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Evaluation of Precision and Reliability of Different Bite Registration Materials Using Conventional and Digital Articulator Systems

Konvansiyonel ve Dijital Artikülatör Sistemlerini Kullanarak Farklı Kapanış Kayıt Materyallerinin Hassasiyet ve Güvenilirliğinin Değerlendirilmesi

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Abstract

Objective: Conventional and digital articulators are currently used to associate the lower and upper jaw models. However, there are not enough studies comparing the reliability of different interocclusal registration materials used in conventional and digital articulatory acquisition methods. This study aims to contribute to the literature on this subject.

Materials and Methods: Plastic mandibular and maxillary models were attached to a semi-adjustable articulator adjusted to the mean values in the maximum intercuspal position. Forty interocclusal recordings were obtained using 4 different interocclusal registration materials (n=10). Impressions from the master models and all interocclusal recordings were digitized. For each interocclusal registration sample, measurements were made between the marked points on the correlated models using both digital and conventional methods, and all measurements were compared with the measurements made on the plastic master model. Two-way analysis of variance was used to compare the data obtained from the measurements between the groups, and Dunnett's test was used as a multiple comparison test to compare the measurements of all groups with the initial measurements.

Results: It was concluded that the measurements obtained with the conventional method gave more successful results than those obtained with the digital method, and polyvinyl siloxane materials had more successful results than wax samples in both methods.

Conclusion: According to the method used in this study, the conventional technique has reliable results ($p<0,05$) and continues to be valid. Software development is needed to scan and use interocclusal recordings for digital model articulation.

Keywords: Bite registration, centric relation, digital bite registration, interdental relation

Öz

Amaç: Günümüzde alt ve üst çene modellerini ilişkilendirmek için geleneksel ve dijital artikülatörler kullanılmaktadır. Ancak geleneksel ve dijital artikülatörler ile kapanış kaydı elde etme yöntemlerinde kullanılan farklı interoklüzal kayıt materyallerinin güvenilirliğini karşılaştıran yeterli çalışma bulunmamaktadır. Çalışmanın, bu konudaki literatüre katkı sağlaması amaçlanmaktadır.

Gereç ve Yöntemler: Mandibular ve maksiller fantom modeller, maksimum interkuspal pozisyonda ortalama değerlere ayarlanmış yarı ayarlanabilir artikülatöre bağlandı. Dört farklı interoklüzal kayıt materyali kullanılarak 40 interoklüzal kayıt elde edildi (n=10). Ana modeller ve tüm interoklüzal kayıtlar dijitalleştirildi. Her bir interoklüzal kayıt örneği için, modellerde işaretlenen noktalar arasında hem dijital hem de geleneksel yöntemlerle ölçümler yapıldı ve tüm ölçümler plastik ana modelde yapılan ölçümlerle karşılaştırıldı. Gruplar arası ölçümlerden elde edilen verileri karşılaştırmak için iki yönlü varyans analizi, tüm grupların ölçümlerini ilk ölçümlerle karşılaştırmak için çoklu karşılaştırma testi olarak Dunnett testi kullanıldı.

Bulgular: Konvansiyonel yöntemle elde edilen ölçümlerin dijital yönteme göre istatistiksel olarak daha başarılı sonuçlar verdiği ($p<0,05$) ve polivinil siloksan malzemelerin her iki yöntemde de mum örneklere göre daha başarılı sonuçlar verdiği sonucuna varıldı.

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Sonuç: Bu çalışmada kullanılan yönteme göre geleneksel teknik güvenilir sonuçlara sahiptir ve geçerliliğini sürdürmektedir. Dijital modellerde interoklüzal kayıtları taramak ve kullanmak için yazılımların geliştiirilmesine ihtiyaç vardır.

Anahtar Kelimeler: Kapanış kaydı, sentrik ilişki, dijital kapanış kaydı, dişlerarası ilişki

Introduction

When a tooth needs a restoration due to caries, fractures, wear, or when it is planned to replace missing teeth with fixed or removable dentures, the morphology of the restoration to be made is created in harmony with the patient's existing teeth and occlusion. Once it is decided that occlusal reconstruction is indicated, a correct treatment position for the mandible should be established and this position recorded accurately (1).

In dentistry, the centric relationship is accepted as the most comfortable, reproducible, physiological and stable position for the mandible. For this reason, in cases where dental references are pathological or absent, it is desired that the condyles be in the centric relation position while recording the jaw relation in the desired vertical dimension. Accurately recording the centric relationship position in a predetermined vertical dimension and transferring it to the laboratory environment significantly affects the success of the restoration and plays a major role in reducing the physician's treatment time (2).

With the development of computer-aided design and computer-aided manufacturing systems, the use of digital methods has become widespread in copying teeth and dental surrounding tissues and recording the interocclusal relationship. However, there are very few studies in the literature comparing the reliability of interocclusal relationship recordings obtained with digital and conventional methods and evaluating the suitability of existing interocclusal registration materials with the digital method (3,4).

The aim of this study is to evaluate the compatibility of interocclusal registration materials currently used in the conventional articulatory method with the digital process.

Our null hypothesis is all bite registration materials can register the centric relation and different materials and methods had no effect on the accuracy of interocclusal recording.

Materials and Methods

Ten groups were performed to examine five different interocclusal recording materials using conventional (Occlufast rock, Zhermack SpA., Italy; Variotime Bite, Kulzer, Germany; Futar D, Kettenbach, Germany; Modeling Wax Pinnacle Standard, Dentsply Sirona, Australia) and digital (Dental Wings iSeries Impression Scanner-Dental Wings, Montreal, Canada) methods, and each group included ten samples (Table 1).

Prefabricated acrylic phantom jaws were used in the study (AD-J 01, Arma Dental, Turkey). After the upper jaw model was fixed to the adjusted articulator according to the mean values, the lower jaw was brought to the maximum intercuspal position and fixed to the articulator with type 2 plaster. The pin of the articulator was fixed by compression in the vertical dimension at the maximum intercuspal position. All maxillary teeth were prepared to represent a situation where the vertical stop points resulting from natural tooth contacts were completely lost (Figure 1). After the preparations, the locations of the markings to be measured were determined to be in the cervical gingival regions of the lower and upper first molars and canines. Triangular shaped reference points were created with the bases facing the teeth and the apical apex of 1 mm in depth. Impressions were taken by applying putty-wash technique with pubovaginal sling (PVS) impression material (Elite HD+, Zhermack SpA, Italy) using prefabricated impression trays.

All PVS-based bite registration materials were applied directly to the occlusal surfaces of the mandibular teeth, using the automatic mixing and application tips included in their packages, with a compatible disperser (3M garant dispenser, 3M, USA) in accordance with the manufacturer's instructions. The upper part of the articulator, which

Table 1. Test groups

Materials	Digital	Conventional
Futar D	FD	FC
Modelling wax	WD	WC
Occlufast rock	OD	OC
Variotime bite	VD	VC

Figure 1. The prepared teeth

was fixed with a pin, was closed and the maxillary teeth were embedded in the material. The materials whose polymerization was completed were separated from the model and homogeneously softened wax interocclusal recording material was placed on the mandibular teeth by giving an arc form and the upper jaw was closed on the material in vertical dimension fixed with pins.

Dental Wings iSeries impression scanner (Dental Wings, Montreal, Canada) was used as an indirect digital scanner for transferring the obtained impressions and interocclusal recordings to digital media.

Mandibular impression, maxillary impression and interocclusal recording material were scanned with an indirect digital scanner and the scan data was transferred to the device compatible software (DWOS 9.1, Dental Wings, Montreal, Canada). Models and bite registrations were associated with precise positioning by the software. The distances between the predetermined reference points on the main models were measured with the digital ruler included in the software, and the obtained values were recorded (Figure 2).

Type 4 plaster was used for the plaster model (Elite rock, Zhermack SpA, Italy). The plaster maxillary model was fixed to the articulator adjusted according to the mean values using type 2 plaster, and the intermaxillary recording was placed on the maxillary occlusal surface. The occlusal surface of the mandibular model was placed on the interocclusal recording, and the mandible was fixed to the articulator with type 2 plaster in the position where maxillo-mandibular relationship was achieved. The mean values were recorded by measuring the distances between the previously marked reference points using a digital caliper. For all subsequent specimens, only the mandibular model was detached from the articulator and all steps were repeated after the maxillary model was fixed to the articulator.

Statistical Analysis

Two-way analysis of variance was used to compare the data obtained from the measurements between the groups, and Dunnett's test was used as a multiple comparison test to compare the measurements of all groups with the initial measurements (Table 2).

Results

When Table 2 (which shows the average differences from the gold standard) is examined, it is seen that the conventional method gives superior results than the digital method. In the conventional method, the largest mean difference was recorded in the WK group with 0.2 mm, while in the digital method, the smallest mean difference was recorded in the VD group with 0.26 mm. It is seen that the results recorded in the PVS-containing materials in the conventional method are very close to each other, while the results obtained with the wax-containing material are far from the PVS group. When the results recorded in the digital method are examined, it is seen that the differences between the groups are more pronounced.

In order to make the comparison between the materials examined with two different methods more understandable, the values recorded in 4 regions of ten samples in each group were recorded by calculating the difference in mm from the gold standard value of the relevant region. During the collection of the differences obtained, the distances away from the gold standard value were added without taking into account the + and - signs indicating the burial and elevation status, in front of the values, and the negative and positive values obtained in this way were prevented from zeroing each other. The distance from the gold standard value of the relevant region for a total of 40 measurements of 10 samples in each group in 4 different regions was calculated and summed in this way, the obtained value was divided by 40 and the deviation distance from the mean gold standard in a measurement for each group was obtained in mm (Table 3).

When Table 3 is examined, it is seen that the average difference of all materials from the gold standard is higher in the digital method than in the conventional method. The smallest mean difference recorded in the conventional method was 0.1 mm in the FK group, and the largest mean difference was recorded in the WK group with 0.2 mm. In the conventional method, the order of the mean difference between the materials from the gold standard is as follows, from smallest to largest, Futar D, Variotime Bite, Occlufast Rock, Modeling Wax.

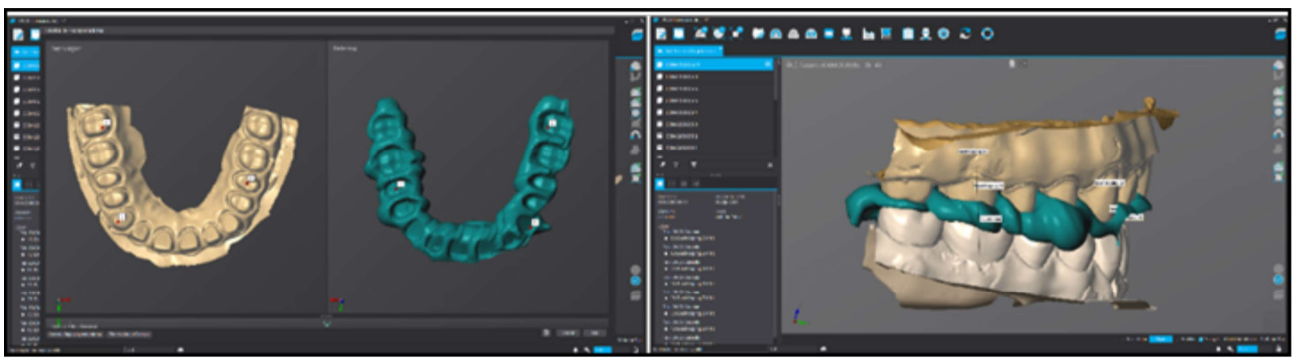

Figure 2. Interocclusal digital registration

Table 2. ANOVA test results

	26-36		p-value from GS	23-33		p-value from GS	13-43		p-value from GS	16-46		p-value from GS
	Mean	SD		Mean	SD		Mean	SD		Mean	SD	
GS	16.96	0.03		20.87	0.02		20.91	0.04		15.42	0.03	
FD	16.46	0.19	0.000	20.60	0.31	0.130	21.19	0.27	0.087	15.34	0.27	0.884
FC	16.99	0.04	1.000	20.70	0.08	0.579	20.86	0.08	1.000	15.35	0.07	0.940
WD	16.66	0.26	0.004	20.65	0.66	0.309	20.85	0.62	0.999	15.24	0.21	0.067
WC	17.28	0.22	0.002	20.76	0.14	0.942	20.84	0.16	0.999	15.62	0.09	0.022
OD	16.46	0.18	0.000	20.69	0.23	0.519	20.90	0.25	1.000	15.25	0.17	0.089
OC	16.93	0.11	1.000	20.71	0.10	0.644	20.86	0.12	1.000	15.50	0.07	0.743
VD	16.54	0.23	0.000	20.41	0.17	0.001	20.93	0.24	1.000	15.37	0.22	0.986
VC	17.02	0.12	0.995	20.68	0.09	0.460	20.83	0.06	0.995	15.37	0.09	0.992
ANOVA p-value	0.000			0.014			0.088			0.000		

SD: Standard deviation, FD: Futar digital, FC: Futar conventional, WD: Modelling wax digital, WC: Modelling wax conventional, OD: Occlufast rock digital, OC: Occlufast rock conventional, VD: Variotime bite digital, VC: Variotime bite conventional

Table 3. Total and mean distances of the groups from the gold standard

Materials	Total difference	Mean
FC	4,114	0.102
VC	4,502	0.112
OC	4,625	0.115
WC	8,176	0.204
VD	10,567	0.264
OD	10,974	0.274
FD	13,491	0.337
WD	16,043	0.401

FC: Futar conventional, VC: Variotime bite conventional, OC: Occlufast rock conventional, WC: Modelling wax conventional, VD: Variotime bite digital, OD: Occlufast rock digital, FD: Futar digital, WD: Modelling wax digital

Discussion

All additional silicone bite registration materials examined in the study gave results close to the gold standard value in the conventional method. The wax bite registration material, on the other hand, gave higher results in the posterior regions compared to the gold standard values when compared with additional silicone materials. In the conventional articulatory method, similar results are found in studies comparing the bite registration materials containing wax and PVS. Ockert-Eriksson et al. (5) investigated the effects of bite registration materials containing two waxes, three PVS and an irreversible hydrocolloid on the precision of interocclusal recordings in fixed, HBP and full dentures. In their study, in which the position changes of the lower and upper jaw models were examined in 3D, it was reported that materials containing PVS in the vertical direction gave significantly more successful results compared to materials containing wax (5). The results of this study show parallel data we obtained from the WC group in our study.

When conventional groups were analyzed by regions, no such pattern was encountered. This suggests that this situation is not due to the materials, but to the sensitivity of the method. In the study conducted by Porter et al. (6), the effect of intraoral and extraoral scanners on closing sensitivity was examined, and it was reported that values outside the confidence interval and farther from the gold standard value were recorded in the left molar region, in two extraoral and one intraoral scanner groups.

The extraoral scanner used in the study scans the interocclusal relationship starting from the right side of the arch. Although it is known that the probability of distortion in full-arch scans performed using extraoral scanners is lower than in intraoral scanners, the scanning sensitivity of measurements and models has been evaluated in studies (6-9). While no problems were encountered in the impression scans we obtained in our study, it was observed that the surface detail of the right half of the quadrant was lower than the left half of the interocclusal recording scans. It is thought that this may be due to the fact that the closing sensitivity gives much more successful results on the right side than on the left side.

However, even when the results recorded in the right quadrant were examined, it was seen that the conventional method gave more sensitive results compared to the digital method. It is not possible to explain this situation only with the difference in scanning sensitivity between regions. In the conventional method, the practitioner can feel the fit of the plaster models on the interocclusal recording material

and the material creates a physical barrier between the models. The compressibility of the material and its resistance to plastic deformation determine the maximum distance that the applicator can compress the models. On the other hand, in the digital method, there is no physical limit that can prevent the models from approaching each other, and the correct articulation completely depends on the scanning sensitivity of the scanner and the success of the best fit algorithm used in matching the surfaces.

Sweeney et al. (3) investigated the effect of different interocclusal recording materials on the sensitivity of model articulation and reported that all values recorded with the digital method, regardless of the material, were significantly far from the gold standard value. Although only the digital method was included in their studies, the results recorded in this area are similar (3).

While Futar D material was the most successful material in the conventional method in order of mean difference from the gold standard, it could not show the same success in the digital method. The success of the material in the conventional method can be explained by its superior physical properties such as high hardness and compression resistance. The inability to show the same success in the digital method can be explained by the inadequacy of the scanning sensitivity of the device. However, it is thought that the color of the material and the color of the laser beam of the device may be incompatible with each other (10).

The Variotime Bite bite registration material is the closest to the gold standard in the digital group. Variotime Bite is an interocclusal registration material produced for laser scanning. The material has a matte appearance after polymerization, and this feature allows the laser beams reflected from the surface to be easily detected by the device camera during scanning. It is thought that the success of the material in the digital method can be explained by this feature. However, the material gave similar and successful results with other polyvinyl siloxane materials in the conventional method. It was observed that the material was more fragile than other polyvinyl siloxane interocclusal recording materials used in the study. Due to this feature, difficulties were experienced when separating the polymerized recordings from the teeth, and two of the obtained recordings were renewed because they were broken during the separation from the teeth (11).

Occlufast Rock is the material with the highest hardness level after polymerization among the materials used in the study. It was observed that the material gave successful results in both methods (12).

Modeling Wax was the material in which the most distant mean values to the gold standard value were recorded in both digital and conventional methods. Similar results were encountered in many studies comparing wax-containing interocclusal recording materials and polyvinyl siloxane interocclusal recording materials. Physical properties such as insufficient dimensional stability of the material, distortion as a result of heat exchange, and low compression resistance have been held responsible for this situation.

When the results of the study were evaluated clinically, it was seen that the conventional articulatory method gave more reliable results than the digital articulatory method. When the data obtained in the study were evaluated statistically, it was seen that the effect of different methods and materials on the accuracy of interocclusal relationship recording was statistically highly significant, and the null hypothesis that different materials and methods had no effect on the accuracy of interocclusal recording was rejected.

Conclusion

The results obtained within the limits of this study, in which the sensitivity and reliability of different closing recording materials were evaluated using digital and conventional articulatory methods, are as follows:

1- Significantly different results were obtained in digital and conventional articulatory acquisition methods for the same interocclusal recording materials. More successful results were obtained in the conventional method compared to the digital method.

2- It was observed that there was a significant difference between the regions measured in the digital method, and the amount of error in closing increased as it progressed from the right end of the arc to the left.

Based on the results of our *in vitro* study under laboratory conditions, it can be said that the conventional method continues to be valid until the full digital method reaches the desired point with software and hardware developments. It is thought that the results obtained from the study will contribute to the clinicians in the choice of interocclusal recording materials. We believe that this issue should be supported by in-vivo studies in order to obtain more reliable clinical information in material comparison.

Ethics

Ethics Committee Approval: Ethics committee approval is not required.

Informed Consent: Informed consent is not required.

Peer-review: Externally peer-reviewed.

Authorship Contributions

Surgical and Medical Practices: E.E., Concept: E.E., S.A., Design: E.E., S.A., Data Collection or Processing: E.E., Analysis or Interpretation: E.E., Literature Search: E.E., Writing: E.E., S.A.

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