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RESEARCH AND EDUCATION

Determining the requirements, section quantity, and dimension of the virtual occlusal record

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ABSTRACT

Statement of problem. Conventional methods associated with many processes in dentistry are being replaced by methods that use digital technology. One of these processes is the making of occlusal records for the positioning of casts in a virtual articulator. Conventional interocclusal records and the articulator are currently being replaced by the intraoral virtual occlusal record and the virtual articulator.

Purpose. The purpose of this study was to determine the requirements, quantity, and dimensions of the virtual occlusal record procedure in order to locate the mandibular cast's 3-dimensional (3D) spatial position in reference to its corresponding maxillary cast on a virtual articulator.

Material and methods. For the conventional procedure, 6 sets of casts were located in maximal intercuspal position without any interocclusal record. Then, using articulating paper, the occlusal contacts were determined. Afterward, the occlusal relationships and stone cast were digitized with a 3D scanner. To locate the maxillary cast, the occlusal contacts were compared by taking different sections as the virtual occlusal record. Finally, the optimum dimension of the virtual occlusal record was determined.

Results. This study determines the requirements, quantity, and dimensions of the virtual occlusal record using current reverse engineering tools. The combinations of the sections were first determined as follows: 3 sections (2 lateral and 1 frontal) and 2 lateral sections proved to be the most accurate. Then, the predictive values (PV) for dimension determination for the left-right lateral combination were calculated.

Conclusions. The main conclusion of this study was that the combination of left and right lateral occlusal records was the most convenient. Additionally, the minimum optimum dimension for a virtual occlusal record was 12×15 mm. (J Prosthet Dent 2015;■:■-■)

The introduction of digital technology has changed many processes in dentistry. This technology is certain to gain in importance over the coming years. In some fields, the tools for digital technology are still being developed, and some procedures in the clinic and dental laboratories are being redefined. One of these new procedures is the digital or virtual occlusal record. Delong et al[1,2] began to study this procedure several years ago; however, the use of recently developed tools, 3D digitalizing systems, and reverse engineering software has not yet been analyzed in depth.

At present, the trend in dentistry is to digitalize the entire process. With a completely digital workflow,[3,4] the use of mechanical articulators and facebows would be avoided. At present, research is focused on intraoral scanners[5-7] and mesh editing.[8] Nevertheless, other areas, such as the transfer of the occlusal relationship from the patient to the virtual articulator,[9,10] still require improvement.

This ever-increasing use of virtual technology makes virtual occlusal record methodology more common in clinics and dental offices. In this study, the most significant parameters of this procedure were analyzed with 6 sets of casts. The input of digitalized data was studied to find out the most adequate data for this procedure. In

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Clinical Implications

The virtual occlusal record procedure is used in the transfer and setting of the mandibular cast to the virtual articulator. Therefore, the requirements, quantity, and dimensions of the virtual occlusal record must be determined.

addition, and in order to locate the mandibular digital model on the virtual articulator, this study also focused on identifying the necessary and most convenient sections of the occlusal record.

In this sense, each intraoral scanner has its own software, and different sections are used in each set. Some intraoral scanners need 2 lateral sections to locate the mandibular model, while others also require the frontal sections. Other scanners require only 1 section. In order to determine the optimum sections for locating the relative position of maxillary and mandibular digital models with the virtual occlusal record, several experiments were carried out, all of them under the same conditions. These conditions were established by starting from the same complete virtual occlusal record and experimenting with different sections from it (Fig. 1).

Finally, the optimal size of the occlusal record was defined, ensuring that the rest of the studied variables remained constant. As long as best fit alignment, resolution, and accuracy are taken into account, this finding will serve as reference for further studies.

MATERIAL AND METHODS

The input data constitute an important aspect of the digital occlusal record process. Robert W. Straga concluded that as long as the whole occlusal surface is scanned, occlusal contacts are more accurately determined when fewer images are used in digitization (Thesis. Comparison of occlusal contacts on mounted dental models to contacts identified on 3D digital models using a new virtual alignment method. University of British Columbia. 2009. https://circle.ubc.ca/handle/2429/6817?show=full). Therefore, when scanning the occlusal surface, a minimum amount of captures must be made to have fewer best fit alignments[11,12] and a more accurate digitization. Because this assumption was followed in this study, overlapping regions or data were avoided.

An industrial 3D scanner (ATOS Compact Scan 5M; GOM GmbH) was used to digitize the casts and to obtain their virtual occlusal records. The casts were scanned with 8 to 10 image captures, and the entire occlusal surface was digitized. They were then mounted on the mechanical articulator, and 3 to 4 image captures were made from the buccal side.

In the first phase, the aim was to determine which sections of the occlusal record were necessary to locate the mandibular cast in the correct position. As proposed by Delong et al,[1,2] the correct position was determined by comparing the existing physical occlusal contacts and the determined virtual contacts.

In the second phase, the dimensions of the sections for each combination were determined, ensuring the same occlusal contacts. Reverse engineering software Geomagic (Geomagic Design X; 3D Systems) was used to edit and process the virtual occlusal record. Six sets were mounted on a mechanical articulator (1801 AR Model PSH Articulator; Panadent) without any interocclusal record,[13,14] and the physical occlusal contacts were checked virtually. The methodology used to check the virtual occlusal record followed that of Delong et al[2] but current digitization technology and software were used. The complete virtual occlusal record served as reference, and the virtual contacts were tested with the physical contacts. The physical occlusal contacts were obtained by using 8 μm articulating paper (8 μ Arti-Fol; Dr Jean Bausch GmbH & Co), and the contacts were verified with metallic polyester film (Arti-Fol metallic Shimstock-film 20 μm; Dr Jean Bausch GmbH & Co).

In the third phase, 3 possible sections were determined: frontal (A), left lateral (B), and right lateral (D) (Fig. 2). To analyze the possible combinations, 2 virtual occlusal record dimensions were made using the complete virtual occlusal record as a reference and the contacts were compared. For this procedure, the "best fit alignment" was applied using the reverse engineering software (Geomagic, Rapidform and GOM Inspect). These comparisons were carried out using different dimensions of the virtual occlusal records: 10×15 mm and 25×15 mm. Finally, once the required sections were determined, the size of the optimum virtual occlusal record was established for each combination.

RESULTS

Table 1 lists the number of contacts obtained by using 10×15 mm for each virtual occlusal record section, thereby determining that the contacts were the same. The "correct" contacts were considered to be those that were generated with the complete occlusal record and the "incorrect" contacts were those generated with the virtual occlusal records and not with the complete virtual occlusal record.

Statistical analysis was carried out to calculate the PVs for each of the reverse engineering software programs used. A diagnostic test was performed to measure the effectiveness of each procedure. The results of this diagnostic test provided valuable information regarding the probability of having or not having contact. In this case, the diagnostic test was the virtual procedure (using

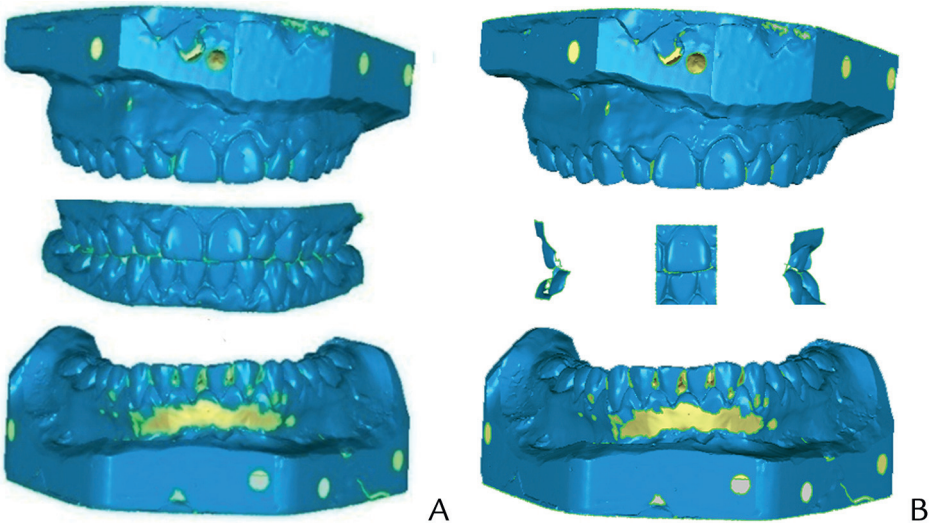

Figure 1. Virtual occlusal record. A, Complete. B, Left lateral, frontal, and right lateral sections.

virtual occlusal record), and the reference diagnostics were the physical contacts obtained with the articulating paper.

Virtual contacts on the digital models were compared with the contacts obtained with the physical articulating paper. As described by Delong et al,[1] the location of the contacts was based on anatomic regions, and, as demonstrated by Delong et al,[2] mean PVs greater than 0.90 were considered to be adequately accurate. The following equations show the different PVs with different sections, and the results are presented in Table 2. Positive predictive value (PV+)**:** probability of contact truly exists when the diagnostic test is positive,

$$(PV+)=\frac{TP}{TP+FP}$$

and negative predictive value (PN–): probability of contact truly is not present when the diagnostic test is negative.

$$(PN-)=\frac{TN}{TN+FN}$$

The next analysis aimed at defining the optimum dimension of the virtual occlusal record section. As Table 2 demonstrates, for the frontal-left-right lateral (ABD) combination, the 10-mm width and 15-mm height were adequate. However, for the left and right lateral section combination, the dimension had to be calculated. The value had to fall in a width range of between 25 mm and 10 mm. Table 3 lists the calculated values.

Table 4 lists the PVs to determine the dimension of the left–right lateral combination (BD). Because the mean PV was grater than 0.90, the 12×15 mm dimension was established as the minimum optimum dimension (Fig. 3).

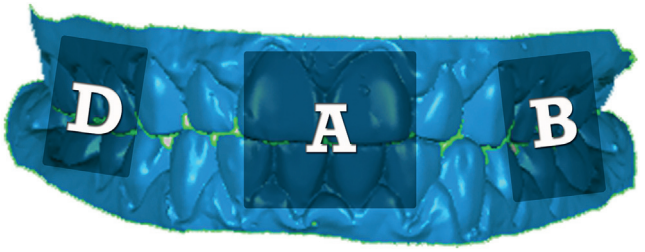

Figure 2. Possible sections of virtual occlusal record: frontal (A), left lateral (B), and right lateral (D).

DISCUSSION

Intraoral scanners and dental CAD/CAM systems use virtual occlusion to locate the mandibular cast on the virtual articulator. Previously published studies on the virtual occlusion were based on stone casts, although the requirements of this procedure have not been sufficiently studied.[1,2,11] This study also focused on the virtual models of stone casts; however, it was conducted with the latest advances in reverse engineering tools and 3D scanners. The results obtained with these state-of-the-art tools are more up-to-date. As in previous studies, procedures were validated with PVs.

A mentioned significant study was carried out by Straga, who concluded that the stereolithography (STL) file quality is important because it measures the accuracy of the stone cast. Therefore, in this study, to analyze only the main variables of the procedure, all digitization was obtained with the same extraoral scanner (ATOS Compact Scan 5M; GOM GmbH). The influence of the intraoral scanner will be analyzed in further studies.

In this study, the resulting deviation values were in a similar range to those of previous studies.[1,2,11] This fact reaffirms the validity of the virtual occlusion procedure,

Table 1. Correct and incorrect number of contacts using 10×15 mm virtual occlusal records in different sections

		ABD		AB		AD		BD		A		B		D	
		Correct	Incorrect												
Set	No. of Contacts*	✓	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓	✗	✓	✗
	2	2	0	2	2	2	2	1	0	2	2	0	6	2	2
2	3	3	0	3	0	2	2	2	0	3	0	1	6	3	2
3	1	1	0	1	0	1	0	1	0	1	0	1	1	1	1
4	5	5	0	5	0	5	0	5	0	5	0	5	0	5	0
5	6	6	0	6	1	5	1	6	1	5	0	6	1	3	3
6	3	3	0	3	0	3	1	3	0	3	3	2	3	3	0
Total	20	20	0	20	3	18	6	18	1	18	5	15	17	17	8

FP, false positive; TP, true positive; FN, false negative; TN, true negative; PV+, positive predictive value; PV–, negative predictive value; Mean PV, mean predictive value.
*Number of contacts with complete virtual occlusal record.

Table 2. Analysis of PVs with different sections

Virtual Occlusal Records	FP	TP	FN	TN	PV+	PV–	Mean PV
10 ×15 mm							
ABD	0	20	0	5	1.00	1.00	1.00
AD	2	18	6	5	0.90	0.45	0.68
AB	0	20	3	5	1.00	0.63	0.82
BD	2	18	1	5	0.90	0.83	0.87
A	2	18	5	5	0.90	0.50	0.70
B	5	15	17	5	0.75	0.23	0.49
D	3	17	8	5	0.85	0.38	0.615
25 ×15 mm							
ABD	0	20	0	5	1.00	1.00	1.00
AD	2	18	2	5	0.90	0.71	0.81
AB	0	20	4	5	1.00	0.56	0.78
BD	3	17	0	5	0.85	1.00	0.93
A	6	14	4	5	0.70	0.56	0.63
B	1	19	11	5	0.95	0.31	0.63
D	2	18	16	5	0.90	0.24	0.57

A, frontal; B, left lateral; D, right lateral; FP, false positive; TP, true positive; FN, false negative; TN, true negative; PV+, positive predictive value; PV–, negative predictive value; Mean PV, mean predictive value.

Table 3. Section dimension determination of BD combination

		20×15		15×15		12×15	
Set	No. of Contacts*	✓	✗	✓	✗	✓	✗
1	2	1	0	1	0	1	0
2	3	3	0	2	0	2	0
3	1	1	0	1	0	1	0
4	5	5	0	5	0	5	0
5	6	6	0	6	0	5	0
6	3	3	0	3	0	3	0
Total	20	19	0	18	0	17	0

*Number of contacts with complete virtual occlusal record.

Table 4. Predictive values for dimension determination of BD combination

Virtual Occlusal Records	FP	TP	FN	TN	PV+	PV–	Mean PV
20×15 mm							
BD	1	19	0	5	0.95	1.00	0.975
15×15 mm							
BD	2	18	0	5	0.90	1.00	0.95
12×15 mm							
BD	3	17	0	5	0.85	1.00	0.925

B, left lateral; D, right lateral, FP, false positive; TP, true positive; FN, false negative; TN, true negative; PV+, positive predictive value; PV–, negative predictive value; Mean PV, mean predictive value.

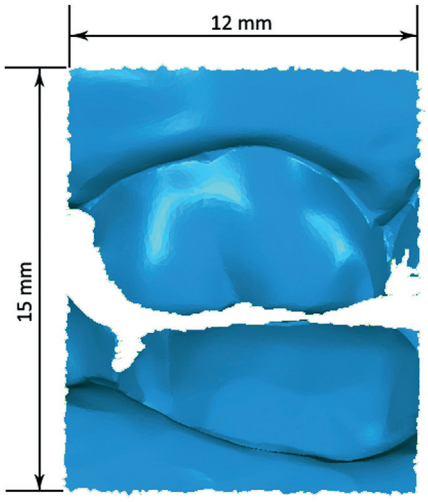

Figure 3. Dimensions of optimum virtual occlusal record for left-right lateral combination (BD).

which in this study was conducted with improved analysis and reverse engineering tools. This also permitted the statement of the requirements for this procedure. Delong et al[1,2] validated the virtual occlusal record procedure. For this validation, they used a complete virtual occlusal record. Therefore, it can be affirmed that the presented novel method constitutes a step forward in this field because it has advanced in the determination of the quantity and the dimension of the sections. Following the example of intraoral scans, this study also concluded that the use of left-right lateral sections was the optimum because it is accurate and involves a significant decrease in time and required materials. Although the introduction of a frontal section could improve the result, this is the solution used by some intraoral scanners on the market.

Finally, as many authors[13,14] state that the use of occlusal records changes the relative position of the maxillary and mandibular casts, this study proved the

influence of the virtual occlusal record on the location of the mandibular cast. Therefore, the accuracy of the procedure must be guaranteed throughout the whole procedure, especially the best fit alignment. Otherwise, as can occur with the conventional procedure, a cumulative error will be introduced in the virtual procedure.

CONCLUSIONS

Based on the results of this study, the following conclusions were drawn:

1. The most convenient combination for the virtual occlusal record was the combination of left and right lateral occlusal records, because the distance between them is higher than in other combinations.
2. The 12×15 mm dimension was the minimum optimum dimension for a virtual occlusal record. This is approximately the dimension of 1 intraoral scanned image.

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