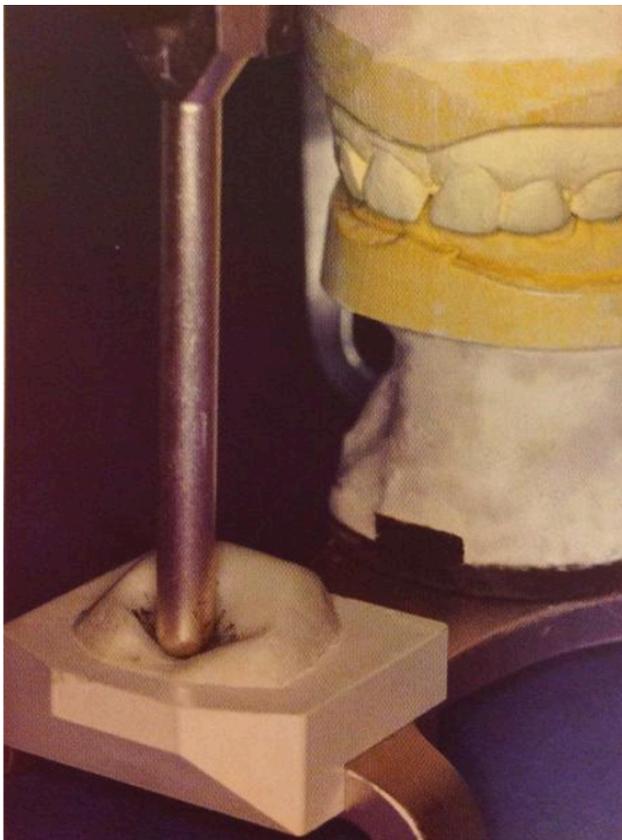


Figure 10. Customized incisal guide table.<sup>16</sup>

Setting the mechanical incisal table at a steeper angle than that of the patient increases the vertical overlap between teeth and thus the fabricated posterior restorations may have taller cusps and positive error will exist resulting in occlusal interference during protrusion and laterotrosion<sup>5</sup>.

#### 5. Semi-adjustable articulator accepts facebow record

##### Advantage of using semi-adjustable articulator

Restorations can be made to function in harmony with the existing teeth in both centric and eccentric movements without the need for extensive intraoral occlusal adjustments<sup>8</sup>.

##### The disadvantages of using semi-adjustable articulator

- Time consuming during facebow transfer and eccentric records registration. However, it saves the time needed for later intraoral adjustments<sup>8</sup>
- Expensive<sup>8</sup>
- The condylar track of these articulators is straight so they can reproduce the curvilinear eccentric condylar movements along the curved walls of the glenoid fossa in a straight path simulation. This entails some intraoral refinement of eccentric contacts on the final restoration (Fig 11)<sup>16</sup>.

##### Uses<sup>10</sup>:

- Treatment planning for orthognathic procedures
- Complex restorative work with multiple missing teeth or full dentures Alteration of the vertical dimension Occlusal analysis.<sup>14</sup>

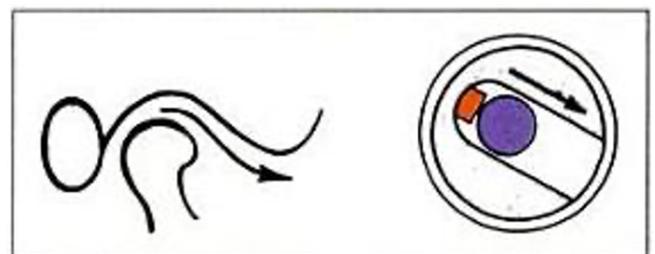


Figure 11. Curved anatomical condylar track versus straight articulator condylar track.<sup>6</sup>

#### 5. Fully-adjustable articulator

Fully-adjustable articulators are very sophisticated. It allows a wide range of adjustments including condylar angle, immediate and progressive side-shifts, the exact intercondylar distance (Fig 13) and working

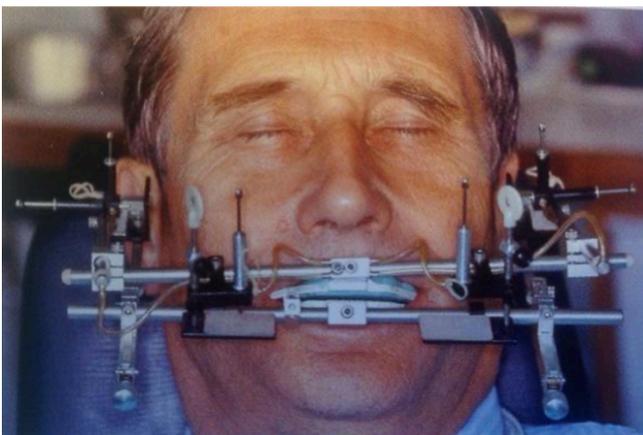
condylar shift, to more accurately simulate the patient's actual jaw movements<sup>8</sup>. Denar 5A (Fig 14) and Stuart are examples.

Unlike the semi-adjustable articulator which allows adjustments of the condylar angle in a straight pathway, the fully-adjustable one allows duplication of the angle and curvature of the patient's condylar incline<sup>8</sup>

A fully-adjustable articulator is capable of duplicating the slight lateral movement of the rotating condyle during lateral movement. This shift may have superior, inferior, anterior or posterior component. Adjustment of this variable allows more accurate determination of fossa width and cup height as well as the direction of grooves and ridges on the fabricated posterior restorations to avoid occlusal interferences<sup>8</sup>.

**Requirements for using a fully-adjustable articulator<sup>5</sup>:**

1. Kinematic facebow
2. Centric occlusal record
3. Pantographic tracing (Fig. 12)



**Figure 12.** Pantographic tracing.<sup>16</sup>

A pantograph is made up of a maxillary clutch that supports six styli and a mandibular clutch that supports six tracing tables. Clutches are attached to upper and lower teeth so that teeth are only contacting a central bearing point and movement are determined by the anatomy of the articulating condyle, disc and fossa. The patient is asked to perform all border movements while the tracing styluses scribe lines across the tables. The pantograph acts as a facebow to mount the upper cast in the right orientation and it stores all jaw movement elements needed to program the articulator<sup>8</sup>. Electronic pantographs provide numeric values of settings, facilitating articulator programming<sup>16</sup>.

**Uses<sup>7</sup>:**

- Full mouth rehabilitation
- Severe tooth surface loss 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 (if has not been done before on provisionals)
- Implant-tooth supported fixed prostheses

Combination of the above with parafunctional habits.



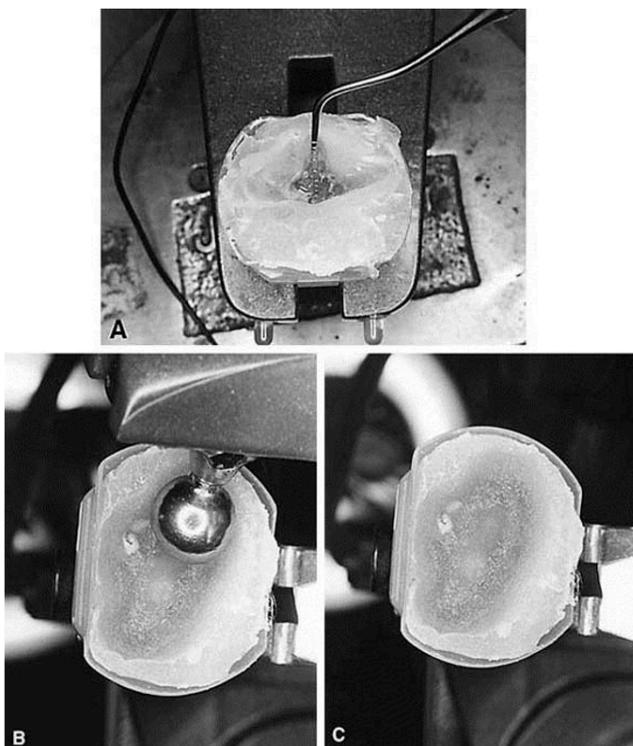
**Figure 13.** Accurate adjustment of the intercondylar width (canyon state dental supply, 2013).



**Figure 14.** Denar D5A fully-adjustable articulator. (canyon state dental supply, 2013)

### 7. Stereographic or fossa-moulded articulators

These are sometimes referred to as scribing articulators. The posterior and anterior guidance mechanisms of the articulator are customized to exactly reproduce the patient's jaw movement. The TMJ Articulator is an example. Stereographic articulators accept dynamic, three-dimensional, functionally engraved records to set the condylar and anterior guidance elements (Fig 15). These records are registered using intraoral studs that mould auto polymerizing resin placed in receptacles. On curing, the condylar inclines and the Bennett shift will be carved on these templates which are then used to program the articulator <sup>14</sup>.



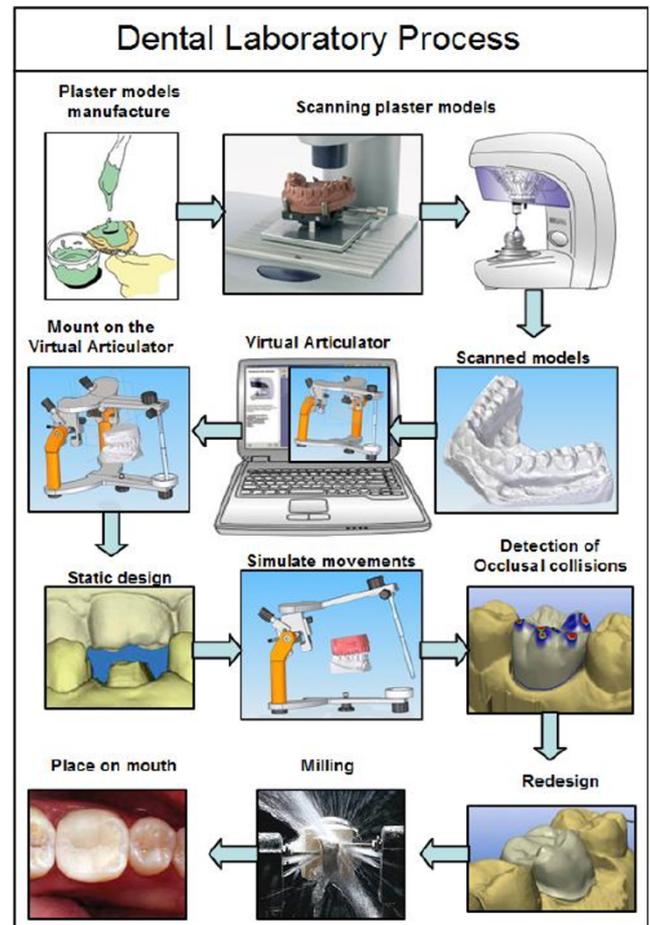
**Figure 15.** Carved resin in the incisal (A) and condylar (B,C) receptacles<sup>19</sup>

None of the available mechanical articulators reproduced the actual mandibular movements, simply because the casts are mounted and the articulator is adjusted according to static interocclusal records that capture maxillary-mandibular teeth at the endpoint of eccentric movements<sup>20</sup>. However, these movements are dynamic and cannot be evaluated by looking at one captured moment<sup>11</sup>.

### 8. Virtual articulators

Computer technology has been implemented into the different fields of dentistry including occlusion. Virtual articulators were introduced as potential substitutes to conventional mechanical ones to overcome the shortcomings of the latter <sup>21</sup>.

After taking digital images of the teeth and the bite record, an ultrasonic system is attached to the patient's condyles and mandible to analyze jaw movements. The patient is instructed to perform all possible mandibular movements. Data obtained is then processed and stored <sup>22</sup>.



**Figure 16.** steps for fabricating a restoration using a virtual articulator.<sup>28</sup>

Digital articulators provide a three-dimensional animation of jaw movements with the ability to visualize dynamic maxillary-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<sup>23</sup>. Data obtained can be saved in

patient's records and transferred to the laboratory for fabrication of prostheses that function in harmony with the opposing teeth. Alternatively, data can be sent directly to the milling machine in the practice (Fig 16). So, the restoration can be prepared and fitted at the same appointment eliminating extra laboratory steps<sup>24</sup>.

Virtual articulators are highly precise and reliable<sup>25,26</sup>. One of several other studies reported almost the same number and location of dynamic occlusal contacts recorded using a virtual articulator as those obtained using a mechanical one<sup>24</sup>.

### Articulator selection:

Proper selection of the dental articulator plays a key role in the success of dental restorations. There is no single articulator that is suitable for all cases<sup>11</sup>. Several factor affect the selection of the articulator include the extent of the restorative work, certain characteristics of patient's occlusion, recognizing the limitations and possible errors in each type and the skills of both the clinician and the technician<sup>8</sup>. Complex cases with temporomandibular joint disease or severe malocclusions need a highly adjustable articulator. Articulators that accept facebow are sufficient for 99% of the cases. It is equally important to select an accurate, easy-to-use facebow system<sup>1</sup>, as the accuracy of mounting the casts is highly dependent on the proper facebow transfer<sup>27</sup>. Table 2 summarizes tips for choosing the right articulator and the needed records:

Clinical use	Recommended articulator	Required records
<b>Diagnosis</b>		
<ul style="list-style-type: none"> <li>•Occlusal evaluation</li> <li>•Trial occlusal adjustment</li> <li>•Diagnostic wax-up</li> </ul>	Average value or semi-adjustable	Facebow, CR or ICP records as appropriate
<b>Restorations</b>		
Single posterior unit	Hand-held casts, simple hinge	ICP record
Multiple posterior units (with canine guidance)	Average value	Facebow and ICP records
Multiple posterior units (with group function)	Semi-adjustable	Facebow, ICP record, Optional lateral check record (if group function being waxed for whole sextant)
Single upper anterior unit	Hand-held casts (if guidance can be developed from adjacent teeth) or average value	ICP record, pre-treatment casts if guidance cannot be developed from adjacent teeth
Multiple upper anterior units	Average value or semi-adjustable	Facebow, ICP record, pre-treatment casts (from which to copy guidance), impression of provisional restorations
Full arch	Average value or semi-adjustable (if canine guidance achievable) Fully-adjustable if shallow guidance from posterior teeth and bruxism	As for multiple anterior restorations CR record at the correct occlusal vertical dimension along with a mechanical or electronic pantographic record

**Table 2.** Tips for choosing the right articulator and the needed records.

### Conclusion

A dental articulator is a masterpiece in every dental practice. Many designs are available. However, none can duplicate the physiologic, functional mandibular movements exactly. The more adjustments allowed by the articulator to match the patient's movements, the better the treatment outcome will be and fewer adjustments will be needed intraorally. Several factors affect the choice of an articulator, but it is safe to say that semi-adjustable articulators satisfy the requirements of most treatment purposes. It must be emphasized that the articulator is only as good as the hands operating it and that the clinician's understanding of occlusion can compensate for the inherent limitations of these instruments.

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