Original Article

Comparison of two CAD software on the consistency between custom abutment design and milling machine output

Fariborz Vafaee[1], Sara Khazaei[1], Maryam Farhadian[2], Amirhossein Jafari[1], Mohammad Saedi[1], Hadi Yousefvand[1]*

[1]Department of Prosthodontic, Hamadan University of Medical Sciences, Hamadan, Iran. [2]Department of Biostatistics, Hamadan University of Medical Science, Hamadan,Iran.

Correspondence: Hadi Yousefvand, Department of Prosthodontic, Hamadan University of Medical Sciences, Hamadan, Iran. yusufvandhadi@yahoo.com

ABSTRACT

As digital technology continues to advance rapidly; the reliability and reproducibility of CAD software programs have become more important than ever. The purpose of this study is to compare the reproducibility of custom abutment designs using two CAD software programs: 3Shape Dental System CAD and exocad DentalCAD. The study consisted of designing abutments for 20 patient scans using 3Shape Dental System CAD and another 20 scans using exocad DentalCAD. The abutments were then milled in the laboratory with a 5-axis milling machine. Afterward, the shaved abutments were scanned and saved as STL files. To evaluate the differences in the designs, a three-dimensional analysis software called Geomagic Control X was used to compare and overlay the output files from either 3Shape Dental System CAD or exocad DentalCAD software with the scanned files. The statistical analysis, specifically the Mann-Whitney test, showed that there was no significant difference in consistency values between the two software programs (P-value=0.552). This means that both software programs perform similarly, demonstrating reliable repeatability and high accuracy as intended. This study highlights that both exocad and 3Shape software have the ability to consistently and accurately produce results. Therefore, using both software solutions for designing customized abutments leads to satisfactory outcomes.

Keywords: Abutment, CAD/CAM, Digital dentistry, Milling, Prothesis

Introduction

The popularity of dental implants is growing, thanks to the success of osseointegration. As a result, there is now a greater emphasis on meeting patients' needs for high-quality restorations, such as abutments and all-ceramic restorations Amraei, Heidari [1]. Since the 1980s, the use of Computer-Aided Design (CAD) and Computer-Aided Manufacturing (CAM) technology by dental technicians has been steadily increasing [2]. CAD/CAM technology has played a crucial role in creating all-ceramic restorations [3]. The use of this technology in producing restorations, particularly for implant restorations, is expanding as the demand for improved performance and aesthetics in implant prosthesis treatments continues to rise [4]. Customized abutments have become more popular because of the limitations of stock abutments. These limitations include the need for shape revisions, compromised grip, and the possibility of an unnatural final prosthesis profile [5]. CAD/CAM technology offers several advantages in abutment design. It allows for the creation of an appropriate profile emergence, reduces the risk of prosthesis breakage by adjusting the thickness on the abutment, provides flexibility in margin positioning, and makes it easier to remove excess cement [6].

The CAD/CAM process involves several steps, including scanning the oral cavity, designing the restoration on a virtual working cast, and milling the restoration from a solid block of restorative material or additive manufacturing [7].

The use of custom abutments is necessary in different clinical situations. These include cases with limited interocclusal space, the need for an implant angle greater than 15 degrees, a gingival crest height that exceeds the stock base crest height by 1 mm, the requirement for parallelism in achieving more than three restoration units, or when optimal soft tissue management is needed [8, 9].

This study directly addresses the clinical need for evaluating the consistency of customized abutment designs across diverse clinical conditions through the use of modern CAD software

programs, paving the way for potential advancements in personalized treatment strategies and improved patient care. In this study, we aim to compare the consistency of design for customized abutments across various clinical conditions using two modern CAD software programs.
Null hypothesis: The two CAD software programs (exocad and 3Shape) exhibit similar functions.

Materials and Methods

The abutments were designed using two different software programs, 3Shape and exocad, which are widely recognized CAD software programs (fig1.a, fig2.a). These programs have comparable design methodologies and both support the preparation of STL files, which can be used with different printers and milling devices. Therefore, we selected these two software programs to create customized abutments in order to compare their compatibility and reproducibility [10-13].

The design process involved creating abutments for a total of 40 cases. For the first 20 cases, 3Shape Dental System CAD software from 3Shape (Copenhagen, Denmark) was used. The remaining 20 cases were created using exocad Dental CAD software from Exocad Gmbh (Germany). After the design phase, the abutments were sent for fabrication. Carving was done using an ARUM 5x-100 five-axis milling machine from Doowon Inc. in Daegeon, Korea, and premilled blanks from Arum in Korea. Scans of the milled abutments were then generated using a Ceramill Map400 scanner from Amann Girrbach GmbH and saved in STL file format (fig1.b, fig2.b).
The output files generated by the 3Shape Dental System CAD or exocad DentalCAD software, as well as the scanned files from the Ceramill Map400 scanner, were overlapped using 3D analysis software (Geomagic Control X, 3D Systems, USA) **(Figure1.c, Figure 2.c).** This software was then used to evaluate the differences in design and their corresponding results.

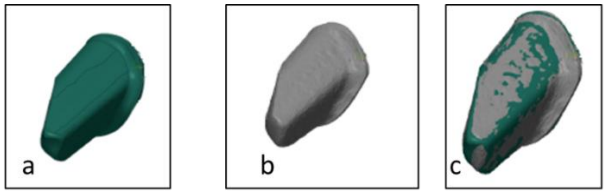

Figure 1: 3shape software document no.1: teeth#13 preparation: a) abutment design. b) abutment milling. C) superimposition of a,b

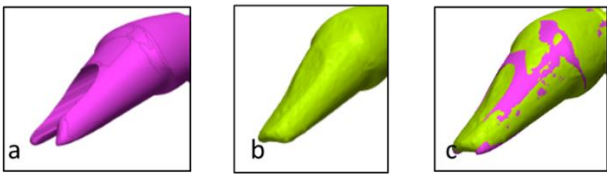

Figure2: exocad software document no.4 :teeth#9 preparation : a) abutment design. b) abutment milling. C) superimposition of a,b

Statistical analysis

A Kolmogorov-Smirnov test was used to assess normality and determined that the distribution of compatibility values across the two software programs was not normal (P-value<0.05). Therefore, a non-parametric Mann-Whitney test was conducted to compare the average consistency between the two software programs.

Results and Discussion

The analysis using SPSS 2021 showed no statistically significant difference in the compatibility values (P-value=0.552), indicating that both software programs performed similarly **(Figure 3)**.

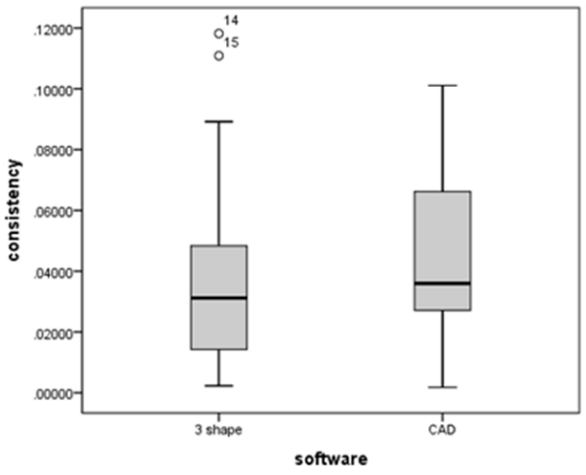

Figure 3: Boxplot of compatibility values in two software

Descriptive information related to compatibility values is provided in the following table: **(Table 1)**

Table 1: Descriptive information

	Software	N	Mean	Std. Deviation
consistency	3 Shape	20	.040	.035
	CAD	20	.044	.032

Therefore, both software solutions demonstrate the potential to deliver reliable repeatability and high accuracy in accordance with the intended design specifications.

The main objective of this study was to evaluate design software for custom abutment design and determine which software solution is superior. The results of this investigation showed no significant difference in consistency values between the exocad and 3Shape software (P-value=0.552), indicating that both software solutions performed similarly. It is important to note that the designer and the person assessing design-to-milling compatibility were different individuals. To ensure unbiased assessment, a third party coded the data, maintaining a blinded study environment. To date, no identical study has been conducted, but there have been comparative studies on the

design of dentures or temporary crowns using exocad and 3Shape software. El Galil *et al*. found clinically acceptable adaptation in both groups, with slightly better results in the 3Shape group. This aligns with our study findings, which may be attributed to the ease of design with 3Shape software and a reduction in errors [14].

Wang *et al*. also found higher accuracy in crowns designed with CEREC and 3Shape software compared to exocad, with CEREC showing greater stability. Our study found slightly better results for 3Shape compared to exocad, although not statistically significant [15].

Harsha *et al*. used exocad and Ortho Analyzer software, alongside a manual method, to assess model analysis accuracy. The result showed no high accuracy levels in comparison to the manual method for both software [16].

Ghaffari *et al*. conducted a study on the compressive strength of temporary crowns created using 3Shape and exocad software. Both methods showed satisfactory strength, but the 3Shape group exhibited slightly higher average strength. This could be attributed to the superior and more precise design achieved with 3Shape software [17].

Hyun *et al*. conducted a comparison between the accuracy and milling performance of two software programs, namely 3Shape and Delta9. The results showed significantly fewer errors in most abutment design options when using the Delta9 CAD software. These findings imply that the Delta9 CAD software has the potential to deliver reliable repeatability and high accuracy in accordance with the intended design [18].

During this study, we came across several limitations. These included the possibility of digital errors like scanner error or alignment issues related to the geomagic measurement technique. Another limitation was that we did not specifically address errors that occurred during the milling stage, such as wear of the milling cutter, because they had a similar impact on both groups. It is important to recognize the potential impact of errors that could have occurred during the overlapping path of design scan and milling scan files. This includes design errors, errors in creating the STL file, and practical errors during the insertion of the STL file. These errors may have influenced the experimental results.

This study highlights the fact that both exocad and 3Shape software have the ability to consistently and accurately produce results. Therefore, using both software solutions for designing customized abutments leads to satisfactory outcomes. In future studies, it would be beneficial to evaluate the long-term clinical success of patient crowns designed with exocad and 3Shape software.

Conclusion

This study highlights that both exocad and 3Shape software have the ability to consistently and accurately produce results. Therefore, using both software solutions for designing customized abutments leads to satisfactory outcomes.

Acknowledgments: None

Conflict of interest: None

Financial support:. None

Ethics statement: The Ethics Review Board of Hamadan University of Medical Sciences approved the present study with the following number: IR.UMSHA.REC.1402.273.

References

1. Amraei H, Heidari B, Khazaei S, Amini P, Firouz F. Laboratory Evaluation of Torque Loss in Titanium, One-Piece and Two-Piece Zirconia Abutments Under Cyclic Loading. Avicenna J Dent Res. 2020 Jun 30;12(2):46-50.
2. Su TS, Sun J. Comparison of repeatability between intraoral digital scanner and extraoral digital scanner: An in-vitro study. J Prosthodont Res. 2015 Oct;59(4):236-42.
3. Nikanjam S, Abbasi S, Khazaei S. Effect of different bleaching methods on optical behaviors of CAD/CAM ceramics. Avicenna J Dent Res. 2021 Dec 16;13(4):113-8.
4. Kapos T, Ashy LM, Gallucci GO, Weber HP, Wismeijer D. Computer-aided design and computer-assisted manufacturing in prosthetic implant dentistry. Int J Oral Maxillofac Implants. 2009;24 Suppl:110-7.
5. Kim JW, Heo YR, Kim HJ, Chung CH. A comparative study on the fit and screw joint stability of ready-made abutment and CAD-CAM custom-made abutment. J Korean Acad Prosthodont. 2013 Oct 1;51(4):276-83.
6. Priest G. Virtual-designed and computer-milled implant abutments. J Oral Maxillofac Surg. 2005 Sep;63(9 Suppl 2):22-32.
7. Abdullah AO, Muhammed FK, Zheng B, Liu Y. An Overview of Computer Aided Design/Computer Aided Manufacturing (CAD/CAM) in Restorative Dentistry. J Dent Mater Tech. 2018 Jan 1;7(1).
8. Alshhrani WM, Al Amri MD. Customized CAD-CAM healing abutment for delayed loaded implants. J Prosthet Dent. 2016 Aug;116(2):176-9.
9. Thulasidas S, Givan DA, Lemons JE, O'Neal SJ, Ramp LC, Liu PR. Influence of implant angulation on the fracture resistance of zirconia abutments. J Prosthodont. 2015 Feb;24(2):127-35.
10. 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(1):41-56.
11. Patzelt SB, Vonau S, Stampf S, Att W. Assessing the feasibility and accuracy of digitizing edentulous jaws. J Am Dent Assoc. 2013 Aug;144(8):914-20.
12. Sun J, Zhang FQ. The application of rapid prototyping in prosthodontics. J Prosthodont. 2012 Dec;21(8):641-4.

13. 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 Apr-Jun;10(2):286-91.
14. Abd El Galil EG, Mohamed SL, Rizk FN, Sabet ME. Evaluation of two computer-aided design software on the adaptation of digitally constructed maxillary complete denture. J Indian Prosthodont Soc. 2021 Oct-Dec;21(4):383-90.
15. Wang F, Zhang T, Zhou Q, Lu Y. Comparison of the morphological accuracy of automatic crowns designed by multiple computer-aided design software programs with different levels of dentition information acquisition. J Prosthet Dent. 2024 Aug;132(2):441-52.
16. Harsha L, Jain RK. Comparative Assessment of Reliability and Accuracy of Two Different Software's Used for Model Analysis. J Res Med Dent Sci. 2021 Sep;9(9):122-6.
17. Ghaffari T, Nourizadeh A, Shafiei E, Mahboub F, Kalantari AR. Compressive Strength of Temporary Crowns Made from Default design in Two Types of Software. J Dent (Shiraz). 2023 Mar;24(1):47-52.
18. Lim HM, Lee KB, Lee WS, Son K, Comparative study of two CAD software programs on consistency between custom abutment design and the output. J Dent Rehabil Appl Sci, 2018 Sep 1;34(3):157-66.