Functional Occlusion: II. The Role of Articulators in Orthodontics

J. R. CLARK, B.D.S., M.SC., F.D.S.(ORTH.), M.ORTH.R.C.S. (ENG.)

I. HUTCHINSON, B.D.S., M.SC., F.D.S., M.ORTH.R.C.S. (EDIN.)

J. R. SANDY, PH.D., M.SC., B.D.S., F.D.S.R.C.S. (EDIN.), F.D.S. M.ORTH.R.C.S. (ENG.), F.F.D.R.C.S.I.

Department of Child Dental Health, Bristol Dental Hospital, Lower Maudlin Street, Bristol BS1 2LY, UK

Abstract. *Opinion is divided on whether there is a place for the use of semi-adjustable dental articulators in orthodontics. In this review we explore the validity and reproducibility of the techniques involved in mounting study models on a semi-adjustable dental articulator. We also look at the role of articulated study models in orthodontic diagnosis and treatment planning, in the finishing stages of orthodontics and in planning for orthognathic surgery. We report that each of the many stages involved in mounting study models on a semi-adjustable articulator is a potential source of error and that only if the technique is carried out with a high degree of accuracy is it worth the additional chairside time.*

Index words: Articulator, Facebow, Functional occlusion.

Introduction

In the United Kingdom, the majority of orthodontists assess a patient's occlusion clinically and with the aid of study models trimmed to occlude in the inter-cuspal position. A minority of specialists in the UK and a rather larger proportion of American orthodontists advocate the use of articulated study models in all patients undergoing orthodontic treatment (Williamson *et al*., 1978; Roth, 1981; Cordray, 1996). These authors maintain that occlusion cannot be accurately assessed without articulation of the models using an inter-occlusal record taken on the retruded path of mandibular closure. The routine use of articulated study models involves considerable chairside and laboratory time. The purpose of this article is to examine the evidence for the use of articulators during orthodontic diagnosis and treatment, and to attempt to provide a rational basis for their use.

Types of articulator

A dental articulator is an instrument that represents the temporomandibular joint and jaws, to which maxillary and mandibular study models are attached. Originally described as long ago as 1756 (Mitchell and Wilkie, 1978), their use was, for many years, exclusive to restorative dentists and prosthodontists. An articulator provides a means of reproducing occlusal relationships outside the mouth, and is an indispensable aid for the fabrication of crowns and bridges.

A number of different types of articulator exist and these vary in their complexity. The simplest articulators incorporate average patient values to represent the inclination of the glenoid fossa and the condyle-fossa relationship, and so cannot accurately reproduce an individual's mandibular excursive movements. Semi-adjustable articulators can be modified by adjustment of the 'condyle-fossa' portion of the instrument using wax records of the patient in lateral and protrusive excursion. Fully adjustable articulators have a large range of adjustability in three dimensions, and are accordingly the most complex and expensive.

Validity of the technique

Any investigation must measure what it purports to measure if it is to contribute to a patient's management, i.e. it must be valid. An articulator must therefore be able to simulate an individual's jaw movement so that casts mounted on it can be observed to articulate in the same way as teeth in the mouth. As mandibular movements are influenced by many soft tissue factors, such as the ligaments of the temporomandibular joints and masticatory muscles, it is impossible for jaw movements to be precisely reproduced (Pameijer, 1985). Semi-adjustable articulators have a condylar path that is in a straight line, unlike the 'true' condylar path, which follows a curved path. Fully adjustable articulators have a number of interchangeable inserts that represent the glenoid fossae, and allow the curved protrusive and lateral movements of the temporomandibular joints to be reproduced. The significance of the condylar path depends upon the degree to which jaw movement is dictated by the condyles. In partially dentate and edentulous patients, guidance of the mandible during function is largely determined by the movement of the condyle in the glenoid fossa. In dentate subjects there tends to be disclusion of the posterior teeth during lateral excursions, i.e. the jaw movement is guided by the anterior teeth and the condylar path has little influence. The use of a semi-adjustable articulator in dentate subjects will provide an adequate representation of the 'true' occlusion for orthodontic diagnosis (Howat *et al*., 1991).

It should also be possible to test the validity of the technique. The only way to test validity in this situation is to compare the occlusal findings on the articulator mounted casts with those in the mouth. Such studies are rare. Celar *et al*. (1999) reported that a semi-adjustable articulator

0301-228X/01/020000+00$02.00

duplicated approximately 73 per cent of intraoral protrusive contacts and 81 per cent of lateral contacts. Tamaki *et al*. (1997) described duplication of 66 per cent of protrusive contacts, and 80 per cent of lateral contacts between a semi-adjustable articulator and the mouth. However, a number of authors (Roth, 1981; Cordray, 1996) have stated that it is impossible to believe the clinical findings as a true representation of the occlusion, because many individuals have occlusal interferences, which result in mandibular displacements on closure and an inability to manipulate the mandible into the retruded axis position. These latter authors claim that only by articulator mounting can the 'true' occlusion be investigated, thereby eliminating any possibility of testing the validity of the technique.

Accuracy and reproducibilty of the technique

If the use of articulator mounted study casts is to be advocated, the clinician must be able to carry the technique out accurately. A number of different stages are involved, each of which has the potential to introduce inaccuracies.

Facebow registration

A facebow registration relates the maxillary occlusal plane to a fixed plane on the skull so that this relationship can be transferred to the articulator. The fixed plane is located using three reference points: two posterior points, through which the condylar hinge axis passes, and a third anterior point, the location of which depends on the articulator being used. The hinge axis is an imaginary line that runs between the condyles of the mandible and which would appear on the face just anterior to the external auditory meatus if projected laterally. The location of this hinge axis can be arbitrarily determined using average data or, more accurately located, using a 'kinematic' hinge axis locator. Some investigators have shown that there is a considerable discrepancy between the arbitrarily and 'kinematically' located hinge axis position (Walker, 1980). If a discrepancy exists between the 'true' hinge axis and the articulator axis, a premature contact will occur on the retruded path of closure on the articulated model, which is not present clinically. This occlusal discrepancy will be small but nevertheless introduces inaccuracies into the technique of articulation and occlusal diagnosis from the articulator-mounted casts.

Mounting the maxillary cast on the articulator

Once the facebow has been attached to the articulator, the maxillary study model is placed in the wax on the bitefork. There may be some flexibility in the facebow and unless the bitefork is supported, further inaccuracies may be introduced at this stage. The amount of plaster required to attach the upper cast to the articulator can cause inaccuracy as the plaster expands on setting. This can be avoided by using a low expansion plaster and two separate mixes of plaster if there is a large space between the mounting plate of the articulator and the maxillary study cast (Peregrina and Feil, 1994).

Retruded axis position record

If the clinician is interested in the range of movement and tooth contact between the retruded contact position and the inter-cuspal position, the inter-occlusal record must be taken with the mandible on the retruded axis. If the two positions coincide, the inter-occlusal record can be taken in the inter-cuspal position. The habitual path of mandibular closure into the inter-cuspal position has been discussed in Part I of this series. In order to accurately record the retruded axis position the neuromuscular feedback, which routinely results in closure into the inter-cuspal position must be broken. A number of different techniques have been described in the literature. Lucia (1964) advocated the use of an acrylic jig placed over the upper central incisors, which the patient bites on for approximately 10 minutes. The same principle has been used by others: Ash and Ramfjord (1996) described the operator using their thumbnail over the incisal edges of the lower incisors; Dawson (1979) used a cotton wool roll between the incisors; and Long (1973) was the first to describe using a leaf gauge. Other authors have advocated the use of repositioning occlusal splints in all patients where a difficulty is encountered in recording the retruded axis position. The splints are worn until a stable, comfortable, repeatable jaw position has been achieved (Cordray, 1996). Whatever the technique used to disorientate the neuromuscular feedback, the method used to guide the mandible onto its retruded axis is bimanual manipulation. A softened wax wafer is lightly applied to the maxillary teeth, and the mandible is guided onto its retruded axis and closed gently until imprints of the lower teeth are made in the wax. Accuracy of the inter-occlusal wax record can be confirmed by clinical examination once the study models have been articulated. However, if the first tooth contact on the retruded path of closure has been difficult to locate clinically, another technique should be used to confirm the accuracy of the mounting. The Denar Mark II articulator can be used in conjunction with an instrument known as the Denar Vericheck (The Denar Mark II System, Technique Manual, Denar Corporation, Anaheim, Ca., USA) to check reproducibility of multiple wax records. The wax records are placed successively between the study models mounted on the Vericheck. Horizontal styli are used to mark paper on an instrument for each record. Superimposition of the marks indicates identical records, in which case, it is likely that they are correctly recording the retruded axis position.

The basic premise for the use of the retruded axis position in the mounting of study models on an articulator is that it is a reproducible position. However, a number of authors have demonstrated that the position recorded is influenced by the manner in which the mandible is guided into the retruded axis position (Ingervall *et al*., 1971; Helkimo *et al*., 1973; Simon and Nicholls, 1980; Williamson *et al*., 1980); the material used as the registering medium (Fattore *et al*., 1984; Assif *et al*., 1988) and the time of day (Shafagh *et al*., 1975; Latta, 1992).

Mounting study models on an articulator in the retruded condylar axis is an operator sensitive procedure requiring skill and practice. Only if the procedure is carried out accurately is it worth the additional chairside and laboratory time involved. Clinicians who decide to undertake this procedure for all their patients must devote considerable

time to the process. Disappointingly little evidence is available on the accuracy, validity, and reproducibility of articulator mounting of study models. Very early work by Kurth (1949), comparing jaw movements with the movements on a semi-adjustable articulator concluded that the articulator was of no value in simulating jaw movements. Janson (1986) compared the reproducibility of occlusal findings between clinical and articulator analyses. Overall, reproducibility of tooth contacts was observed more frequently in the articulator than in the mouth. Dos Santos and Ash (1988) and Hatano *et al*. (1989) compared the mandibular movements generated by different articulators and by pantographic tracings of jaw movements. The differences between the recordings were statistically significant, those demonstrated by the pantograph representing the 'true' jaw movement. None of the articulators used exactly simulated the subjects' jaw movements. Alexander *et al*. (1993) compared findings from articulator mountings and magnetic resonance scans, and concluded that the retruded contact position and inter-cuspal position could be reliably located on articulator mounted models. In the few studies that use articulator mountings to describe tooth contact patterns (Johnston, 1988; Utt *et al*., 1995; Clark and Evans, 1998), one must assume that the study models have been accurately positioned and that the articulator itself mimics the patient's anatomy. The findings will then represent the patient's 'true' functional occlusion.

Articulators in orthodontics

Bearing in mind the limitations described above, articulator-mounted study models must be capable of providing additional information, over and above that which can be derived from a routine intra-oral examination and the use of hand-held study casts, if they are to be of any value in orthodontics.

Articulators in diagnosis and treatment planning

In orthodontic diagnosis the clinician makes an assessment of the malocclusion with the patient occluding in the inter-cuspal position. Studies show that in most untreated populations there is a small (less than 2 mm) slide between the retruded contact position and the inter-cuspal position (Shefter and McFall, 1984; Kirveskari *et al*., 1986; Agerberg and Sandstrom, 1988; Rosner and Goldberg, 1986) and this can therefore be accepted as entirely normal. If the orthodontic diagnosis is carried out with the teeth in the inter-cuspal position and the resulting occlusion following orthodontic treatment has a similar small discrepancy between the retruded contact position and the inter-cuspal position, this too can be considered entirely normal. The value of articulator mounting of such a case, to identify the small slide between the retruded contact position and the inter-cuspal position, would therefore seem to be unnecessary.

However, there is a small proportion of patients who have a large discrepancy between the retruded contact position and the inter-cuspal position, the extreme end of which is known as a 'Sunday bite'. Orthodontic diagnosis carried out with the teeth in the inter-cuspal position will give a very misleading view of the malocclusion and an inappropriate treatment plan. In Class II cases, patients may posture forwards hiding a large overjet and Class II molar relationship; in Class III cases the slide forwards may create the impression of the Class III relationship being more severe than in reality (hence, the term 'pseudo'-Class III). In these cases it is important to establish the inter-occlusal relationship with the teeth in the retruded contact position. Such large discrepancies between the retruded contact position and the inter-cuspal position are usually easy to identify clinically. It may be necessary to deprogramme the neuromuscular feedback in order to manipulate the mandible into its retruded axis using the techniques described above. It can be difficult to hold the study models together in this retruded contact position, as there is often only a single tooth contact, and models articulated using an inter-occlusal wafer as described above can be useful in providing an accurate picture of the antero-posterior relationship of the maxilla to the mandible in diagnosis and treatment planning. Failure to diagnose the discrepancy between the retruded contact position and the inter-cuspal position prior to starting treatment may result in an inappropriate treatment plan, and this will become apparent very early in treatment. Once the orthodontic treatment commences and the occlusion is disrupted, the neuromuscular feedback, which previously caused the closure into the inter-cuspal position, is also disturbed and the patient often adopts a different inter-cuspal position with the mandible in a position closer to the retruded contact position.

Patients with hypodontia and adults with multiple missing teeth may not have a reproducible inter-cuspal position from which to make a diagnosis. In such cases, the only reproducible inter-occlusal relationship that can be recorded is with the mandible on its retruded axis. Such cases therefore require articulator-mounted study models with the inter-occlusal record taken on the retruded axis for accurate diagnosis prior to formulation of a joint orthodontic-restorative treatment plan.

Articulators in 'finishing'

Part I of this series discusses the evidence for a particular occlusal scheme in lateral excursion being preferable. The conclusion reached is that there is no overwhelming evidence for either canine guidance or group function being superior. Indeed, epidemiological studies show that most natural populations have occlusal contacts on both the working and non-working sides during lateral excursions—an undesirable situation according to most proponents of functional occlusion. Whether or not these non-working side contacts are harmful to the dentition in the long term—by triggering bruxism, temporomandibular disorders, or instability of tooth position—is still a matter for conjecture. Until such time as longitudinal, prospective trials are reported on the effects of occlusal interferences on the dentition and masticatory system, it would seem prudent to eliminate these wherever possible provided this does not unduly lengthen orthodontic treatment. These interferences will be detectable clinically, by thorough intra-oral examination.

Articulators in orthognathic planning

Articulation of study models is an essential part of the pre-surgical preparation in patients undergoing orthognathic surgery. The articulator is used to support the study models on which the surgical moves are performed (model surgery) prior to the construction of inter-occlusal occlusal wafers. The crucial question for model surgery is whether it is necessary to use a facebow record to transfer the condyle-tooth relationship to the articulator. The answer is dependent on which type of surgery is being performed. When the surgery will involve separation of the tooth bearing part of the mandible from the condyle, as in mandibular ramus ostetomies, there is no benefit in maintaining the condyle-tooth relationship during model surgery and an arbitrary articulator-mounting is adequate. By contrast, in all cases involving maxillary surgery autorotation of the mandible will be necessary, either to re-establish the occlusion in single jaw procedures, or to establish the intermediate inter-occlusal relationship in bimaxillary procedures. In these cases it is therefore essential that the condyle-tooth relationship is recorded as precisely as possible so that the auto-rotation simulated on the articulated models resembles the mandibular auto-rotation encountered at the time of surgery. If an inter-occlusal acrylic wafer is made on articulated models where the auto-rotation does not simulate the patient's, the potential ramifications are:

1. Inaccurate diagnosis regarding the need for mandibular surgery, i.e. the model surgery may indicate that autorotation of the mandible will give an acceptable incisor relationship, but at surgery mandibular auto-rotation results in an increased or decreased overjet, and a mandibular osteotomy is indicated.
2. Tendency to alter the condyle-fossa relationship at surgery, i.e. to distract the condyle from the fossa, which will result in post-surgical relapse.

Summary

There are few indications for the use of articulator-mounted casts in orthodontics.

Their use is advocated in the following circumstances:

1. Where a significant discrepancy (>2 mm) exists between the retruded contact position and the inter-cuspal position. Diagnosis will be assisted by knowledge of the magnitude of the discrepancy, which can be measured on the articulator.
2. Orthodontic cases with multiple missing teeth, in which a stable inter-cuspal relationship cannot be recorded.
3. Cases undergoing maxillary and bimaxillary orthognathic procedures.
4. Although the evidence for occlusal parameters in the aetiology of TMD is equivocal, the articulator-mounting of study models pre-orthodontic treatment and pre-debond in individuals with TMD is recommended. This will enable the clinician to ensure that occlusal interferences are eliminated prior to debond and a record retained of the funcional occlusal relationships for medico-legal purposes.

References

Agerberg, G. and Sandstrom, R. (1988)
Frequency of occlusal interferences: a clinical study in teenagers and young adults,
Journal of Prosthetic Dentistry, **59,** 212–217.

Alexander, S. R, Moore, R. N. and DuBois, L. M. (1993)
Mandibular condyle position: comparison of articulator mountings and magnetic resonance imaging,
American Journal of Orthodontics and Dentofacial Orthopedics, **104,** 230–239.

Ash M. M. and Ramfjord S. (1996)
Occlusion,
W.B. Saunders Co., Philadelphia, USA.

Assif, D., Himel, R. and Grajower, Y. (1988)
A new electromechanical device to measure the accuracy of inter-occlusal records,
Journal of Prosthetic Dentistry, **59,** 672–676.

Celar, A. G., Tamaki, K., Nitsche, S. and Schneider, B. (1999)
Guided versus unguided mandibular movement for duplicating intraoral eccentric tooth contacts in the articulator,
Journal of Prosthetic Dentistry, **81,** 14–22.

Clark, J. R. and Evans, R. D. (1998)
Functional occlusal relationships in a group of post-orthodontic patients: preliminary findings,
European Journal of Orthodontics, **20,** 103–110.

Cordray, F. E. (1996)
Centric relation treatment and articulator mountings in orthodontics,
Angle Orthodontist, **2,** 153–158.

Dawson, P. E. (1979)
Centric relation. Its effect on occluso-muscle harmony,
Dental Clinics of North America, **23,** 169–180.

Dos Santos, J. and Ash, M. (1988)
A comparison of the equivalence of jaw and articulator movements,
Journal of Prosthetic Dentistry, **59,** 36–42.

Fattore, L., Malone, W. F., Sandrick, J. L., Mazur, B. and Hart, T. (1984)
Clinical evaluation of the accuracy of inter-occlusal recording materials,
Journal of Prosthetic Dentistry, **51,** 152–157.

Hatano, Y., Kolling, J. N., Stern, N. and Clayton, J. A. (1989)
Graphic comparison of mandibular border movements generated by various articulators. Part II: Results,
Journal of Prosthetic Dentistry, **61,** 425–429.

Helkimo, N., Ingervall, B. and Carlsson, G. E. (1973)
Comparison of different methods in active and passive recording of the retruded position of the mandible,
Scandinavian Journal of Dental Research, **81,** 265–271.

Howat, A. P, Capp, N. J. and Barrett, N. V. J. (1991)
Occlusion and malocclusion,
C. V. Mosby, St Louis.

Ingervall, B., Helkimo, M. and Carlsson, G. E. (1971)
Recording of the retruded position of the mandible with application of varying external pressure on the lower jaw in man,
Archives of Oral Biology, **16,** 1165–1171.

Janson, M. (1986)
Reproducibilty of occlusal findings. A comparison between clinical and articulator analyses,
Acta Odontologica, **44,** 95–99.

Johnston, L. E. (1988)
Gnathologic assessment of centric slides in post retention orthodontic patients,
Journal of Prosthetic Dentistry, **60,** 712–715.

Kirveskari, P., Alanen, P. and Jamsa, T. (1986)
Functional state of the stomatognathic system in 5,10 and 15 year old children in southwestern Finland,
Proceedings of the Finnish Dental Society, **82,** 3–8.

Kurth, L. E. (1949)
Mandibular movement and articulator occlusion,
Journal of the American Dental Association, **39,** 37–48.

Latta, G. H. Jr (1992)
Influence of circadian periodicity on reproducibility of centric relation records for edentulous patients,
Journal of Prosthetic Dentistry, **68,** 780–783.

Long, J. H. (1973)
Locating centric relation with a leaf gauge,
Journal of Prosthetic Dentistry, **29,** 608–610

Lucia, V. O. (1964)
Principles of articulation,
Dental Clinics of North America, **23,** 199–211.

Mitchell, D. L. and Wilkie, N. D. (1978)
Articulators through the years. Part I. Up to 1940,
Journal of Prosthetic Dentistry, **39,** 330–338.

Pameijer, J. H. N. (1985)
Periodontal and occlusal factors in crown and bridge procedures,
Dental Center for Postgraduate Courses, Holland.

Peregrina, A. and Feil, P. H. (1994)
Reproducibility of occlusal contacts relative to mounting cast variables,
Quintessence International, **25,** 617–619.

Rosner, D. and Goldberg, G. F. (1986)
Condylar retruded contact position and inter-cuspal position correlation in dentulous patients Part I: three-dimensional analysis of condylar registrations,
Journal of Prosthetic Dentistry, **56,** 230–239.

Roth, R. H. (1981)
Functional occlusion for the orthodontist,
Journal of Clinical Orthodontics, **15,** 32–51, 100–123, 174–198, 246–265.

Shafagh, I., Yoder, J. L. and Thayer, K. E. (1975)
Diurnal variance of centric relation position,
Journal of Prosthetic Dentistry, **34,** 574–582.

Shefter, G. J. and McFall, W. T. (1984)
Occlusal relations and periodontal status in human adults,
Journal of Periodontology, **55,** 368–374.

Simon, R. L. and Nicholls, J. I. (1980)
Variability of passively recorded centric relation,
Journal of Prosthetic Dentistry, **44,** 21–26.

Tamaki, K., Celar, A. G., Beyrers, S. and Aoki, H. (1997)
Reproduction of excursive tooth contact in an articulator with computerised axiography data,
Journal of Prosthetic Dentistry, **78,** 373–378.

Utt, T. W., Meyers, C. E., Wierzba, T. F. and Hondron, S. O. (1995)
A three-dimensional comparison of condylar position changes between centric relation and centric occlusion using the mandibular position indicator,
American Journal of Orthodontics and Dentofacial Orthopedics, **107,** 298–308.

Walker, P. M. (1980)
Discrepancies between arbitrary and true hinge axis,
Journal of Prosthetic Dentistry, **43,** 279–285.

Williamson, E. H, Caves, S. A., Edenfield, R. J. and Morse, P. K. (1978)
Cephalometric analysis: comparisons between maximum inter-cuspation and centric relation,
American Journal of Orthodontics, **74,** 672–677.

Williamson, E. H., Steinke, R. M., Morse, P. K. and Swift, T. R. (1980)
Centric relation: a comparison of muscle-determined position and operator guidance,
American Journal of Orthodontics, **77,** 133–145.