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T-scan Occlusal Analysis of Two Digitally Printed Implant Overdentures Fabricated by Two Virtual Articulation Modules (In Vivo study)

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Aim: The purpose of this study is to evaluate occlusion of implant overdentures fabricated using two different virtual articulators.
Materials and methods: Ten completely edentulous patients were selected to participate in this study. For each patient, four intraforaminal implants were inserted then received two digital complete overdentures; the first overdenture (Group I) was fabricated using completely adjustable virtual articulator, and the second overdenture (Group II) was fabricated using mathematically simulating virtual articulator. Mandibular movements were recorded using Zebris jaw motion optic. After designing and printing the overdentures, T-scan occlusal analysis was done for both groups. Numerical data was analyzed using paired t- test.
Results: There was no significant difference between the two groups in biting force distribution (p>0.05). In centric occlusion where (SD) values for occlusal contact distribution between right and left posterior segments of the overdentures, had recorded acceptable and comparable occlusal load with no anterior contact. In protrusive movement, the contact of anterior teeth in group I (67.25 % ±4.99) had a higher mean value for biting force distribution than group II (64.50% ±5.80). In lateral movement, the occlusal contact distribution between working side and balancing sides was better in group I; (70.34% ±4.33), (29.66±4.33) working and balancing side respectively than group II; (74.80% ±10.01), (25.32% ±9.78) working and balancing side respectively, yet the differences were not significant.
Conclusion: Within the limitations of this study, it was found that designing balanced occlusion for digital implant overdentures with completely adjustable virtual articulator is more reliable than mathematically simulating virtual articulator.

Keywords: Zebris jaw motion analyzer, Virtual articulator, Digital, T-scan, Overdenture.

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Introduction

Achieving optimal occlusion is a crucial step in the successful planning and construction of any dental prosthesis for completely edentulous patients that necessitates an accurate registration of maxillomandibular relationship in harmony with mandibular movements to ensure maintaining the stability of physiological dynamics, which are fundamental for performing natural functions such as biting, swallowing, and speaking without interference. [1-3]

For decades, a facebow transfer has been used to determine the terminal hinge axis position and to orient dental casts on a mechanical articulator in the same relationship as that in patient's mouth. The mechanical articulator is used to simulate condylar position and jaw's movements which allow the fabrication of the dental prostheses with appropriate occlusal design without interferences. Articulator's settings should be adjusted according to individual, function-specific, joint values. However, this method does not track the exact mandibular motion, and the mechanical articulator cannot represent the dynamic condition of the occlusion and jaw movements.[1,2,4-7]

Nowadays, digital era in dentistry has become an important aspect of modern prosthodontics aiming to overcome the limitations of conventional methods. Various electronic systems have been introduced recently for tracking jaw movements that record and reproduce the exact mandibular movements. Dynamic occlusion is reconstructed guided by a virtual articulator and CAD software, that simulates jaw movements and allows visualization of occlusal contacts. With these tools, static and dynamic occlusion could be calculated and visualized. [1,4,6,8-10]

Virtual articulators are classified into two major types: mathematically simulated virtual articulator and completely adjustable virtual articulator.[11]

-Mathematically simulated virtual articulator imports the articulator geometry and simulates the movement of the mechanical articulator, making it a fully adjustable 3D virtual articulator. While completely adjustable virtual articulator is designed so that the electronically recorded mandibular movements can be displayed on a computer by moving the digitized dental arches along those paths for a dynamic occlusal analysis with no need to select an articulator from the CAD software.[4,11]

Virtual articulation as a part of digital workflow in complete denture requires further studies. Thus, the purpose of this study was to evaluate the accuracy of completely adjustable virtual articulator versus mathematically simulated virtual articulator on occlusion of digitally fabricated complete overdenture.

Materials and Methods

- **Patient selection and grouping**

This study was approved by the ethical committee of the faculty of dentistry Ain Shams university under the approval number (FDASU-RecIR112215).

Ten completely edentulous patients were selected from the department of oral and maxillofacial prosthodontics, Faculty of Dentistry, Ain-Shams University. Patients with skeletal (class I) jaw relationship and adequate interocclusal distance were included in this study. They were free from TMJ disorders, any anatomical variations e.g., Skeletal class II, III or neuromuscular disorders e.g., Epilepsy & Parkinsonism and any systemic disease that would affect the surgical or the prosthetic phases.

A detailed explanation about the study was provided to all participants, and they were informed that the study would need their best co-operation. They all agreed to participate and follow the instructions given to them in the form of a signed consent. All the required measures were taken to ensure the protection of the security of the patient's personal information and their health privacy information. All participants were clearly

given notice concerning their rights, privacy practices and their legal duties.
To ensure the uniformity of all steps, all surgical and prosthetic steps were done by the same prosthodontist.

- **Surgical phase**

For each one of the patients, four intraforaminal implants were inserted in the mandible using a surgical guide. then received two sets of digitally complete overdentures that were classified into two groups according to the type of virtual articulator used for fabrication of the overdenture;
Group I: Overdenture was fabricated using completely adjustable virtual articulator.
Group II: Overdenture was fabricated using mathematically simulated virtual articulator.

- **Prosthetic phase**

For each patient, primary impressions were made for both arches, to produce study casts that were used for the construction of the special trays. For the lower arch, the open tray impression technique was used, and the secondary impressions were made for both arches using a medium base rubber impression material (Elite Medium Viscosity, Zhermack, Italy.). After obtaining maxillary and mandibular master casts, four ball abutments were screwed to implant analogs within the mandibular master cast then their housings were seated then recording denture bases were fabricated.
Jaw relation was done using a jaw motion tracking device Zebris Optic Jaw Motion Analyzer+ (zebris Medical GmbH, Isny, Germany.)

Centric relation and mandibular movements were recorded using two different virtual articulator modules in the Zebris software system;
In Group I: (function & occlusion) module was selected, representing the completely virtual articulation.

For gothic-arch tracing; the tracing screw was attached to the maxillary recording base and the guiding plate was attached to the mandibular recording base, then both were adjusted according to the predetermined vertical dimension of occlusion. A para-occlusal clutch holding a signal emitter was attached to the buccal aspect of the mandibular recording base

The steps were clearly explained to the patients. The head frame (digital face bow) was attached to the patient's head while sitting in an upright position. First, the spatial position of maxilla was determined. The mandibular movements were then captured; patients were asked to perform mandibular movements (chewing cycle, protrusion, left lateral, and right lateral), each cycle should start and end from the centric position (fig.1).

Fig.1. A digital facebow attached to the patient's head and a signal emitter attached to the mandibular occlusion block.

Every movement was performed three times, and the computer calculated the average value, the data was collected by the software. The data provided by the Zebris software was exported as extensible markup language (xml) format file. Finally, the centric relation position was confirmed on the software and the occlusion blocks were locked in this position and the centric relation was recorded by the bite registration material (CharmFlex® Bite).
In Group II: (jaw relation) module was selected, representing the mathematical virtual articulation. The same steps were repeated for each patient as previously mentioned in group I, and an Artex report of all mandibular movements was provided by the Zebris software.

For each patient, two xml format files were released provided by (function & occlusion) and (jaw relation) module respectively.

Digital designing the complete over denture (CAD) requires; Scanning of maxillary and mandibular master casts and the occlusion blocks in centric relation position using Intraoral scanner (Medit i600, Medit; MEDIT Co., Seoul, Korea.) to obtain their virtual models in the form of STL files. These STL files were uploaded to the digital design dental software program (Exocad software, 2.4 Darmstadt; exocad GmbH, Germany.).

After designing denture bases, teeth selection from teeth library in the software was done, followed by alignment of the virtual casts; for group I, according to the STL files combined with xml file of (function& occlusion) module, the maxillary & mandibular virtual casts were automatically aligned by the completely adjustable virtual articulator (fig.2a).

Then virtual occlusion design was done in centric and eccentric relations by dynamic movement of the virtual casts equivalent to the mandibular movement of the patient.

For group II, the Artex virtual articulator was selected from the Exocad software. The maxillary & mandibular virtual casts were mounted on this virtual articulator guided by the xml file of (jaw relation) module and the Artex report with all the parameters needed to adjust the articulator settings (fig.2b).

Then virtual occlusion design was done in centric and eccentric relations simulating patient's mandibular movements on the virtual articulator. After that the complete overdentures were digitally designed and fabricated. Each patient received two sets of 3D printed PMMA acrylic dentures that were fabricated using two different virtual articulators. Then, the housings of the ball abutments were picked up for all dentures.

Fig.2. Alignment of virtual casts on two different virtual articulators. Complete virtual articulation(A), Mathematically virtual articulation(B).

- **Evaluation of the occlusion of the dentures**

Occlusal analysis for both groups was done by T-Scan III occlusal analysis system(Tekson, Inc.USA.). The maxillary central incisor width was measured using a periodontal probe. The sensor was placed in the patient's mouth, with the sensor support pointer between the two central incisors and the handle was held parallel to the occlusal plane. And the patient was asked to close in centric relation, so that the tooth contact would be observed on the screen. Graph window and Graph Zoom window were automatically opened for the current movie. These windows contain color-coded "traces" representing the distribution of the forces along the arch and teeth under heavy contact as shown in (fig.3).

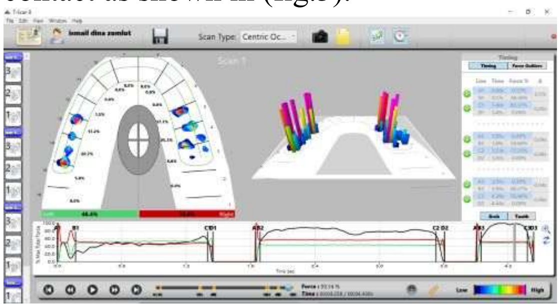

Fig. 3. T-scan occlusal analysis report.

The same steps were followed to record the occlusal contacts in protrusive and lateral eccentric positions. Each movement was repeated thrice and an average of three recordings were taken.

Statistical Analysis

Numerical data was presented as mean and standard deviation (SD) values. They were analyzed for normality by viewing distribution and using Shapiro-Wilk's test. They were found to be normally distributed and were analyzed using paired t-test. The significance level was set at p<0.05 within all tests. Statistical analysis was performed with R statistical analysis software version 4.4.1 for Windows.

Results

Results of intergroup comparisons presented in Table (1) showed that for all measured contacts, there was no significant difference in biting forces distribution measured in both groups (p>0.05). Summary statistics are presented in Figure (4).

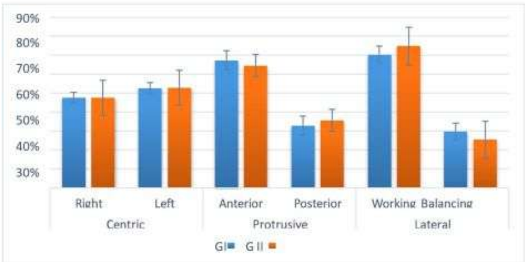

Fig. 4. The bar chart represents biting force distribution for the two groups.

As shown in table (1); in centric occlusion, right & left posterior areas of the dentures had recorded acceptable and comparable occlusal load with no anterior contact for both groups. While in the protrusive movement, the contact between anterior teeth of group I(67.25 % ±4.99) has higher mean value for biting force distribution than group II (64.50% ±5.80). In the lateral movement, the occlusal contact distribution between working side and balancing sides in group I showed better occlusal force distribution with; working side (70.34% ±4.33) and balancing side (29.66±4.33) than group II with; working side (74.80% ±10.01) and balancing side (25.32% ±9.78) yet the differences were not significant.

Table (1): Mean and Standard deviation (SD) values for occlusal force distribution in different groups.

Occlusal contact type	Side	Occlusal force (%) (Mean±SD)		t-value	p-value
		Group I	Group II		
Centric	Right	47.40±2.79	47.40±9.19	0.00	1
	Left	52.60±2.79	52.62±9.22	0.01	0.995
Protrusive	Anterior	67.25±4.99	64.50±5.80	0.62	0.580
	Posterior	32.75±4.99	35.50±5.80	0.62	0.580
Lateral	Working	70.34±4.33	74.80±10.01	0.71	0.531
	Balancing	29.66±4.33	25.32±9.78	0.70	0.536

Discussion

Digital fabrication of complete overdentures leads to standardization of both clinical results and research work and provides the ability to customize tooth shape and occlusal scheme setting. Thus, a quality controlled complete overdenture fabricated with more predictable results than the conventional techniques.[12-14]

This study used CAD/CAM techniques for overdenture fabrication that requires a computerized (3D) virtual jaw relation reconstruction for maxillary & mandibular virtual models with their occlusal bases.[15,16]

In a virtual environment, the virtual articulator represents the temporomandibular joints and jaws, onto which virtual maxillary and mandibular arch models can be attached to simulate mandibular movements. [17]

To improve occlusal registration accuracy, as the tissue-supported base used for complete dentures, may cause errors due to soft tissue compression while recording the jaw relationship, the occlusion blocks were engaged with two implants in the cast. [18,19]

Zebris Jaw Motion Optic, a digital jaw motion analyzer based on optical scanning was used in this study to analyze and track mandibular movements, to identify the rotational hinge axis and to record centric jaw relations. [17, 20,21]

Mandibular movements records are transferred in real time via Bluetooth or cable to the Zebris WinJaw+ software, to calculate the coordinates of the transverse horizontal axis and reproduce the traces of protrusive mandibular movements. The software reproduces colored graphic recordings of the condylar tracks on the sagittal plane of both condyles. Zebris records provide all the necessary parameters for the adjustment of virtual articulators' settings. The movement data can be transferred to the CAD/CAM systems (Exocad) as real movement data or for programming virtual articulators to be used as the reference for designing the occlusion of the prostheses. [22,23]

Lingualized bilaterally balanced occlusion has been reported to improve stability. Thus, arrangement of the denture teeth and simulating the mandibular movements on the virtual articulator to realize dynamic occlusal adjustments by the dental CAD software program to design centric occlusion based on a lingualized occlusion scheme for both groups by the dental CAD software program and was consistent with intraoral occlusion of the definitive denture fabricated by CAM, the protrusive and lateral balanced occlusion were confirmed intraorally as well. [20]

Designing restorations with functional occlusal surfaces is crucial to minimize the need for occlusal adjustments. The occlusal surface of restorations can be tailored to be more functional based on individual mandibular movement parameters and paths. Mandibular movements provide information to eliminate occlusal interferences and to provide physiologic muscle balance. Virtual articulators facilitate the analysis of mandibular movements, enabling the calculation and visualization of static and kinematic occlusal collisions. This allows for adjustments to the digital occlusal surface to ensure smooth, collision-free movements.[24]

In this study, Occlusal analysis was done using T-Scan III. This allowed the occlusal contacts to be recorded conveniently and easily. The device provides precise recordings of the force as well as timing of tooth contact which are utilized as valuable diagnostic variables. T-Scan does not only enable accurate occlusal contact recording, but in addition it helps analyze their force level as well as timing with high precision (100%). The T Scan III computerized system can determine prematurity, high points, non-uniform force concentration and regions of excessive force rapidly. In addition, it can accurately analyze disocclusion time. This system avoids subjectivity in the articulating paper markings interpretation. [25]

In agreement with other study, occlusal forces on working sides were supposed to be double its value on the balancing side (67% and 33% respectively) that gives favorable occlusal balance. The higher the difference the less accurate the distribution of occlusal forces was considered.[26]

To eliminate side to side unbalanced prosthesis torquing, centering of the occlusal force in complete dentures helps to achieve favorable directing of forces. The positive outcomes of this approach on prosthesis insertion were validated with the occlusal force display features incorporated in the T-Scan III computerized occlusal analysis system which measures the precise location and distribution of occlusal forces. The balanced force distribution significantly improves the basal tissue seat supporting the denture by ensuring proper seating of the denture while being loaded during mastication that can be achieved through even distribution of occlusal forces across the broadest and most supportive tissues available.[27,28]

Advantages of virtual articulators include full analysis of static/dynamic jaw movements and occlusion, detailed visualization of tooth contacts and virtual treatment design. Accurate reproduction of the individual jaw movements, some information must be recorded from the patient and transferred to the articulator including the spatial relationship between maxillary arch and skull. [8-10, 29]

Zebris Jaw Motion used to accurately reproduce the inherent condylar guidance as well as the locational relationship between the maxilla and mandible. The validity and accuracy of both typed of virtual articulators was confirmed by T-scan evaluation for the final prostheses and the obtained results were satisfactory.

Reliability of direct assembly of completely adjustable virtual articulator using 4D optical recording with Zebris was tested and stated that setting a completely adjustable virtual articulator through a full digital procedure with Zebris system is possible.[23] While in the mathematically simulating virtual articulator group, positioning of the virtual models in the 3-D space of the digital articulator may be subjected to human error.

The limitation of the present study is the small sample size, so further research is recommended with larger sample sizes.

Conclusion

Within the limitations of this study, it was concluded that:

It could be stated that designing harmonious balanced occlusion for digital implant overdentures with completely adjustable virtual articulator is more reliable than mathematically simulating virtual articulator with minimal need for occlusal adjustments.

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-**Data availability**: data are available on request.
-**Ethics approval**: (OMP21-22D)
-**Competing interests**: no interest.

References

1- Han CG, Park YB, Shim JS, Kim JE. Restorative space analysis by jaw motion tracking using a template in completely edentulous patients. Applied Sciences. 2021 Apr 27;11(9):3933.

2-Lepidi L, Suriano C, Wang Hl, Granata S, Joda T, Li J. Digital Fixed Complete-Arch Rehabilitation: From Virtual Articulator Mounting to Clinical Delivery. J Prosthet Dent. 2020; 127:398-403.

3- Jakubowska S, Szerszeń MP, Kostrzewa-Janicka J. Jaw motion tracking systems–literature review. PROTETYKA STOMATOLOGICZNA. 2023 Mar 27;73(1):18-28.

4- Solaberrieta E, Garmendia A, Minguez R, Brizuela A, Pradies G. Virtual facebow technique. The Journal of Prosthetic Dentistry. 2015 Dec 1;114(6):751-5.

5- Chaturvedi S, Addas MK, Alqahtani NM, Al Ahmari NM, Alfarsi MA. Clinical analysis of CAD-CAM milled and printed complete dentures using computerized occlusal force analyser. Technology and Health Care. 2021 Jan 1;29(4):797-811.

6- Bhambhani R, Joshi S, Roy SS, Shinghvi A. Choosing the denture occlusion-A Systematic review. The Journal of Indian Prosthodontic Society. 2020 Jul 1;20(3):269-77.

7- Wang J, Jin C, Dong B, Yue L, Gao S. Fully digital workflow for replicating treatment dentures: A technique for jaw relation transfer and dynamic occlusal adjustment. The Journal of Prosthetic Dentistry. 2023 Sep 1;130(3):288-94.

8- Gärtner C, Kordass B. The virtual articulator: development and evaluation. International journal of computerized dentistry. 2003 Jan 1;6(1):11-24.

9- Yuan Y, Liu Q, Yang S, He W. Four-dimensional superimposition techniques to compose dental dynamic virtual patients: a systematic review. Journal of Functional Biomaterials. 2023 Jan 6;14(1):33.

10- Kim JE, Park JH, Moon HS, Shim JS. Complete assessment of occlusal dynamics and establishment of a digital workflow by using target tracking with a three-dimensional facial scanner. Journal of prosthodontic research. 2019 Jan 1;63(1):120-4.

11- Luu D, Kan E, Kim SW, Lee JD, Lee SJ. Comparison of Accuracy in Digital and Conventional Cross-Mounting. Journal of Prosthetic Dentistry. 2024;132(4):784-791.

12- Abd El Aziz MS, Abd El EA, Tella M. Fully digital workflow for reinforced mandibular implant overdenture–A novel method. The Journal of Indian Prosthodontic Society. 2022 Apr 1;22(2):205-9.

13- Mai HN, Lee DH. A digital technique to replicate edentulous arches with functional borders and accurate maxillomandibular relationship for digital complete denture. Journal of Prosthodontics. 2020 Apr;29(4):356-9.

14- Kanazawa M, Iwaki M, Arakida T, Minakuchi S. Digital impression and jaw relation record for the fabrication of CAD/CAM custom tray. Journal of prosthodontic research. 2018;62(4):509-13.

15- Li W, Yuan F, Lv P, Wang Y, Sun Y. Evaluation of the quantitative accuracy of 3D reconstruction of edentulous jaw models with jaw relation based on

reference point system alignment. PLoS One. 2015 Feb 6;10(2):e0117320.
16- Li W, Xie Q, Wang Y, Sun Y. A pilot study of digital recording of edentulous jaw relations using a handheld scanner and specially designed headgear. Scientific reports. 2018 Jun 12;8(1):8975.
17- Lin H, Pan Y, Wei X, Wang Y, Yu H, Cheng H. Comparison of the performance of various virtual articulator mounting procedures: a self-controlled clinical study. Clinical Oral Investigations. 2023 Jul;27(7):4017-28.
18- Papaspyridakos P, Lal K. Simple technique to transfer occlusal vertical dimension and articulate a definitive implant cast for a full arch implant prosthesis. Journal of Prosthetic Dentistry. 2008 Oct 1;100(4):320-2.
19- Rungcharassaeng K, Kan JY. Fabricating a stable record base for completely edentulous patients treated with osseointegrated implants using healing abutments. The Journal of prosthetic dentistry. 1999 Feb 1;81(2):224-7.
20- Wang J, Jin C, Dong B, Yue L, Gao S. Fully digital workflow for replicating treatment dentures: A technique for jaw relation transfer and dynamic occlusal adjustment. The Journal of Prosthetic Dentistry. 2023 Sep 1;130(3):288-94.
21- Özdemir G, Albayrak B, Yüzbaşıoğlu E, Us YÖ. Virtual articulators, virtual occlusal records and virtual patients in dentistry. Journal of Experimental and Clinical Medicine. 2021 May;38(3s):129-35.
22- Lepidi L, Grande F, Baldassarre G, Suriano C, Li J, Catapano S. Preliminary clinical study of the accuracy of a digital axiographic recording system for the assessment of sagittal condylar inclination. Journal of dentistry. 2023 Aug 1;135:104583.
23- Peng T, Yang Z, Ma T, Zhang M, Ren G. Comparative evaluation of the volume of occlusal adjustment of repositioning occlusal devices designed by using an average value digital articulator and the jaw movement analyzer. Journal of Prosthetic Dentistry.2023;1:S0022-3913(23)00419-5.
24- Li L, Chen H, Zhao Y, Wang Y, Sun Y. Design of occlusal wear facets of fixed dental prostheses driven by personalized mandibular movement. The Journal of Prosthetic Dentistry. 2022 Jul 1;128(1):33-41.
25- Shawky A, Osama AM. Comparing the effect of occlusal adjustment using T scan and articulating paper on the vertical bone height changes around dental implants supporting lower single fixed detachable hybrid prosthesis. Egyptian Dental Journal. 2021 Apr 1;67(2):1583-91.
26- Bahig D, Faty M. Assessment of retention and occlusion of digitally manufactured complete dentures. Egyptian Dental Journal. 2023 Apr 1;69(2):1377-85.
27- Kerstein RB, Thumati P, Padmaja S. Force finishing and centering to balance a removable complete denture prosthesis using the T-Scan III computerized occlusal analysis system. The Journal of Indian Prosthodontic Society. 2013 Sep; 13:184-8.
28- Ahmed Shawky A, Bahig DE. Evaluation Of Retention and Assessment of Biting Force Distribution of a Complete Denture Fabricated Using 3D Printed Custom Trays with Arcus Digma Versus Conventional Method (A Cross Over Study). Ain Shams Dental Journal. 2021 Sep 1;23(3):120-30.
29- Lepidi L, Chen Z, Ravida A, Lan T, Wang HL, Li J. A full-digital technique to mount a maxillary arch scan on a virtual articulator. Journal of Prosthodontics. 2019 Mar;28(3):335-8.