Reproducibility of Wax Interocclusal Records on Different Articulators

Abstract
Context: The construction of a dental prosthesis needs the duplication of intermaxillary relationships of the patient on the articulator. This procedure is normally fulfilled using interocclusal records to program the articulator according to the patient’s condylar inclinations. Wax is a popular recording material used for this purpose but has proven to suffer from inaccuracies due to its dimensional variation over time. Aims: This study intends to test the reproducibility of eccentric interocclusal wax records over time. Setting and Design: Thirteen dental students aged between 18 and 30 years participated in this study. Maxillary and mandibular casts of the participants were mounted on two types of articulators; wax lateral and protrusive interocclusal records were used to program these articulators. Subjects and Methods: Horizontal and lateral condylar inclinations were obtained for each participant. The interocclusal records were stored for 10 days and the casts of each participant were remounted on the articulators. The interocclusal records were reused to obtain new condylar inclinations of each participant. The initial and the delayed condylar inclinations were compared to evaluate the impact of storage time on wax records. Statistical Analysis Used: Paired Student’s t-test was used for this comparison. Results: No significant difference (0.38 < P < 0.92) was found between initial and delayed condylar inclinations for both articulators. An interclass correlation coefficient analysis was used to test the reproducibility of measures, and the correlation was significantly elevated (intraclass correlation coefficient > 0.600). Conclusions: The use of wax interocclusal records for articulator programming was shown to be acceptable even with delayed intervals, without concerns of possible variations of condylar settings due to storage time.

Keywords: Articulator, occlusion, wax

Introduction
A dental prosthesis needs to be in harmony with the movements of the mandible to prevent any undesirable effect on the periodontal tissues and the temporomandibular joint elements. This harmony is a crucial step to the success of the prosthesis and the fulfillment of the goals of function, preservation as well as the reduction of intraoral adjustments. The construction of the dental prosthesis requires the use of an articulator able to mimic closely the mandibular movements.

The articulator is programmed according to the patient’s condylar settings: the horizontal condylar inclination and the lateral condylar inclination (Bennett’s angle). These inclinations can be calculated by interocclusal eccentric records using different materials. Wax interocclusal records are widely used and routinely suggested in dental textbooks[1,2] some described it as the material of choice in many instances for interocclusal record.[3] Lassila[4] reported that wax was a reliable material only when it was left at the site of registration, for example, on removable dentures. Millstein and Clark[5] found that laminated and metalized waxes were the most accurate and dimensionally stable compared to other types of waxes, but these types of waxes were highly technique sensitive during treatment and handling procedures. Many authors questioned the reliability of wax in recording centric relation (CR) incriminating the dimensional stability of the material with time.[6,7] According to Michalakis et al.,[8] wax presented the greatest linear changes of all materials tested at all-time intervals. He attributed these changes to the coefficient of thermal expansion of wax and the distortion of this material due to the release of internal stresses. Ghazal et al.,[9] tested the vertical discrepancies of interocclusal materials during storage. He found that wax had the highest vertical discrepancies after 48 h of storage, but he argued that wax can be a reliable material if it is used in conjunction

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with acrylic resin. Karthikeyan et al.\textsuperscript{[10]} suggested the use of wax records within an hour of recording to preserve its accuracy. Müller et al.\textsuperscript{[11]} concluded that wax was appropriate as an interocclusal record if corrected with zinc oxide eugenol paste and used within 30 min.

In contrast, Utz et al.\textsuperscript{[12]} considered unrefined wax reliable as an interocclusal record material compared to other materials. The reliability of metalized wax as interocclusal material has been demonstrated by Togano et al.\textsuperscript{[13]} during the registration of interocclusal record in removable partial dentures construction. The comparison to other recording materials such as zinc oxide eugenol pastes and polyvinylsiloxanes was favorable. Similarly, Pagnano et al.\textsuperscript{[14]} considered acrylic resin base and wax interocclusal records being the most accurate for CR in free-end saddles cases compared to other material combinations. Baumann, in a study on the effect of interocclusal recording material on mounted casts, compared occlusal contacts on the mounted casts and concluded that metalized wax was the most accurate material compared to polyvinylsiloxane and bis-acrylic resin.\textsuperscript{[15]}

Reproducibility is an important factor in determining the validity of a method, especially in restorative procedures where occlusal relationships need to be stable and reproducible in every phase of the treatment. Reproducibility of CR with interocclusal records was tested by many authors. Wax was considered unreliable over time in reproducing centric records.\textsuperscript{[16−18]} Notwithstanding these reports in the literature, Wood and Elliott\textsuperscript{[19]} in a study about reproducibility of CR found wax highly reproducible according to the Roth CR bite registration technique.

Little has been reported about the reproducibility of wax during lateral interocclusal record and the impact of time factor on patient condylar settings calculated from eccentric interocclusal wax records.

This study intends to test the reproducibility of eccentric interocclusal wax records over time, by comparing condylar settings of patients calculated on two types of articulators, namely, Whip-Mix (WM) and Dentatus (DENT) within a time frame of 10 days between the initial and the delayed readings. The null hypothesis is that wax variation over time will have an impact on the condylar settings calculated on both articulators.

**Subjects and Methods**

This study was conducted according to ethical principles and with full compliance to the requirements of the ethical council at Saint Joseph University of Beirut. This study protocol tagged as “number: 162” was granted full approval by the ethical council at Saint Joseph University of Beirut.

Thirteen dental school students of both sexes and between the ages of 18 and 30 participated in this clinical study. All participants signed an informed consent form. To be eligible, the participants had to meet the following criteria: (1) have a complete dentition, (2) have an Angle Class I jaw relationship, and (3) have had no extractions, artificial crowns, or extensive restorations. Participants showed no signs and symptoms of temporomandibular disorders or parafunctions, such as bruxism. Moreover, the participants did not undergo any dental restoration during the whole period of the study to prevent any alteration of occlusal surfaces of the teeth.

Stone casts using an improved dental stone (Silky-Rock; Whip-Mix Corporation, Louisville, KY, USA) were obtained for each participant using irreversible hydrocolloid impression material (Jeltrate Dentsply Caulk, Milford, DE, USA) with perforated metallic trays (Coe Stainless Steel Trays; GC America Inc., Alsip, IL, USA). Maxillary casts were mounted, respectively, on two different semi-adjustable articulators with corresponding facebow transfers: WM #8500 Whip Mix Model 8500 articulator [arcon type - Figure 1] with WM Quick Mount (Whip-Mix Corporation, Louisville, KY, USA) or DENT ARH articulator (AHR) [nonarcon type - Figure 2] with DENT earbow (Dentatus USA, New York, NY, USA), according to manufacturer’s instructions.

Mandibular casts were articulated with the maxillary cast using wax (Beauty Pink Wax-Miltex, Plainsboro, NJ, USA) records made in maximum intercuspal position and mounted accordingly.

Eccentric interocclusal records were made in two sets as required for lateral right and left excursions. Protrusive interocclusal records were made also to program horizontal condylar inclination for DENT articulator as suggested by the manufacturer. An arithmetic mean was computed from the two sets for each condylar setting. Lateral movements were generated by occluding lightly with opposing canine teeth placed tip to tip. Participants were asked to rehearse the movements in front of a mirror until they were able to perform it consistently. A 5 mm displacement was considered acceptable when a tip-to-tip relationship of anterior teeth was not possible or the eccentric displacement was not sufficient.

![Figure 1: Whip-Mix articulator model 8500](image-url)
Metalized wax (Alu wax Bite and Impression Wax, waxed cloth sheets; Alu wax Dental Products Co., Grand Rapids, MI, USA) was used as interocclusal recording material. The wax was softened in water bath at 42°C for 15 s and rolled into wafers. It was then positioned over the occlusal surfaces of posterior mandibular teeth. The participant was asked to close into the eccentric position guided with a mirror. The wafer was air chilled on different sides, retrieved from the mouth, and allowed to bench cool to room temperature. The interocclusal records were used within 2 h.

The WM and DENT articulators were programmed to calculate the condylar inclinations (horizontal condylar inclination, Bennett’s angle), using the lateral and protrusive eccentric interocclusal records. Angle measurements were subsequently recorded on the worksheet for every participant.

The wax interocclusal records were disposed individually in a plastic bag identified with the number and the name of the patient written on as well as the date of the recordings. All records were stored in a refrigerator with a constant temperature of 5°C. The respective casts of every patient were identified with name and number of the patient and stored without removing the mounting plates from the maxillary casts.

After a period of 10 days, each case was remounted on both articulators, the mandibular cast articulated with maxillary cast according to the maximum intercuspal position guided by indexes made during the first mounting. The respective lateral and protrusive interocclusal records were reuses to program the articulators as done previously. The calculated condylar inclinations were recorded on the chart of each patient and were tagged as delayed measurements.

All these procedures were performed by one experienced operator only for consistency purposes and to mitigate operator-induced error.

Statistical analysis was performed using a software program (SPSS for Windows, Version 18.0, Chicago, IL, USA). The level of significance was set at $\alpha = 0.05$. Paired Student’s $t$-tests were conducted to explore significant differences in mean horizontal condylar guidance and mean lateral condylar guidance for both articulators, between initial and delayed readings. The reproducibility of measurements between initial and delayed readings was verified using the interclass correlation coefficient analysis.

### Results

The mean horizontal condylar guidance on WM articulator was not significantly different between initial and delayed time ($P = 0.435$).

The mean horizontal condylar guidance on DENT articulator was not significantly different between initial and delayed time ($P = 0.924$).

The mean lateral condylar guidance on WM articulator was not significantly different between initial and delayed time ($P = 0.923$).

The mean lateral condylar guidance on DENT articulator was not significantly different between initial and delayed time ($P = 0.388$) [Table 1].

The reproducibility of measures between initial and delayed readings of condylar settings was significantly elevated (intraclass correlation coefficient >0.600; $P < 0.05$) for both articulators, namely, WM and DENT and for both measurements, namely, horizontal and lateral condylar guidelines [Table 2].

### Discussion

An accurate interocclusal record is essential to achieve precision fixed and removable prosthesis. Therefore, an ideal interocclusal recording material should allow to reproduce accurate maxillomandibular relationships even after long storage time.

This study was conducted to test the reproducibility of lateral wax interocclusal records after a relatively long storage time by comparing its effect on the condylar inclinations calculated on two articulators. The results of

| Mean (SD) | Significance |
|-----------|--------------|
| Initial   | Delayed      |
| Horizontal condylar guidance (WM) | 50.6 (9.3) | 52 (6.7) | 0.435 |
| Horizontal condylar guidance (DENT) | 50.5 (8) | 50.3 (5.5) | 0.924 |
| Lateral condylar guidance (WM) | 12.2 (6) | 12 (6.3) | 0.923 |
| Lateral condylar guidance (DENT) | 13.9 (6.9) | 15 (5.5) | 0.388 |

WM=Whip-mix, DENT=Dentatus, SD: Standard deviation
the study were unexpected as they showed no significant difference between the initial condylar inclination readings and the delayed condylar readings calculated from wax interocclusal records stored for 10 days. These results were not affected by the type of articulator, namely, arcon or non-arcon and were consistent for both horizontal and lateral condylar inclinations [Table 1].

Inaccuracies from the casts and their mounting on the articulators were eliminated since the same casts were used in the initial and the delayed readings. The upper cast was readily mounted on the upper member of the articulator without a facebow record as the mounting plate was not removed after the initial readings. On the other hand, the lower cast was mounted according to the maximal intercuspals record guided by the indices made on the casts during the initial mounting. Since the same wax interocclusal records were used, the results reflected only the dimensional changes of the wax as a function of storage time.

The results of the present study were corroborated with previous studies which considered wax to be an acceptable interocclusal recording material, namely, Utz et al.,[12] and Togano et al.,[13] who considered wax most accurate material for bite registration compared to other materials. On the other hand, our results did not match several other studies,[7–9] which questioned the accuracy of wax after a storage time. Gupta et al.[18] concluded that wax records should be used on the spot to achieve an acceptable accuracy in relating casts on articulators.

The results of the present study point to the fact that vertical errors at the occlusal level of teeth, due to variations of recording material over time, are not always detected by measurements on the condylar level of the articulator as noticed by Müller et al.[20] On this point, Caro et al.[21] found that a change of 5 degrees in horizontal condylar guidance does not necessarily have an impact on lateral occlusal contacts. Another explanation of the findings of this study is the fact that the wax interocclusal records do not have the “spring” effect of elastomeric interocclusal materials as described by Gupta et al.[18] This enables the practitioner to obtain repeatable condylar measurements from wax interocclusal records independently from the closure force of the articulator.

This study’s conclusion is counter to the ones reported by many other authors who questioned the accuracy of wax centric interocclusal record and demonstrated its dimensional variations as related to storage time. However, few of these authors investigated the impact of storage time on lateral interocclusal records and subsequently on the condylar inclination readings recorded on the articulator. In comparing the vertical variations of wax records (ranging between 20 and 100 µm as cited Ghazal et al.[9] to the vertical discrepancies generated, when records of different materials (wax, polyether, polyvinylsiloxanes, and acrylic resin) were transferred to casts (~500 µm as noted by Vergos and Tripodakis),[22] better insight is gained into the results of this study. Vergos and Tripodakis[22] also concluded that although some differences in vertical accuracy existed between different recording materials during the procedures of recording the maxillomandibular relationships, these differences were inexisten when the records were transferred on the casts, and all the materials were equally inaccurate. Muller et al.,[23] noted in a study on the influence of the derived casts on the accuracy of different recording materials that none of the materials were reliable. The most accurate material generated deviations of approximately 300 µ. The results of this study may be equally explained by the fact that achieving reproducibility in jaw relationships through interocclusal records is dependent more on the clinical variations (i.e., clinical operator) than of the recording techniques and materials used as noticed by Eriksson et al.[24] The conservation of occlusal wax records has also played a role in the observed results. Most of the similar studies stored the wax records at room temperature for different intervals of times, whereas in this study, the wax records were stored at a temperature of 5°C.

The compressive force encountered during the mounting process for initial and delayed condylar readings was not standardized, but the procedures were performed by one experienced prosthodontist only, and the forces used were considered adequate and acceptable for this type of procedures. It may be assumed that this factor would not affect the results. Another point that supports the assumption of this study is that wax has better resistance to compression[23] compared to other interocclusal recording materials such as polyethers or polyvinylsiloxanes.

The convention wisdom that storage time may affect the accuracy of interocclusal recording materials by different degrees and subsequently has an impact on CR contacts between casts on the articulator is not true about the impact of storage time on condylar settings issued from lateral interocclusal records. This will enable the practitioner to use...
properly handled and conserved wax lateral interocclusal records in case that delayed remounts on articulator are needed without having to record new ones.

The null hypothesis of this study was rejected since storage time of wax interocclusal records did not have any significant effect on the condylar setting readings on two different articulators.

Within the limitations of this study, the practitioner can use wax lateral interocclusal records for articulator programing in relatively delayed intervals without concerns of possible variations of condylar setting due to storage time.

Conclusions

A study was conducted on reproducibility of wax lateral interocclusal records after a long storage time by comparing its effect on the condylar settings of two types of articulators arcon and nonarcon (WM and DENT). It was found that there was no significant difference between initial and delayed readings of condylar settings on both articulators. It was concluded that wax lateral interocclusal records can be used safely, even after a long storage time, to program articulators.

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Conflicts of interest

There are no conflicts of interest.

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