Evaluation of two computer-aided design software on the adaptation of digitally constructed maxillary complete denture

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Abstract

Aims: This study was conducted to evaluate the adaptation of maxillary complete denture designed by two different open computer-aided design software programs (3Shape and Exocad) using Geomagic surface matching software.

Settings and Design: This was a nonrandomized crossover clinical trial.

Materials and Methods: Twenty completely edentulous patients were selected in this study. Forty complete dentures were designed using two different software programs: twenty dentures were designed by 3Shape software and the other twenty dentures were designed by Exocad software. Maxillary dentures were evaluated regarding their adaptation by measuring the deviations that occurred between the fitting surface of the three-dimensional printed dentures, and the scanned master casts using Geomagic surface matching software.

Statistical Analysis Used: An unpaired *t*-test was used for statistical analysis.

Results: According to the positive average deviation value that represented pressure areas, 3Shape-designed maxillary dentures showed significantly lower mean deviation values (0.041115 ± 0.018165 mm) than Exocad-designed maxillary dentures (0.500665 ± 0.032619 mm). Regarding the negative average deviation values that represented the gap areas, Exocad-designed maxillary dentures showed significantly lower mean deviation values (0.161555 ± 0.007842 mm) than 3Shape-designed maxillary dentures (0.231350 ± 0.009146 mm). The results of the total average deviation values showed significantly lower mean deviation values (0.096950 ± 0.008868 mm) of 3Shape-designed maxillary dentures than Exocad-designed maxillary dentures (0.250755 ± 0.021154 mm).

Conclusion: 3Shape and Exocad software programs produced acceptable maxillary dentures regarding denture adaptation. However, maxillary dentures designed by 3 Shape software showed better adaptation than maxillary dentures designed by Exocad software.

Keywords: 3Shape software, computer-aided design, denture adaptation, digital complete dentures, Exocad software, Geomagic software

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INTRODUCTION

The conventional complete denture is considered the gold standard in treating completely edentulous patients, but unfortunately, this conventional protocol requires multiple patient visits, in addition to a long laboratory time. Nowadays, complete dentures can be constructed using the traditional method, and be simplified by computer programs, not only to decrease the number of patients visit but also to produce a very efficient complete denture.[1]

In the 1990s, Maeda *et al.*[2] fabricated a complete denture for the first time by using computer-aided design/computer-aided manufacturing (CAD/CAM) technology. It was made from photo-polymerized composite resin material with the help of a rapid prototyping technique, which is three-dimensional (3D) laser lithography.

All commercially available systems for complete dentures can receive the standard tessellation language (STL) files whether these files are cast scans, impression scans, or even intraoral scans.[3-5]

A digital denture could be designed using few commercial CAD software closed systems such as Avadent software (Global Dental Science Scottsdale, AZ, USA), and Dentca software (Dentca Inc, CA, USA), while 3Shape (3Shape, Copenhagen, Denmark), Exocad software (Exocad GmbH, Germany), DWOS full denture (Dental wings by Straumann, Germany) and Bluesky software (Bluesky Bio) are open systems..[6-10]

Concerning the accuracy and the precision of digital denture fabrication, the digital denture accuracy and precision are greater than the conventional methods. This accuracy will affect denture retention, stability, and denture fit.[10-12] It is predicted that after several years, the digital denture will be the conventional treatment due to its speed, accuracy, treatment quality, patients' satisfaction, and comfort.[13,14]

Thus, this study was prompted to evaluate which open system software program whether 3Shape or Exocad produces more adapted maxillary denture.

MATERIALS AND METHODS

Study design
This was a nonrandomized crossover clinical trial.

Patient selection
Twenty completely edentulous patients with a mean age of 60 years old were selected with the following inclusion criteria: completely edentulous patients for at least 6 months ago, patients with well-developed ridges of different sizes and shapes, and patients having Class I maxillomandibular relationship. Patients with inflamed mucosa, flabby ridge, and undergoing chemotherapy or radiotherapy were excluded. The period of this study started from March 2019 to February 2021. No follow-up period was needed. This research was approved by the Research ETHICS Committee, Faculty of dentistry, Ain Shams University and with code: FDASU-Rec ID021909.

All patients were informed in detail about the nature and period of the investigation, in addition to the purpose of the study. Each patient was informed about the clinical and laboratory procedures of this study, they agreed to take part in the study, knew their legal duties toward this study, and signed on informed consent. All participants were informed about their legal rights for having the best-adapted denture at the end of this study. Guidelines were followed according to the ethical committee of the institution for clinical trials.

For all patients, primary impressions were taken using alginate impression material (Cavex, Holland) in a properly selected and modified stock tray, then poured in dental stone (Durguix, hard natural stone, Spain) to obtain preliminary casts. Self-cured acrylic resin trays (Cold cured acrylic resin, Acrostone, Egypt) were constructed and used to take secondary impressions with rubber base material (Speedex, Coltene, Whaledent AG, Switzerland). Secondary impressions were boxed, then poured in dental stone to obtain the master cast. Occlusion blocks were constructed using self-cured acrylic resin (Cold cured acrylic resin, Acrostone, Egypt) and wax rims (Cavex wax, The Netherlands, Holland) to record the jaw relation using the check bite registration technique.

Grouping of the study
A total of forty complete dentures were constructed:
- Group A: Twenty maxillary and mandibular complete dentures were designed by 3Shape software
- Group B: Twenty maxillary and mandibular complete dentures were designed by Exocad software.

Data acquisition
Master casts with jaw relation records of the patients were scanned using 3Shape D850 scanner (D850, 3Shape, Copenhagen, Denmark) to have a total number of twenty scanned master cast and twenty scanned jaw relation records. The STL files were imported to the selected software.

Computer-aided design
Forty dentures were designed by two different software programs: 3Shape software program (3Shape dental

designer, 3Shape A/S, Copenhagen, Denmark) and Exocad software program (Exocad DentalCAD; Exocad GmbH).

Group A "3Shape software"

A new order was created for each cast by selecting "Full denture design with PMMA material" in 3Shape software. STL files of master casts and jaw relation records were imported to software, both were virtually mounted and superimposed together by "Best fit match."

Model analysis was made according to the following: the occlusal plane was defined by selecting three control points. Maxillary points were defined such as two maxillary tuberosity and the incisive papilla, in addition to the insertion of two points at the maxillary right and left canine areas. Mandibular points were defined, three points for drawing each retromolar pad (central, buccal, and lingual points), in addition to two points at mandibular right and left canine areas. Borders of the maxillary and mandibular casts were drawn using the "Draw outline button."

Surveying was done automatically on the software, the suitable teeth set up was chosen from the teeth library. Denture bases were automatically generated by the software for the maxillary and mandibular dentures then modified by changing any point position.

The denture was finalized by characterization of the gingiva through the addition of more material at the cervical portion of the teeth and smoothing the surfaces, then the data were saved.

Four files were exported as STL file format, two files for the maxillary and mandibular denture bases and another two files for the maxillary and mandibular teeth. Files were ready for denture manufacturing [Figure 1].

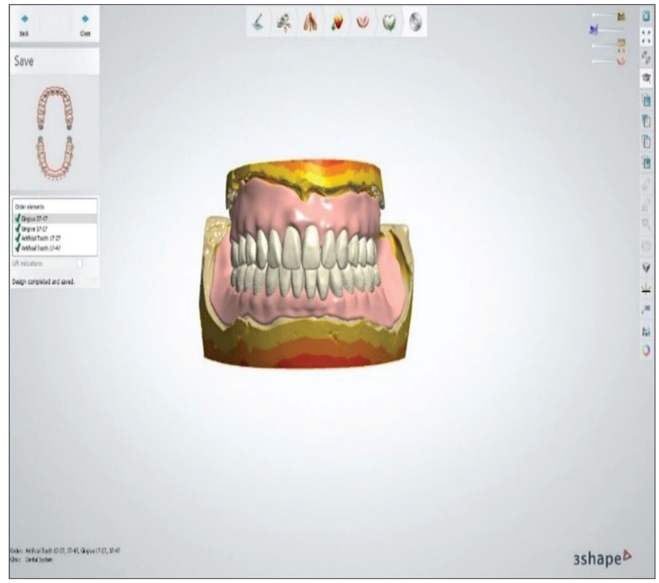

Figure 1: Final design of 3Shape dentures

Group B "Exocad software"

An order was created for each cast by selecting "Full denture design with PMMA material" in Exocad software. STL files of master casts and jaw relation records were imported. They were virtually mounted and aligned using the same method as Group A.

Maxillary model analysis was performed according to the following: the occlusal plane was defined by identifying three control points. Incisive papilla was marked using three or four points so that the blue dot was exactly at the center of the papilla and the other points were marked according to the most prominent part of the incisive papilla. Maxillary tuberosity was marked on both sides. Median palatine raphe was automatically defined by clicking "auto-detect." Canine and first premolar areas were marked. The pterygomandibular fold was identified by placing the red dots on their exact location.

Mandibular model analysis was performed by marking the first premolar positions and the buccal frenum areas. The crest of the ridge was marked by dragging the red point exactly at the center of the ridge. Molar points were identified either by clicking "Auto detect." Borderlines for the distal side of the last molars were identified and the retromolar pad was drawn by marking three points joined together. Maxillary and mandibular models together were finally checked.

The teeth setting was automatically selected from the Exocad library that provides three different teeth sizes (L, XL, and XXL). Path of insertion and removal, denture borders, and teeth setting were defined as the same method used with 3Shape software. Finalizing the design through clicking the "Finish" button to save the files exported as STL file format for denture manufacturing [Figure 2].

Computer-aided manufacturing

Dentures of the two groups were fabricated using an additive manufacturing technique. Dent2 3D printer (Mogassam, Egypt) was used for printing. Each denture had four STL files that were printed separately. Two files for maxillary and mandibular denture bases and another two files for maxillary and mandibular teeth.

STL file of the designed denture bases and the denture teeth was imported to Flash Print software (FlashPrint, Zhejiang Flashforge, China) for automatic generation of supporting arms [Figures 3 and 4]. Exporting

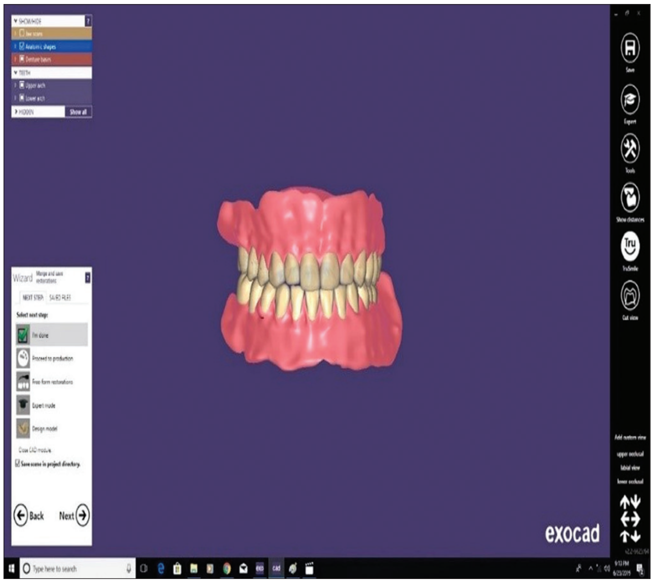

Figure 2: Final design of Exocad denture

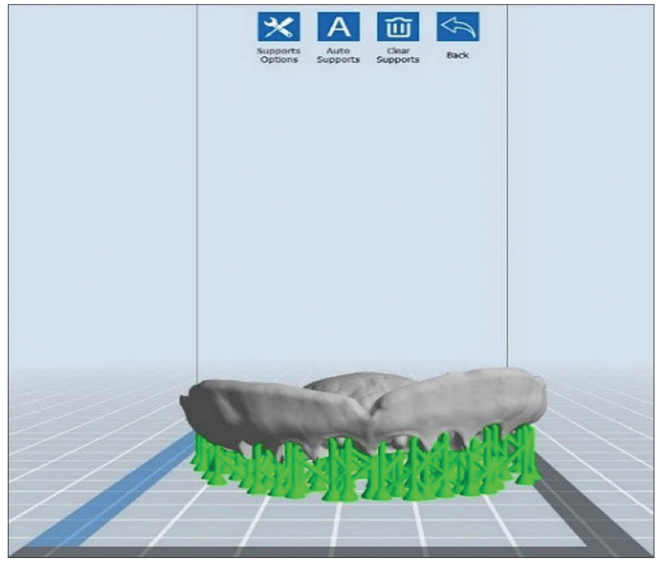

Figure 3: Denture bases with the supporting arms on flash print software

new files for the supported denture bases and the teeth was done.

The STL file of denture bases with the supporting arms was sent to the same 3D printer filled with pink denture base printing resin (NextDent, Denture 3+, Netherlands). The STL file of denture teeth with the supporting arms was sent to the same 3D printer filled with white teeth printing resin (NextDent teeth, Netherlands). The printing resin was the same for both dentures.

Finishing of the denture bases and denture teeth was done by removing the support arms by carbide disc, then they were rinsed in alcohol. Minimum polishing was made to them. The teeth were attached to the denture base by fitting them in the teeth recess in the denture bases. The excess resin of both denture bases and denture teeth was used to attach them together. The complete dentures were cleaned, dried, and placed in the postcuring unit (Mogassam, Egypt) for 15 min.

Denture adaptation evaluation

The fitting surface of the maxillary dentures was sprayed, scanned, and flipped to resemble a cast surface then was saved as an STL file [Figure 5].

Geomagic software (Geomagic Control X 64, 3D systems) was used to evaluate the adaptation of the maxillary denture bases of both the groups. The master cast STL file was selected as reference data, and the STL file of the flipped fitting surface of the denture was selected as measured data. Both files were automatically aligned together by selecting the "best-fit alignment" icon.

The adaptation of the denture bases was automatically generated as a color map according to the distance between the fitting surface of the denture base and the reference data. The cyan to the blue color indicated space between the denture base and the cast surface, the yellow to the red color indicated impingement of the denture base to the cast, and the green color indicated intimate contact between the two surfaces, in addition to the presentation of the denture adaptation as numerical values. The average positive deviation value indicated the pressure areas. The average negative deviation value indicated the gap distance [Figure 6].

The obtained data were recorded, tabulated, and statistically analyzed. The most adapted dentures were delivered to the patients.

Statistical analysis methods

The sample size was calculated by G*Power software for windows version 3.1.9.4 assuming a large effect size, a sample size of 20 dentures in each group was calculated to have 95% power, $\alpha = 0.05$, $1\text{-}\beta = 0.95$.

Statistical analysis was performed with IBM (IBM Corporation, NY, USA) SPSS (SPSS, Inc., an IBM Company) Statistics Version 20 for Windows. An unpaired *t*-test was used for comparison between both groups. The significant level was set at $P \leq 0.05$.

RESULTS

Results of a total of forty maxillary complete dentures: twenty maxillary dentures designed by 3Shape (Group A) and twenty maxillary dentures designed by Exocad (Group B)

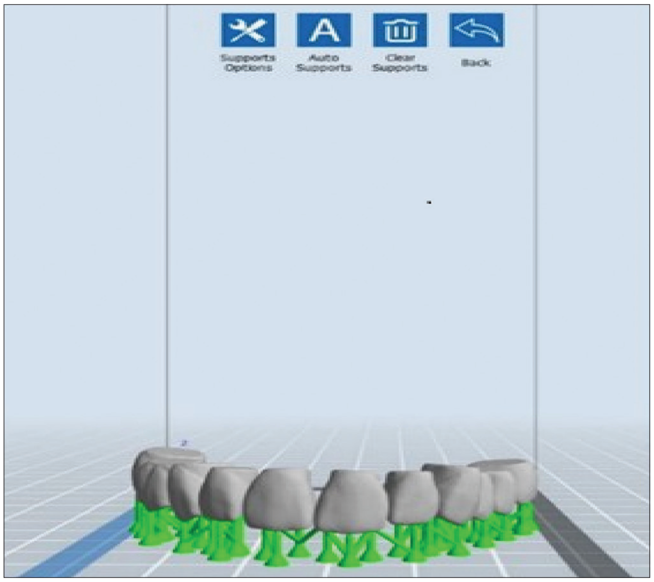

Figure 4: Denture teeth with the supporting arms on FlashPrint software

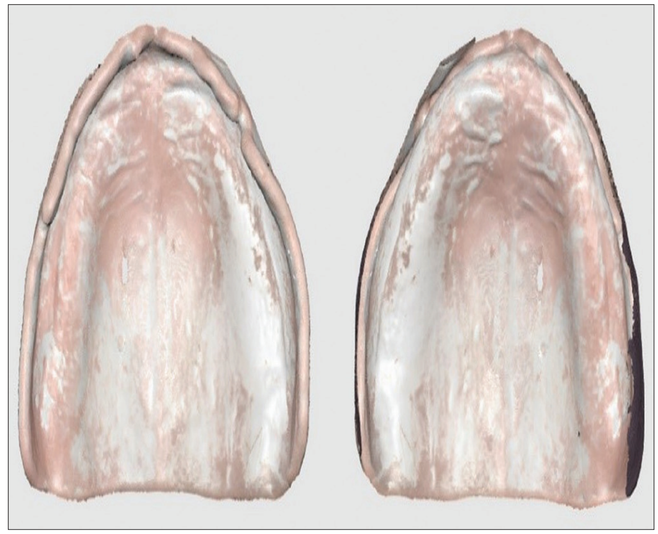

Figure 5: The scanned and the flipped fitting surface of the denture

were presented in the form of positive average deviation values (pressure areas), negative average deviation values (gap areas), and total average deviation value.

Positive average deviation values (pressure areas)

3Shape-designed maxillary dentures had less positive average deviation from the scanned master cast, so less pressure areas, while Exocad-designed maxillary dentures had higher deviation. This difference was statistically highly significant using an unpaired *t*-test, with a 95% confidence interval from −0.106411 to −0.072609 [Table 1].

Table 1: Mean, standard deviation, and *P* value of unpaired *t*-test of the positive average deviation values of the denture adaptation (pressure areas) of two groups

Denture adaptation: Positive average values (pressure area), mean±SD		
3Shape-designed maxillary dentures	Exocad-designed maxillary dentures	*P*
0.0411155±0.018165	0.500665±0.032619	≤0.0001*

*Highly significant at $P \leq 0.0001$. SD: Standard deviation

Negative average deviation values (gap areas)

Exocad-designed maxillary dentures had less negative average deviation from the scanned master cast, so less gap areas, while 3Shape-designed maxillary dentures had higher deviation. This difference was statistically highly significant using an unpaired *t*-test, with a 95% confidence interval from 0.064342 to 0.075248 [Table 2].

Table 2: Mean, standard deviation, and *P* value of unpaired *t*-test of the negative average deviation values of the denture adaptation (gap areas)

Denture adaptation: Negative average values (gap area), mean±SD		
3Shape-designed maxillary dentures	Exocad-designed maxillary dentures	*P*
0.231350±0.009146	0.161555±0.0.007842	≤0.0001*

*Highly significant at $P \leq 0.0001$. SD: Standard deviation

Total average deviation values

Regarding total average deviation values, 3Shape-designed maxillary dentures had less deviation from the scanned master cast, so better adaptation, while Exocad-designed maxillary dentures had higher deviation. This difference was statistically highly significant using an unpaired *t*-test, with a confidence interval from − 0.164188 to − 0.143422 [Table 3].

Table 3: Mean, standard deviation, and *P* value of unpaired *t*-test of the total average deviation values of the denture adaptation

Denture adaptation: Total average deviation, mean±SD		
3Shape-designed maxillary dentures	Exocad-designed maxillary dentures	*P*
0.096950±0.008868	0.250755±0.021154	≤0.0001*

*Highly significant at $P \leq 0.0001$. SD: Standard deviation

DISCUSSION

The main approach for this study was to evaluate which software program will produce the most adaptable denture since adequate denture adaptation will result in good retention, stability, and support.[15]

Patients were selected to obtain the data of this study; this ensures the real results of having master casts with different residual alveolar ridge shapes and sizes. However, any available anatomical factor for a specific patient will not affect the results of the study as it is a crossover study. Patients having Class I maxillomandibular relationships were selected for standardization and easily recording the jaw relation.[16-18] No control group was made since a control group will require a conventional maxillary complete

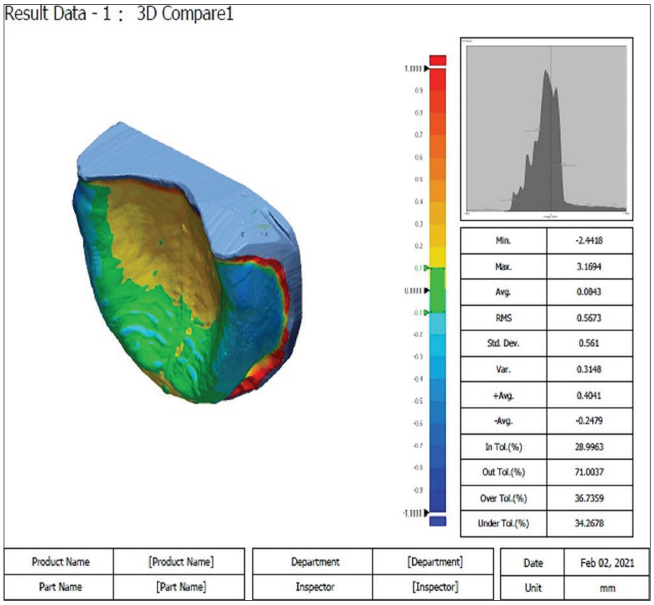

Figure 6: Results of three-dimensional comparison were generated as Geomagic report

denture processed by manual techniques with different material; therefore, it will not be standardized.

The operator who designed the dentures was different from the operator who assessed and evaluated the adaptation of the constructed denture. Patients' data were also coded by a third person to ensure the blindness of the assessor.

CAD software evolution allowed the digitalization of complete dentures which allowed for CAM of either the denture bases or the artificial teeth. 3Shape and Exocad software programs are the most popular CAD software programs used in digital dentistry with an open-source license, both software programs have similar designing steps, also these programs allow the operator to import any STL file and export it to any manufacturing machine whether a 3D printer or milling machine, unlike the closed systems that only allow their exported files to be manufactured through their machines.[19-22]

Although 3Shape and Exocad software programs accept intraoral scanning, in this study, the desktop scanner was used to scan the master casts and jaw relation records instead of the intraoral scanner because till now, the intraoral camera does not accurately record the functional depth of the vestibules, especially in the mandibular ridges.[23,24]

Adaptation is defined as the degree of fit between a prosthesis and supporting structures.[25] Adaptation measurements were performed on maxillary ridges since they have better surface area than the mandibular ridges, so this allows Geomagic software to detect easily several anatomical points for automatic alignment between the measured and the reference data using "best fit alignment" to generate the report of the denture adaptation which gives a realistic result.[26]

The adaptation of the denture bases is interpreted as a color map according to the distance between the fitting surface of the denture base and the reference data. The cyan to the blue color indicated space between the denture base and the cast surface, the yellow to the red color indicated impingement of the denture base to the cast, and the green color indicated intimate contact between the two surfaces. The denture adaptation was also presented as numerical values. The average positive deviation value indicated pressure areas and the average negative deviation value indicated the gap distance. This method was in accordance with several studies.[27-31]

In this study, the positive average deviation values for 3Shape- and Exocad-designed dentures were 0.411155 ± 0.018165 and 0.500665 ± 0.032619 mm, respectively, while the negative average deviation values of 3Shape- and Exocad-designed dentures were 0.231350 ± 0.009146 and 0.161555 ± 0.001754 mm, respectively. Regarding the total average deviation values of 3Shape-designed dentures and Exocad-designed dentures were 0.096950 ± 0.008868 and 0.250755 ± 0.021154 mm respectively. The results are consistent with the study of You *et al*.[32] which stated that the negative average deviation values were 0.299 ± 0.035 mm, also it was consistent with the study of Kalberer *et al*.[33] which stated that the total average deviation values were 0.0953 ± 0.0075 mm, while Russo *et al*.[30] stated that the total average deviation values were 0.018 ± 0.021 mm. While Hwang et al.[34] conducted a study stated that the positive average deviation values were 0.0632 ± 0.004 mm, while the negative average deviation values were 0.063 ± 0.005 mm, and the total average deviation values were <0.1 mm.

The results of this study showed that each software program was capable of producing dentures with superior adaptation since it is considered that the acceptable range for the adaptation deviation is 0.05 mm up to 0.3 mm.[16,34,35] However, these differences in the results between the two software programs might be due to that 3Shape software had easier steps and fewer number of designing steps, especially the steps of the model analysis, unlike Exocad software that required multiple design steps, which might lead to progression of errors. The increased number of steps of model analysis needs prolonged computational time that might lead to decreased focus, especially with a less experienced operator. This was in addition to the compatibility between the 3Shape software and its scanner, where there is no Exocad scanner available in the market.

Clinical implication

This study helps operators to select the most suitable software program in their clinic for designing complete dentures.

Limitations

- The evaluation of adaptation was performed extra-orally, so the dynamic feature of the soft tissues during mastication cannot be assessed
- This study compared only the maxillary complete dentures, not the mandibular ones.

Recommendation

- Clinical evaluation for adaptation of maxillary complete dentures is recommended
- Adaptation of the digital maxillary complete dentures is recommended to be evaluated using other types of scanners instead of 3Shape desktop scanners
- Evaluation of adaptation of mandibular complete denture is recommended.

CONCLUSIONS

Both the software programs produced acceptable maxillary complete dentures regarding denture adaptation. However, maxillary complete dentures designed by 3Shape software showed better adaptation than maxillary complete dentures designed by Exocad software.

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Conflicts of interest

There are no conflicts of interest.

REFERENCES

1. Kattadiyil MT, AlHelal A, Goodacre BJ. Clinical complications and quality assessments with computer-engineered complete dentures: A systematic review. J Prosthet Dent 2017;117:721-8.
2. Maeda Y, Minoura M, Tsutsumi S, Okada M, Nokubi T. A CAD/CAM system for removable denture. Part I: Fabrication of complete dentures. Int J Prosthodont 1994;7:17-21.
3. Russo L, Salamini A, Troiano G, Guida L. Digital dentures: A protocol based on intraoral scans. J Prosthet Dent 2021;125:597-602.
4. Baba NZ, Alrumaih HS, Goodacre BJ, Goodacre CJ. Current techniques in CAD/CAM denture fabrication. Gen Dent 2016;64:23-8.
5. AlHelal A, AlRumaih HS, Kattadiyil MT, Baba NZ, Goodacre CJ. Comparison of retention between maxillary milled and conventional denture bases: A clinical study. J Prosthet Dent 2017;117:233-8.
6. Ma Z, Han W, Iv Y, Li Y, Cao J, Han Y, *et al.* Design of complete dentures by adopting CAD developed for fixed prostheses. J Prosthodont 2016;27:212-9.
7. Kattadiyil MT, Goodacre CJ, Baba NZ. CAD/CAM complete dentures: A review of two commercial fabrication systems. J Calif Dent Assoc 2013;41:407-16.
8. Su FY, Tsai JC, Morton D, Lin WS. Use of an open-source CAD software program and additive manufacturing technology to design and fabricate a definitive cast for retrofitting a crown to an existing removable partial denture. J Prosthet Dent 2019;122:351-4.
9. Lee SY, Kim H, Lee D, Park C. Modified digital workflow for artificial tooth exchange in a complete denture: A dental technique. J Prosthet Dent 2020;123:236-8.
10. Kanazawa M, Iwaki M, Arakida T, Minakuchi S. Digital impression and jaw relation record for the fabrication of CAD/CAM custom tray. J Prosthodont Res 2018;62:509-13.
11. AlHelal A, Jekki R, Richardson PM, Kattadiyil MT. Application of digital technology in the prosthodontic management of a patient with myasthenia gravis: A clinical report. J Prosthet Dent 2016;115:531-6.
12. Goodacre BJ, Goodacre CJ, Baba NZ, Kattadiyil MT. Comparison of denture tooth movement between CAD-CAM and conventional fabrication techniques. J Prosthet Dent 2018;119:108-15.
13. Bacali C, Mesaroş A Ştefania, Năstase V, Constantiniuc M. Particularities of CAD-CAM commercial systems with applicability in the orofacial sphere; digital complete denture. Health Sport Rehabil Med 2019;20:22-5.
14. Srinivasan M, Kalberer N, Naharro M, Marchand L, Lee H, Müller F. CAD-CAM milled dentures: The Geneva protocols for digital dentures. J Prosthet Dent 2020;123:27-37.
15. Murray MD, Darvell BW. The evolution of the complete denture base. Theories of complete denture retention-a review. Part 1. Aust Dent J 1993;38:216-9.
16. Goodacre BJ, Goodacre CJ, Baba NZ, Kattadiyil MT. Comparison of denture base adaptation between CAD-CAM and conventional fabrication techniques. J Prosthet Dent 2016;116:249-56.
17. McGarry TJ, Nimmo A, Skiba JF, Ahlstrom RH, Smith CR, Koumjian JH. Classification system for complete edentulism. J Prosthodont 1999;8:27-39.
18. Rangarajan V, Gajapathi B, Yogesh P, Ibrahim Mm, Kumar Rg, Karthik P. Concepts of occlusion in prosthodontics: A literature review, Part II. J Indian Prosthodont Soc 2016;15:200-5.
19. Schweiger J, Stumbaum J, Edelhoff D, Güth JF. Systematics and concepts for the digital production of complete dentures: Risks and opportunities. Int J Comput Dent 2018;21:41-56.
20. Patzelt SB, Vonau S, Stampf S, Att W. Assessing the feasibility and accuracy of digitizing edentulous jaws. J Am Dent Assoc 2013;144:914-20.
21. Sun J, Zhang FQ. The application of rapid prototyping in prosthodontics. J Prosthodont 2012;21:641-4.
22. Bilgin MS, Baytaroğlu EN, Erdem A, Dilber E. A review of computer-aided design/computer-aided manufacture techniques for removable denture fabrication. Eur J Dent 2016;10:286-91.
23. Lo Russo L, Salamini A. Removable complete digital dentures: A workflow that integrates open technologies. J Prosthet Dent 2018;119:727-32.
24. Goodacre B, Goodacre C. Using intraoral scanning to fabricate complete dentures: First experiences. Int J Prosthodont 2018;31:166-70.
25. Driscoll CF, Freilich MA, Guckes AD, Knoernschild KL, Mcgarry TJ. The glossary of prosthodontic terms. J Prosthet Dent 2017;117:e1-105.
26. Yoon SN, Oh KC, Lee SJ, Han JS, Yoon HI. Tissue surface adaptation of CAD-CAM maxillary and mandibular complete denture bases manufactured by digital light processing: A clinical study. J Prosthet Dent 2020;124:682-9.
27. Hsu CY, Yang TC, Wang TM, Lin LD. Effects of fabrication techniques on denture base adaptation: An *in vitro* study. J Prosthet Dent 2020;124:740-7.
28. Wang C, Shi YF, Xie PJ, Wu JH. Accuracy of digital complete dentures: A systematic review of *in vitro* studies. J Prosthet Dent 2020;125:249-56.
29. Jin MC, Yoon HI, Yeo IS, Kim SH, Han JS. The effect of build angle

on the tissue surface adaptation of maxillary and mandibular complete denture bases manufactured by digital light processing. J Prosthet Dent 2020;123:473-82.
30. Lo Russo L, Guida L, Zhurakivska K, Troiano G, Chochlidakis K, Ercoli C. Intaglio surface trueness of milled and 3D-printed digital maxillary and mandibular dentures: A clinical study. J Prosthet Dent 2021:S0022-3913(21)00262-6.
31. You SM, You SG, Lee BI, Kim JH. Evaluation of trueness in a denture base fabricated by using CAD-CAM systems and adaptation to the socketed surface of denture base: An *in vitro* study. J Prosthet Dent 2020:S0022-3913(20)30573-4.
32. You SG, You SM, Kang SY, Bae SY, Kim JH. Evaluation of the adaptation of complete denture metal bases fabricated with dental CAD-CAM systems: An *in vitro* study. J Prosthet Dent 2020;125:479-85.
33. Kalberer N, Mehl A, Schimmel M, Müller F, Srinivasan M. CAD-CAM milled versus rapidly prototyped (3D-printed) complete dentures: An *in vitro* evaluation of trueness. J Prosthet Dent 2019;121:637-43.
34. Hwang HJ, Lee SJ, Park EJ, Yoon HI. Assessment of the trueness and tissue surface adaptation of CAD-CAM maxillary denture bases manufactured using digital light processing. J Prosthet Dent 2019;121:110-7.
35. Artopoulos A, Juszczyk AS, Rodriguez JM, Clark RK, Radford DR. Three-dimensional processing deformation of three denture base materials. J Prosthet Dent 2013;110:481-7.