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An Investigation of the ability of Computerized Axiography to Reproduce Occlusal Contacts

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Abstract - *Intraoral excursive tooth contacts were compared with contacts made on both an unprogrammed and programmed Denar D5a articulator. 20 subjects were used to obtain study models which were mounted using a facebow transfer in Intercuspal Position. Cadiax Data was used to customise the articulator and left and right intraoral excursive contacts were examined and transferred from the mouth to the articulator using occlusagram wax bites. Using image analysis, the proportion of corresponding tooth contacts and the percentage of corresponding tooth contacts were significantly better when the articulator was programmed.*

KEYWORDS: Articulator, facebow, programmed, Cadiax, Axiograph, occlusion, occlusal contacts, Denar

INTRODUCTION

Articulators are an essential tool used in the field of restorative dentistry. They are useful for the diagnosis of occlusal interactions, in the planning of dental restorations involving diagnostic wax ups, and in the manufacture of definitive restorations and occlusal splints[1]. In all of these cases the articulator is acting to replicate the movements of the condyles within the temporo-mandibular joint, and of the mandible in lateral, vertical and protrusive dimensions[2].

The degree to which an articulator can replicate the complexity of an individual's jaw movements relies firstly upon the capability of the articulator to accurately simulate the anatomy which determines those movements and secondly the ability to record the necessary information from an individual to successfully 'program' an articulator.

Although study casts held together by hand will give information as to the alignment of the individual arches and teeth, they do not permit analysis of the dynamic and functional relationships of the teeth. For this the casts must be attached or located within an articulator.

The simplest articulators can do nothing more than open and close around an arbitrary hinge axis that may differ from that of the patient. They are no more than cast holders and have no use as a tool to assist in diagnosis [2]. More complex semi-adjustable articulators allow for individual variation in the position of the teeth relative to the hinge axis, and for programming of the condylar angle and immediate side shift. Fully adjustable articulators will allow for changes to the shape of the simulated articular fossa against which the simulated condyle moves. It is generally accepted that the more closely an articulator can replicate the movements of the jaws, the more accurately laboratory items can be manufactured and so would be less likely to introduce interferences that require chairside time to adjust [1], however there is little evidence to bear this out.

Lateral and protrusive wax check-bites were for many years an accepted means of setting condylar angles and values for side-shift, however they have been discredited as inaccurate and unreliable and of little practical value [3-6]. For many practitioners it is common practice to use articulators that can replicate via a facebow the distance from the teeth to the hinge axis, but to keep the articulator settings set to "average" values.

Fully adjustable articulators offer the benefit of being able to have the superior wall, medial wall and Bennett angle, amongst other settings, adjustable to match those of the patient. Early methods of transferring this data involved the use of pantographs – mechanical devices to produce tracings of jaw and condyle movements which were then copied on the articulator. This was time consuming and complex to achieve [7]. More modern methods involve computer aided pantographs and axiographs which can simplify and speed up the process and improve accuracy [8-10], however at a not inconsiderable financial outlay.

The electronic CADIAXCompact is a computer aided axiographic instrument capable of recording any condylar movement in space. In addition, the velocity of condylar movement can also be quantified. The displacement of a point (hinge axis of the mandible) relative to a "reference position" can also be recorded. This mode which is called the E.M.P.I for Electronic/ Mandibular/ Positions/ Indicator, is particularly useful in tracking the slide from centric relation to intercuspal contact position if present. The amount of this slide has been reported to be 1.25mm +/- 1mm as measured at the Incisal edge [11].

The reliability and validity of the electronic pantograph in calculating condylar settings for five different articulators (Denar D5a, Denar Mark II, Whip Mix 8500, Hanau Modular, and the Panadent PCH) has been tested and it was concluded that deviations from the means were relatively small and at the 10mm condylar track position the highest degree of accuracy and reliability was achieved [12].

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The reproducability of excursive tooth contacts in an articulator programmed using computerised axiographic data obtained from the CADIAX has been examined [13]. The programmed SAM2 "P" articulator was found to demonstrate reproduction of 82% of protrusive tooth contacts and 90% of the laterotrusive tooth contacts. The exact locations of the excursive contacts conicided in 66% of the protrusive contacts and 81% of the laterotrusive contacts. To date, no study of the accuracy of the electronic CADIAXCompact when used to programme the Denar D5a fully adjustable articulator has been reported. The aim of this study is to test the accuracy of the electronic CADIAXCompact to establish its efficacy for programming the Denar D5a articulator in relation to the articulator being as an average value instrument.

MATERIALS AND METHODS

Ethical approval was applied for and successfully received prior to the start of the study. Twenty subjects were voluntarily selected from a population of dental students at Leeds Dental Institute consisting of 12 women and 8 men. Their ages ranged from 19-34 yrs. The study outline was explained both verbally and in a written format on an information sheet given to each subject. Informed Consent was then obtained and recorded on the consent form.

Clinical session 1

A brief clinical exam was performed to assess the subjects' suitability in accordance with the acceptance criteria which included absence of signs and symptoms of temporomandibular dysfunction, able to undertake a full range of mandibular movement without pain, crepitus, clicks and deviations of the mandible and were fully dentate (excluding 3rd molars).

Alginate impressions were taken and a facebow transfer record was made using the Denar Slidematic Facebow. Extra hard beauty wax was used as the pickup material on the bitefork.

Shimstock was then used to detect holding contacts in intercuspal position (ICP), these were charted for later comparison with the articulator mounting.

The alginate impressions were disinfected in a 2 % hypochlorite solution for 10 minutes and then cast using type IV die stone (vacuum mixed with measured powder/water ratio) within 1 hour and trimmed in accordance with normal laboratory techniques.

Mounting of Study casts

The Articulators were mounted following the instructions published by Denar. The Mandibular cast was located to the maxillary cast in ICP by locating the position of best interdigitation manually.

Clinical session 2

The subjects were then examined and the articulated casts verified to be correctly mounted in ICP. This was achieved by checking the correspondence of 8µ thick shim holds on a tooth by tooth basis with the mounted casts on the articulator and the patient's teeth together in ICP. Any discrepancies were corrected by remounting the casts and re-checking ICP correspondence.

Lateral excursive movements were recorded using occlusogram wax. A wax wafer was pre-cut to fit over the maxillary cast and checked to fit over the subjects teeth. The subject, sitting upright to allow relaxed posture and excursive movements, was then asked to bite into the wax to full intercuspation. The subject was then asked to perform a left lateral excusive movement keeping the teeth in contact throughout the movement. The same procedure was performed on the subject with a second occlusogram wafer with the movement from ICP to the right, again maintaining tooth to tooth contact throughout the movement.

The CADIAXCompact axiograph was then fitted to the patient (Figure 1). The lower bow was attached to the lower anterior teeth by means of the impression clutch filled with an addition silicone jaw registration material. The lower bow was then attached to the clutch in a central position. The upper bow was inserted bilaterally into the external auditory meatus and secured in place with the head strap and nose piece. The electronic flag sensors were then connected to the maxillary bow and styli to the mandibular bow. A Cadiax axiographic tracing was then performed.

The reference point was recorded with chin point guidance of the mandible into an open unstrained retruded position. Before the actual recordings were made the subject was instructed on the movements to be performed. Mediotrusion left and right, protrusive and full opening and closing movements were then performed and the movements repeated to check for reproducibility. All of the movements were started from the reference position and completed without any contact of the upper teeth against the lower clutch allowing true unguided mandibular movements to be performed. The articulator settings to programme the D5a® with top wall and rear wall settings were then read from the Cadiax. The data were transferred electronically by USB link to the laptop and stored for reference in the GAMMA software programme. An example of one axiographic tracing can be seen at Figure 2, showing the recorded articulator programming data.

Intraoral excursive tooth contacts were compared with contacts made on both an unprogrammed and programmed Denar D5a articulator.

Collection of contact area data

The upper model was coated in a thin film of 10:1 water to PVA adhesive, thinned with an airstream and allowed to dry fully. This was to allow marks created by articulating paper to be wiped clean easily.

With the articulators initially programmed to arbitrary average values (SCI – Saggital Condylar Inclination = 25°, TCI- Transverse Condylar Inclination = 6°, Intercondylar width = 110 mm. Rear wall, top wall and ISS- Immediate Side Shift all set to 0) the models were moved into left then right excursions from a starting point of ICP using Blue GHM foil to record any contacts during the excursion (Figure 3). For each side an image of the ink tracings created by the GHM foil was made using a digital camera

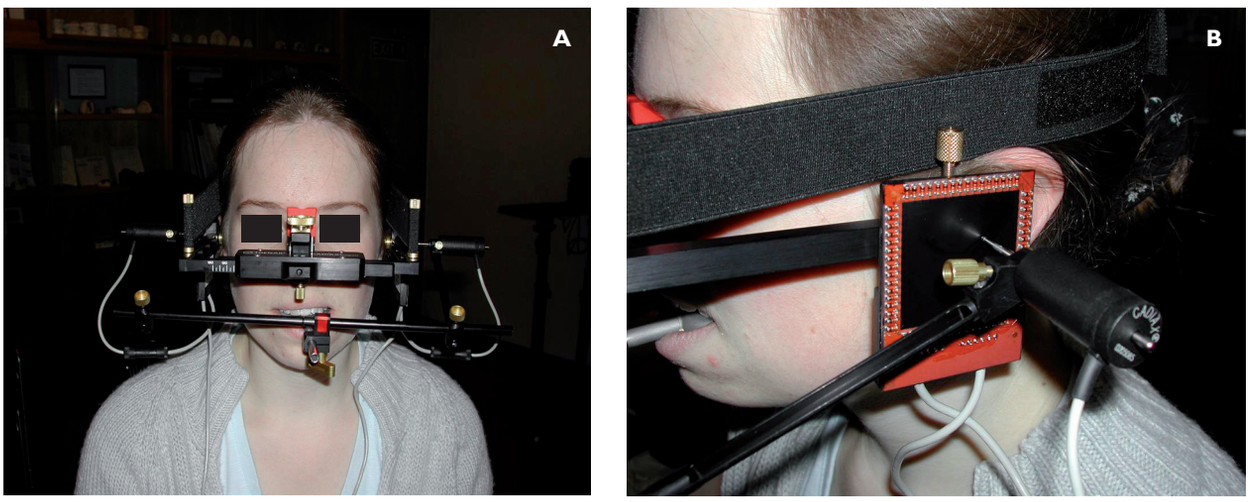

Figure 1. *Arrangement of the CADIAXCompact showing frontal view (a) and close up of the electric flag sensor (b)*

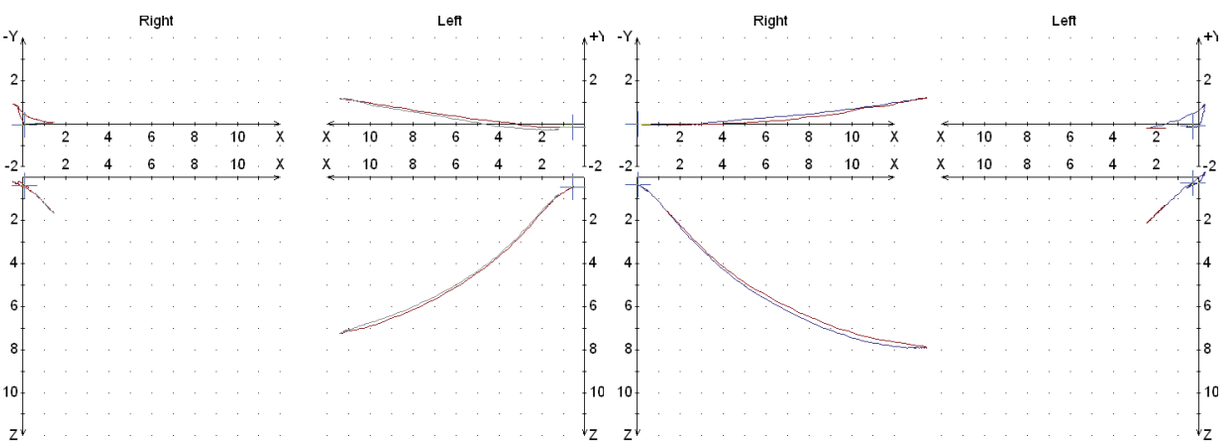

Figure 2. *Examples of left and right mediotrusive excursions of one of the subjects*

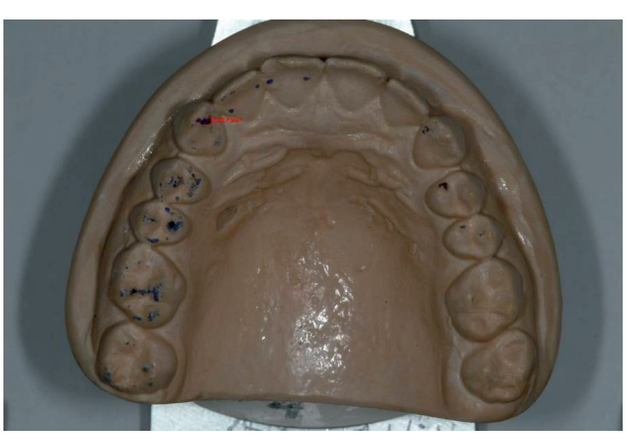

Figure 3. *Image obtained of articulating paper marks as input to image analysis software*

set vertically above the model at a set distance from the teeth. The process was repeated, this time programming the articulator settings using the data collected clinically. Finally for each subject the occlusogram wax records taken clinically were also imaged on the casts. The same lighting conditions were used throughout, and a single examiner examined the models.

Analysis of data

The images were evaluated using image analysis software to count the number of pixels covered by the GHM foil marks or by the areas where the occlusogram wax had been removed during the intraoral lateral excursions (Figure 4). The wax records were then overlaid (Figure 5) and the number of corresponding contacts and areas of correspondence of those contacts was measured and compared.

When looking at the percentage of agreement of the size of the area of overlap between marks obtained during lateral excursions when the articulator is set to programmed or

average values, it was taken that if *k* teeth are obtained for right-lateral mouth and 1 tooth overlaps with *x* % overlap then the percentage of overlap equals *x* % divided by *k*, and if 2 teeth overlap with *x* % and *y* % overlap respectively the percentage of overlap equals (*x* %+*y* %)/*k* and so on.

RESULTS

Twelve women and 8 men were recruited into the study, their ages ranged from 19 to 34 years. Cadiax data was obtained using the Gamma software program to calculate the articulator settings for the Denar D5a (R) articulator. The (R) signifies that the data has been used to calculate the top wall and rear wall settings for the articulator leaving the intercondylar distance set at 110mm. The program settings have been set to calculate the top wall and rear wall settings as well as the SCI (Saggital Condylar Inclination), TCI (Transverse Condylar Inclination) and ISS (Immediate Side Shift). The intercondylar distance is calibrated to 110mm leaving each condyle at 55mm on the articulator for each subject.

The mean SCI for the right condyle was 46.3°, range 32°-60° n=20. The mean SCI for the left condyle was 36.6°, range 25°-60° n=20. The mean TCI for the right condyle was 7.7°, range 5°-13° n=20. For the left condyle the mean TCI was 9.4°, range 5°-30°, n=20. The left and right ISS mean values were calculated at 0 mm with a range of 0-0.1 mm for the right side and 0-0.2 mm for the left side.

The number of contacts that were observed in the mouth, but not replicated by articulator movements is depicted in Figure 6.

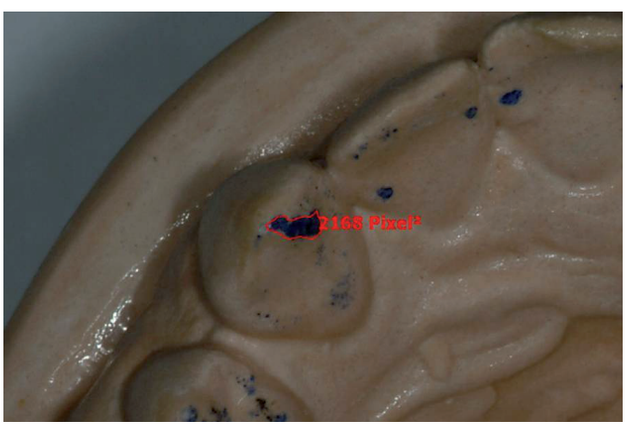

Figure 4. *Close up of one of the contacts as imaged in Figure 3 showing pixel count of contact area*

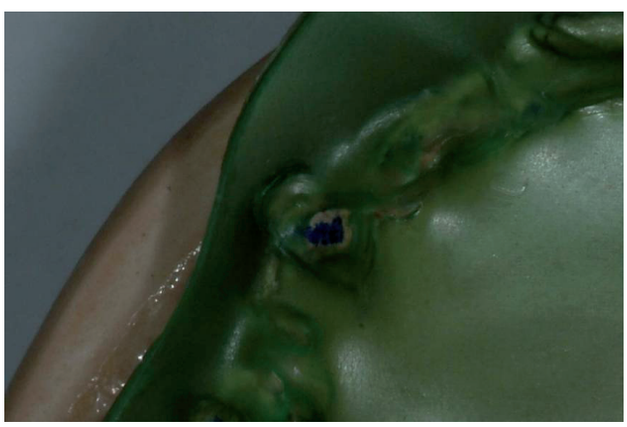

Figure 5. *Intraoral wax record positioned over the marks created during lateral excursion to the same side using the articulator*

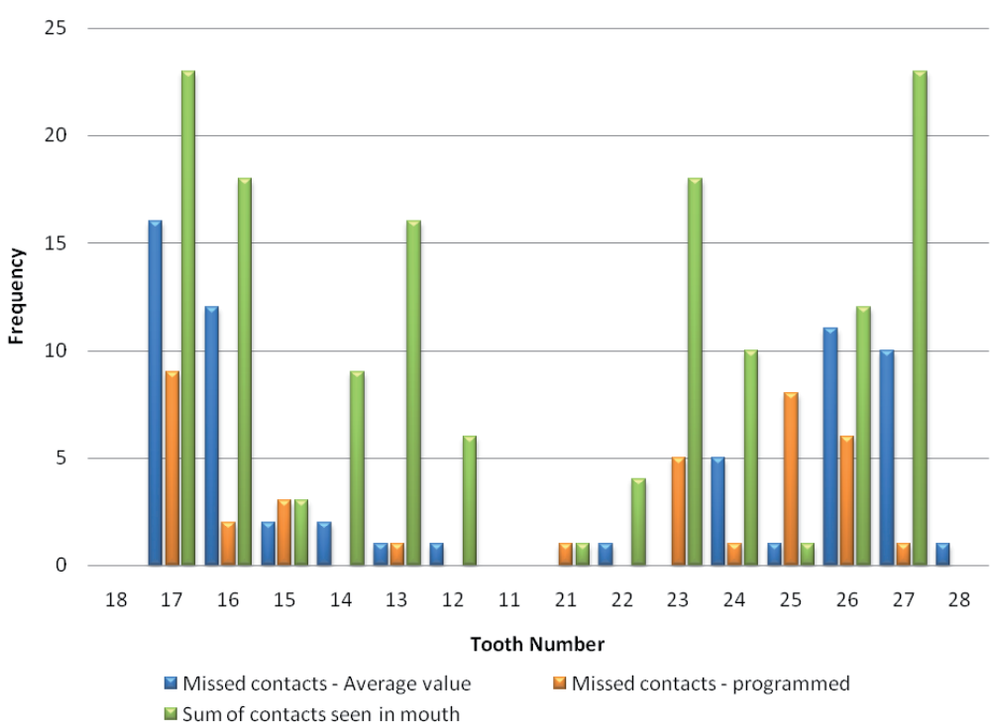

Figure 6. *Chart of comparison of combined working side and non-working side contacts observed in the mouth via occlusogram wax transfer that were missed by the Average setup and programmed articulators*

Comparison of the degree of correlation in the number and position of contacts observed both clinically and on the articulators revealed a 58 % replication for the average value setup of the articulator (92/159 contacts). The programmed articulator correctly replicated the contacts to a value of 71 % (114/159 contacts). The difference between the two is statistically significant ($p>0.001$).

Using the methodology described previously, the data was analysed using the Wilcoxon Paired Signed Ranks test for determination of level of significance (Table 1)

DISCUSSION

The results of the study show that there is a statistically significant difference in the overlap or correspondence of excursive tooth contacts reproduced between the Denar D5a articulator set to average values and the same articulator programmed using data obtained from a Cadiax Compact recording when compared with the actual tooth contacts in the mouth of the subjects tested recorded with occlusogram wax. Using the Wilcoxon paired signed ranks test both the proportion of corresponding tooth contacts and the percentage of corresponding tooth contacts are significantly better, or closer to the contacts produced in the mouth, when the programmed articulator tested in this study was used.

The study could be considered to suffer from certain inaccuracies which include; casting of models through to articulation of study models to articulation using a facebow, all of which have inherent material and operator errors. These inherent errors however apply equally to comparible studies. Due to the constraints of using a rigid mechanical framework in an attempt to reproduce a biological system, the articulator will never completely replicate the anatomy and physiology of the temporomandibular joint. Tooth mobility as a result of compression of the periodontal ligament, mandibular flexure, laxity of the TMJ capsule and ligaments, compression of synovial fluid, blood vessels and fibrous tissue all within a complicated joint system are all anatomical variables which, to date are not replicated by any articulator system.

Nevertheless, whilst accepting these complexities, it is suggested that the data produced by this study provides valuable information regarding the use of programmed articulators. The results would suggest that using the Cadiax Data to customise the Horizontal Condylar Inclination, the Saggital Condylar Inclination, Immediate side shift together with top wall and rear wall settings will allow a more accurate and dynamically functional study cast which will reproduce excursive tooth contacts during right and left movements to a closer degree of the contacts seen in the mouth. Clearly there would be benefit to repeating the study to determine the reproducibility of the methods used to determine occlusal contacts.

The clinical relevance of these conclusions would suggest that where restorations are made for a patient using articulated models then the occlusal guiding surfaces of the restorations will be closer to the desired occlusal scheme which is planned for the restoration if the work is completed on a programmed articulator. However, restrictions of the articulator and its inadequacy must be borne in mind when undertaking the fit of any restorative work into the patient's own dynamic, anatomical articulator. The relative youth of the subjects in the study, and the intact nature of their dentitions, may suggest that they have less immediate side shift than older patients or dentitions with more wear, and so a larger study, with a more varied population is indicated in order that the results be transferrable to the general population.

CONCLUSIONS

The data presented shows that a significantly more accurate articulator mounting can be achieved if the articulator is programmed rather than set to average values. Further study on the direct clinical effect of such improved accuracy is required, for example the manufacture of prostheses on programmed and non-programmed articulators could be directly compared for amount of chairside adjustment and accuracy of reproduction of the occlusion.

ACKNOWLEDGEMENTS

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MANUFACTURER'S DETAILS

- Alginate: [Cavex ColorChange; Cavex Holland BV]
- Denar instruments: [Waterpik, USA]
- Extra hard beauty wax: [Miltex inc, PA, USA]
- Hypochlorite solution: [Perform; Schülke-&-Mayr GmbH, Germany]
- Type IV die stone: [Velmix, Kerr]
- Occlusogram wax: [Bose Dentale, Spezialitaten GmbH, Lubeck, Germany]
- Blu-Mousse: [Parkell, Inc. NY, USA]
- CadiaxCompact Axiograph: [Cadiax, version 4.12, Gamma Co. Klosterneuburg, Austria]

Table 1. *Percentage of overlap of areas of contact produced using the average value settings and programmed settings, with level of significance calculated using the Wilcoxon Paired Signed Ranks Test*

		Median percentage overlap	Range	Level of significance
Right lateral	Average values	2.1	0 – 60	p=0.003
	programmed	14.2	0 – 41.8	
Left Lateral	Average Values	3.5	0 - 60	p=0.001
	programmed	18.5	0 - 80	

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