THE JOURNAL OF PROSTHETIC DENTISTRY

CLINICAL RESEARCH

Comparison of nonscheduled, postinsertion adjustment visits for complete dentures fabricated with conventional and CAD-CAM protocols: A clinical study

Carl Drago, DDS, MS[a] and Andrew J. Borgert, PhD[b]

ABSTRACT

Statement of problem. Unscheduled denture-adjustment visits may disrupt both patients and clinicians. Denture-adjustment visits have not been correlated with denture-processing methods.

Purpose. The purpose of this clinical study was to identify differences in the number of unscheduled postinsertion-adjustment visits of patients with complete dentures fabricated by injection molding (IM) versus dentures fabricated by computer-aided design and computer-aided manufacturing (CAD-CAM).

Material and methods. One hundred six participants were evaluated in the study. They were consecutively treated in a private practice setting and followed up for 1 year after the insertion of new complete dentures. The first 33 received dentures fabricated using an IM system, and the other 73 were milled using a CAD-CAM system. All participants had been edentulous for at least 1 year. Participant ages ranged from 29 to 83 years. IM dentures were fabricated by a commercial dental laboratory; CAD-CAM dentures were milled by a commercial manufacturer. All participants were scheduled for 1- or 2-week postinsertion office visits. Further adjustment visits were scheduled according to participant request. The results were tabulated, and univariable tests of association were performed including chi-square and the Fisher exact tests for categorical comparisons and the Wilcoxon rank sum test for comparison of ordinal continuous data. A multivariable logistic regression model was used to control for the influence of multiple predictor variables on the outcome of interest.

Results. Edentulous years ranged from 1 to 60. Approximately one half (n=56) of all participants returned for scheduled postinsertion visits approximately 1 to 2 weeks after insertion of the dentures. No significant demographic or clinical differences were noted between participants receiving CAD-CAM or conventional dentures. Return visits for unscheduled adjustments were not associated with the method of denture fabrication or any other demographic features (P=.55).

Conclusions. Based on the results of this study, there were no significant differences in the number of unscheduled, postinsertion visits for participants whose dentures were fabricated following IM or CAD-CAM milling protocols. Clinicians may choose to fabricate complete dentures with either protocol and expect similar clinical results in terms of the number of unscheduled postinsertion visits. (J Prosthet Dent 2019;122:459-66)

Felton[1] stated that edentulism is the terminal outcome of a multifactorial process involving biologic and patient-related factors. Treatment of edentulous patients with complete dentures is technically demanding,[2] and making definitive impressions is one of the most critical steps in complete denture fabrication.[2,3] The objectives of complete denture definitive impressions include accurate replication of denture-bearing areas to produce stable and retentive prostheses while providing comfort to patients and desired esthetics and preserving remaining tissues.[4] In a systematic review of complete denture fabrication techniques, Ye and Sun[5] reported that

This study was supported in part by the Gundersen Lutheran Medical Foundation. This research did not receive any specific grant from funding agencies in the public, commercial, or not-for-profit sectors.

[a]Prosthodontist, Gundersen Health System, LaCrosse, Wis.; and Adjunct Associate Professor, Graduate Prosthodontics, Marquette University School of Dentistry, Milwaukee, Wis.

[b]Biostatistician, Gundersen Lutheran Medical Foundation, LaCrosse, Wis.

Clinical Implications

Choosing the computer-aided design and computer-aided manufacturing process used in this study is unlikely to affect the number of unscheduled, postinsertion appointments for edentulous patients when compared with that for patients with dentures made with an injection molding process.

simplified methods could replace or partially replace traditional fabrication methods. Jo et al[6] reported the results of a controlled clinical trial regarding different impression methods used for fabricating complete dentures with the primary outcome of general patient satisfaction. They reported that the conventional method resulted in better patient satisfaction than the simplified dentures.

Dentures and denture teeth have been fabricated using polymethyl methacrylate for many years. Acrylic resin denture teeth chemically bond to acrylic resin denture bases and are also preferred for cost and esthetic reasons.[7] Computer-aided design and computer-aided manufacturing (CAD-CAM) technologies have been used for single-visit restorative and fixed prosthodontic treatments for several years.[8,9] Rapid prototyping (RP) is another innovative technology adapted for use in dentistry. With appropriate software, it has been possible to position teeth in occlusion and modify tooth shapes, angles, and flange design using specific computer software programs.[10]

Bilgin et al[11] discussed 2 approaches for fabricating complete dentures with CAD-CAM and RP protocols. The authors concluded that CAD-CAM and RP technologies eliminated the need for clinicians to assign denture esthetics to technicians and provided patients the opportunity to participate in esthetic designing.

Matsuda et al[12] evaluated a partially digitized system for scanning and interocclusal records for complete denture fabrication. The authors concluded that this CAD-CAM method with preliminary digital scans and specialized trays would be feasible for clinical use for complete denture fabrication but that further improvements and refinements were needed.

Kanazawa et al[13] described the fabrication of complete dentures using a CAD-CAM system and measured deviations between the master 3D complete denture image and the 3D data of the dentures. Even though the authors only reported results for 1 denture, they concluded that it was possible to fabricate complete dentures using this CAD-CAM system.

Goodacre et al[14] described a commercially available CAD-CAM system that imaged, designed, and milled complete dentures. A prototype 3D tooth arrangement program was developed to arrange prosthetic teeth virtually as part of the overall CAD-CAM fabrication of complete dentures. They subsequently compared the surface accuracy of a conventional denture fabrication method versus a CAD-CAM method of fabricating complete dentures[15] and reported that the overall mean values were comparable. However, the range of misfit was greater with conventional techniques than that with CAD-CAM denture bases; complete denture bases milled from prepolymerized blocks of resin had more uniform adaptation to the edentulous jaws than those fabricated using conventional techniques.

Bidra et al[16] presented clinical and patient-centered results of 2-visit CAD-CAM dentures and implant-retained overdentures. An average of 3.3 denture adjustments were needed after insertion (0-10) during the 1-year period. They concluded that the clinical and patient-centered outcomes for CAD-CAM monolithic dentures fabricated using a 2-visit protocol were evaluated favorably at 1-year follow-up visits.

Using the term "denture adjustments" in a PubMed search, 222 publications were cited. Articles that identified denture maintenance,[17] prognoses of new complete dentures from patient denture assessments of existing dentures,[18] and clinical performances of CAD-CAM complete dentures[19] were found. No specific studies reported on potential correlations between denture-adjustment clinical visits and denture fabrication methods.

Denture fabrication is a time- and technique-sensitive process. One of the potential limitations of complete denture treatment is how well denture bases fit edentulous jaws. Denture adaptation is a complex phenomenon subject to many variables, including accuracy of the denture base fit.

The purpose of this clinical study was to report on differences in unscheduled, postinsertion visits for denture adjustments relative to participants treated with dentures processed conventionally versus dentures milled by a CAD-CAM denture technology. The null hypothesis was that no differences would be found in the number of unscheduled, postinsertion visits regarding dentures processed conventionally and dentures fabricated by a CAD-CAM, milled technology.

MATERIAL AND METHODS

A CAD-CAM protocol (AvaDent CORE; Global Dental Sciences) was introduced into the author's prosthodontic practice at the Gundersen Health System, LaCrosse, WI, in March 2015. Participant records were identified through a computerized search of the electronic medical records using the American Dental Association codes (5110, maxillary complete denture; 5120, mandibular complete denture). Gundersen Health System is an independent, fee-for-service health-care provider.

The appointment series for complete dentures in this practice included a scheduled postinsertion visit approximately 1 to 2 weeks after denture insertion. The experimental variable for this study was defined as unscheduled postinsertion visits by participants treated with complete dentures (American Dental Association codes: 5410, maxillary complete denture adjustment; 5411, mandibular complete denture adjustment) after the first scheduled visit 1 to 2 weeks after insertion. A dental assistant reviewed the charts and recorded the requisite data up to 1 year after insertion of the new dentures.

Consecutive edentulous participants (N=106) aged 29 to 83 years were included in this study. All participants had been edentulous for at least 1 year and had previously worn complete dentures (range: 1 to 60 years). Participants were treated by 1 of 2 board-certified prosthodontists using the same materials used for preliminary impressions for diagnostic casts and custom denture impression trays, jaw-relation records, and clinical evaluation appointments. After participants and clinicians had approved the trial dentures, the dentures were fabricated with 1 of 2 methods: injection molding (SR Ivocap Injection System; Ivoclar Vivadent AG) or CAD-CAM (AvaDent CORE; Global Dental Sciences). The type of processing was determined by the date the scanner was purchased.

Participants with conventionally processed complete dentures were treated with a 5-visit protocol: preliminary impressions, definitive impressions/custom trays, jaw-relation records/tooth selection, wax evaluation, and insertion. Clinical and laboratory remount procedures were accomplished at the denture-insertion appointments (Fig. 1A).

Participants with CAD-CAM complete dentures were treated with a 4-visit protocol: preliminary scanning and impression; definitive scan and impression/custom trays and jaw-relation records (Fig. 1B); biofunctional (AvaDent CORE; Global Dental Sciences) evaluation (white milled dentures); and insertion. Mandibular impressions were made first by adjusting the peripheral borders of custom impression trays in a conventional fashion, followed by border molding using a heavy-body polyvinyl siloxane impression material. Definitive impressions were made using a light-body polyvinyl siloxane impression material. The intaglio surfaces of the mandibular impressions were then scanned using an intraoral scanner (TRIOS 3; 3Shape, Inc). Impression scanning was performed using a handheld intraoral scanner outside of the mouth because the authors found it to be more predictable than using the laboratory bench-top scanner provided by the milling center.

Maxillary impressions were made in a similar fashion (Figs. 2, 3). After the maxillary impressions were made, occlusion rims were contoured on the impression trays

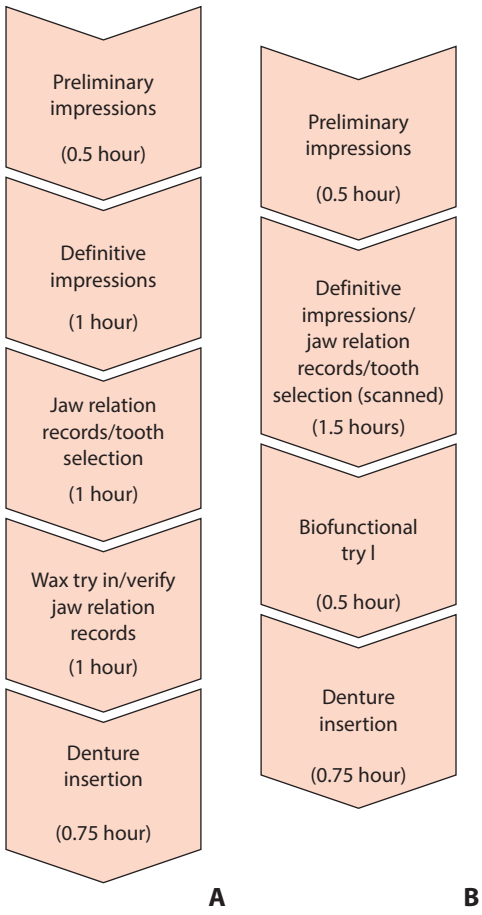

Figure 1. Appointment series. A, Conventional fabrication protocol. B, CAD-CAM fabrication protocol. CAD-CAM, computer-aided design and computer-aided manufacturing.

for orientation of the incisal/occlusal planes, lip support, and incisal display (Fig. 4). The distal portions of the mandibular impressions were removed to eliminate posterior interferences between the maxillary and mandibular impressions/record bases (Fig. 5). Jaw-relation records were made at a clinically acceptable vertical dimension of occlusion.

The maxillary impressions and records were scanned extraorally by 1 dental assistant; these scans were combined with the previous digital mandibular scans (Fig. 6). The data were transmitted electronically to the design/milling center in Arizona where the dentures were designed (Fig. 7). The designs were sent to the clinicians by electronic mail and were digitally modified as needed by the clinicians and then milled as biofunctional dentures for evaluation (Fig. 8). If changes were needed, they were made on the evaluation dentures, and the biofunctional dentures were rescanned as needed. The scans were transmitted electronically to the milling/design center where the requisite changes, if needed, were made. The dentures were processed, milled, and inserted (Fig. 9). Clinical and laboratory

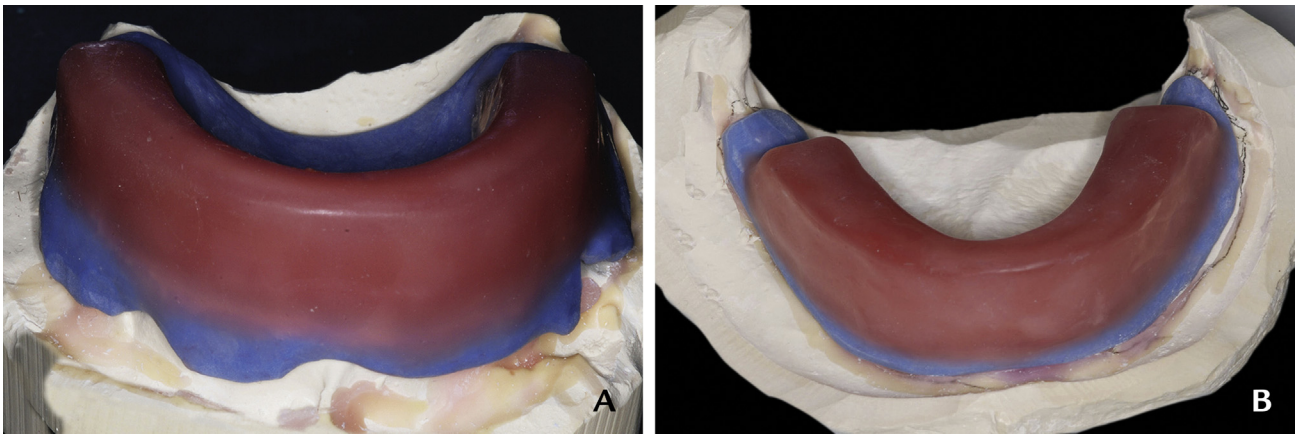

Figure 2. Custom impression tray with wax occlusion rim on diagnostic cast. A, Maxillary. B, Mandibular.

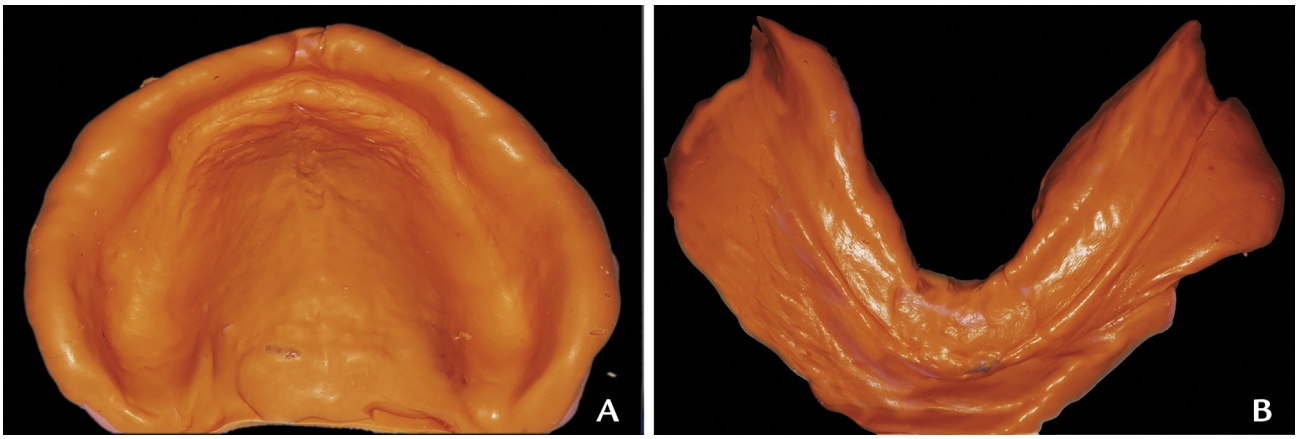

Figure 3. Intaglio surfaces of definitive denture impressions. A, Maxillary. B, Mandibular.

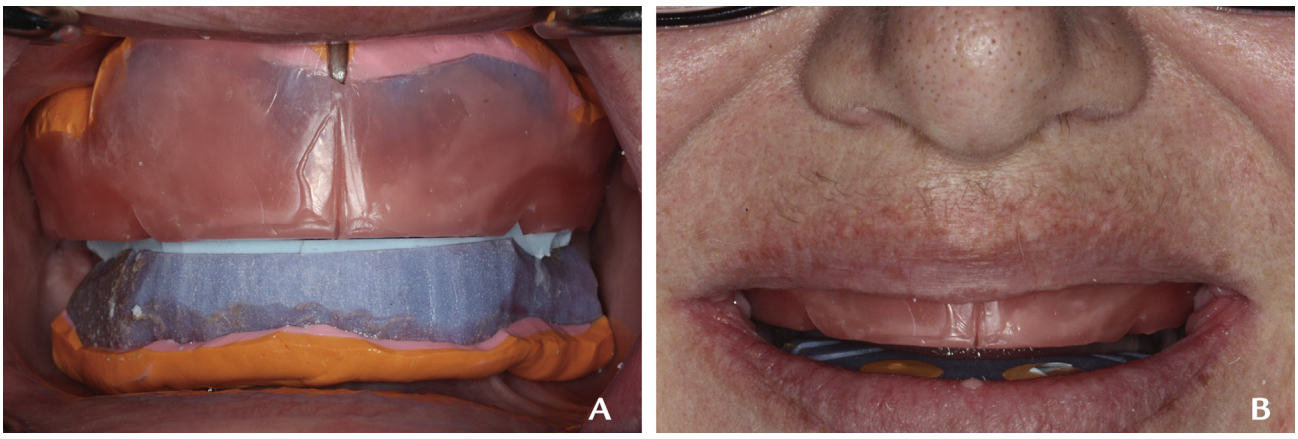

Figure 4. Preliminary jaw-relation records. A, Intraoral view. B, Clinical image with impressions and occlusion rims in place.

remount procedures were accomplished at the denture-insertion appointments. Participants in both groups were followed up for 1 year after insertion of the new complete dentures.

Univariable tests of association used in this analysis included chi-square and the Fisher exact tests for categorical comparisons and the Wilcoxon rank sum test for comparison of ordinal continuous data. Analyses were performed using a statistical software program (SAS, v9.4; SAS Institute, Inc).

RESULTS

Of the 106 participants in this study, 73 (68.9%) received CAD-CAM dentures and 33 (31.1%) received

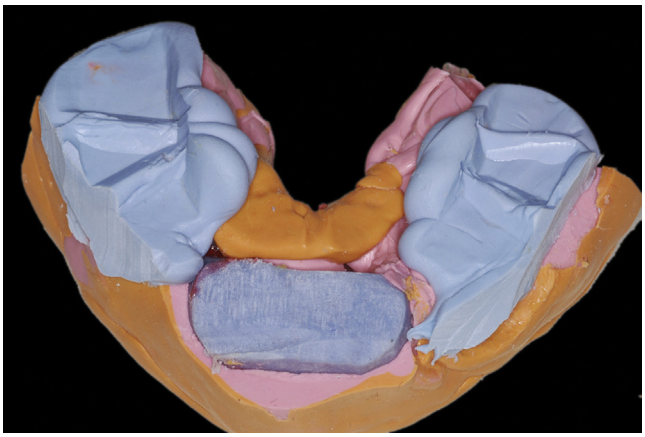

Figure 5. Mandibular impression with occlusion rim with polyvinyl siloxane interocclusal record after removal of distal portions of mandibular impression. Mandibular impression scanned before removal of distal segments.

conventional dentures. Sixty-five (61.3%) participants received both maxillary and mandibular dentures. Approximately two-thirds of participants were female (n=66); less than half were lifelong nonsmokers (n=46) (*P*=.34). Approximately one half of the participants (n=56) returned for their scheduled visits 1 to 2 weeks after insertion of the dentures (*P*=.55). No significant demographic or clinical differences were noted between participants receiving CAD-CAM or conventional dentures (Table 1).

Twenty-three (21.7%) individuals returned for at least 1 unscheduled adjustment up to 1 year after insertion of the dentures (*P*=.94). Univariable analysis revealed that participant returns for unscheduled adjustments were not associated with the method of denture fabrication (CAD-CAM versus conventional) (Table 1). Return visits for unscheduled adjustments were significantly associated with patients with single dentures and patients who returned for scheduled postinsertion visits (Table 2) (*P*=.006).

The range and number of participants seen for unscheduled postinsertion-adjustment visits are noted in Table 3. Participants treated with CAD-CAM dentures took longer to achieve satisfactory levels of comfort with their dentures than did participants treated with conventional dentures. Also, the CAD-CAM participants took longer to return for unscheduled visits than did conventional denture participants.

DISCUSSION

The number of unscheduled visits for participants in this study with complete dentures fabricated by injection molding or CAD-CAM milling did not differ significantly; therefore, the null hypothesis was not rejected. The average number of unscheduled visits for denture adjustments was less than expected by the author: 1.8 for conventionally processed dentures versus 1.7 for CAD-CAM milled dentures. Only 20% of the participants returned for unscheduled postinsertion denture adjustments: 16 (70%) had CAD-CAM dentures and 7 (30%) had conventional dentures. No statistically significant relationship was found between the type of denture fabrication and unscheduled denture adjustments (*P*=.94). The author expected a difference in postinsertion adjustments between the 2 participant groups perhaps because of increased accuracy of fit between denture bases and edentulous jaws for the CAD-CAM dentures. Differences in postinsertion-adjustment visits were also expected because conventionally processed acrylic resin dentures are known to undergo polymerization shrinkage.[20] The lack of participants in this study who returned even for scheduled postinsertion visits was also striking and may have been related to the techniques, protocols, patient adaptation skills, and clinical expertise of the prosthodontists. It also may be related to the location of this practice in the southwest corner of Wisconsin. Patients sometimes travel great distances for dental care and may have elected not to return if they perceived no problem. Some may have performed their own adjustments, even though they were specifically informed not to do so.

The results of this study noted that fewer number of denture adjustments were needed than those recorded in the study of Bidra et al[16] over a 1-year follow-up period. Their study included patients with mandibular complete dentures and mandibular implant-supported overdentures, whereas the present study included only patients with complete dentures. The sample size in the study of Bidra et al[16] was also considerably smaller.

Keenan et al[21] reported that injection molded dentures resulted in slightly fewer increases in vertical dimension of occlusion than conventional polymerization techniques; CAD-CAM–fabricated dentures were not studied. In an in vitro study, Lechner and Lautenschlager[22] reported that dimensional changes of heat-processed acrylic resin maxillary complete dentures ranged from 0.24% to 0.87%. In a similar in vitro study involving mandibular complete dentures, Lechner and Thomas[23] recorded linear measurements that indicated shrinkage in all dimensions after processing heat-polymerizing acrylic resin complete dentures. They concluded that the differences in shrinkage across mandibular dentures resulted in qualitative changes, leading to pressure areas in the distal lingual and anterior labial regions of edentulous mandibles.[23] Takamata and Setcos[24] reviewed the merits of various types of denture processing, including heat-activated, light-activated, microwave processing, and vacuum-plus-pressure low-temperature polymerization techniques. They concluded all denture fabrication processes had benefits and limitations.

In an in vitro study to determine which process produced the most accurate and reproducible adaptation between denture bases and edentulous jaws, Goodacre

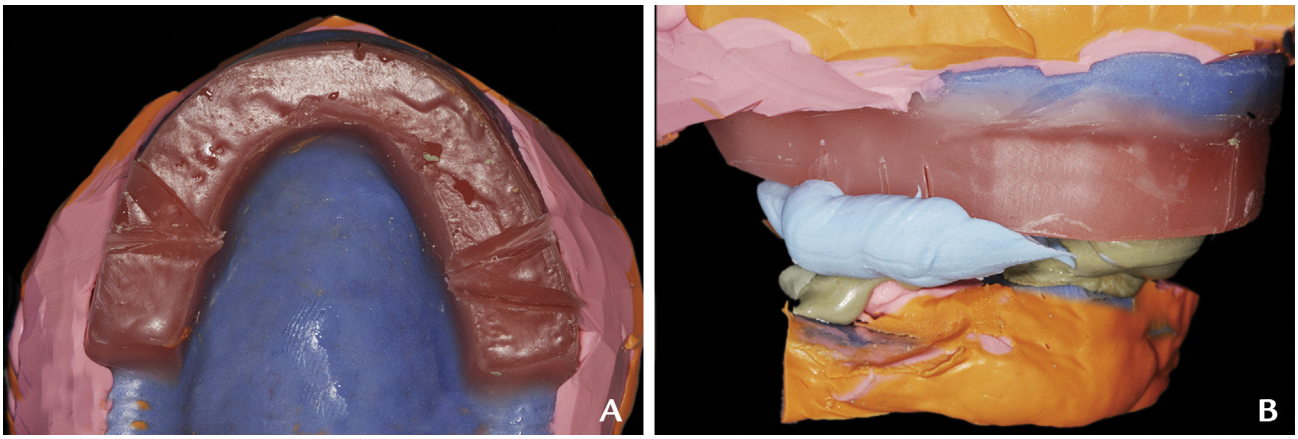

Figure 6. A, Maxillary occlusion rim before making centric jaw-relation record after definitive impression was made. B, Right lateral laboratory image of jaw-relation record. Note that right distal portion of mandibular impression removed so that occlusal surfaces could be articulated without interference.

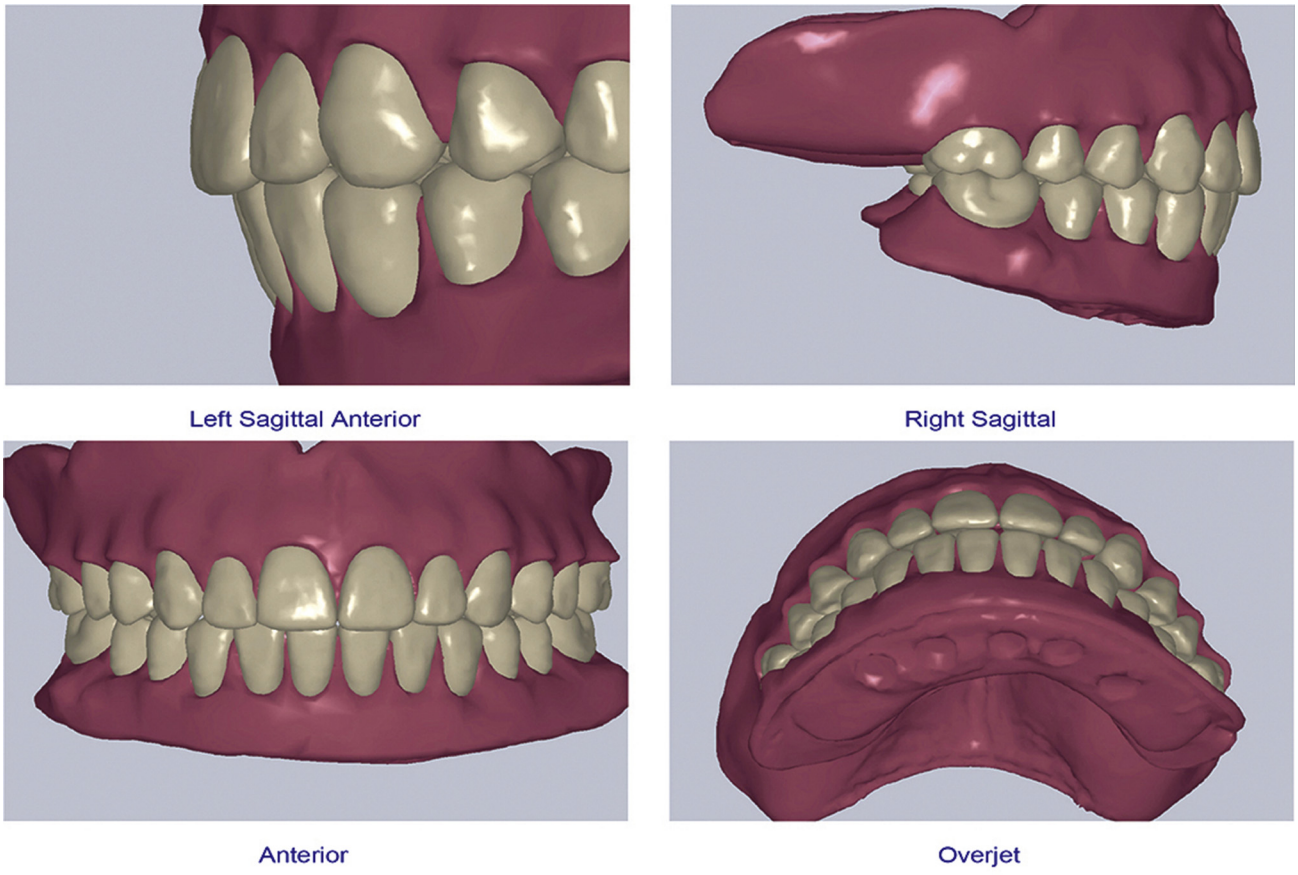

Figure 7. Screen images of initial virtual tooth arrangement as received from design/milling center.

et al[15] compared denture base adaptation of pack-and-press, pour, injection, and CAD-CAM techniques for fabricating dentures. They concluded that the CAD-CAM fabrication process, the same as used in the present study, was the most accurate and reproducible process.

This study had limitations including the nonrandom design and 2 different clinicians performing the clinical procedures albeit with similar procedures and materials. They were not blinded to the type of denture that was fabricated. All participants received the same post-insertion instructions and were given the same

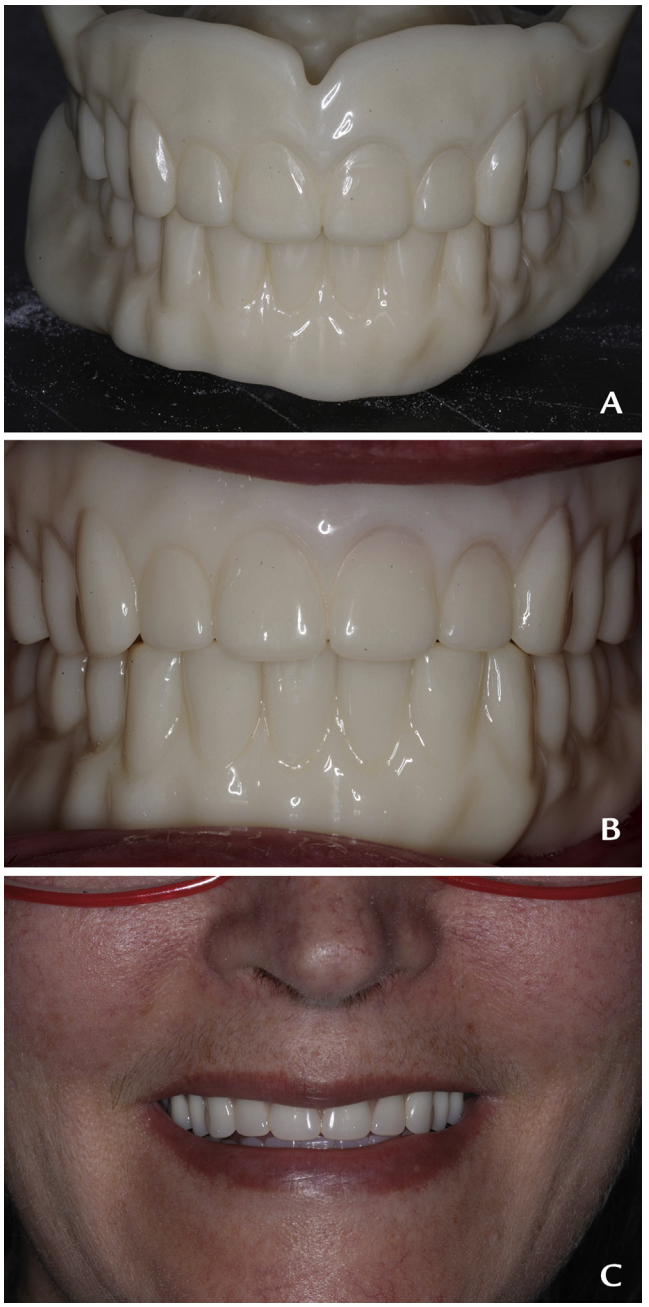

Figure 8. Biofunctional evaluation (white dentures) (AvaDent CORE; Global Dental Sciences); dentures milled consistent with jaw-relation records made at definitive impression appointments. VDO, centric jaw-relation records, tooth position, lip support, retention and stability of impressions, and initial jaw-relation records verified at this appointment. A, Extraoral image. B, Intraoral image. C, Smile image. VDO, vertical dimension of occlusion.

Figure 9. Patient with definitive dentures in place.

Table 1. Demographics and primary outcomes for all participants

Characteristic	CAD-CAM (n=73)	Conventional (n=33)	*P*
Edentulous years, median (range)	7 (1-60)	10 (1-50)	.92
Male gender, n (%)	24 (33)	16 (48)	.12
Xerostomia, n (%)	20 (27)	7 (21)	.50
Complete dentures, n (%)	43 (59)	22 (67)	.45
Never smoker, n (%)	35 (48)	11 (33)	.34
Returned for scheduled postinsertion visits, n (%)	40 (55)	16 (48)	.55
Patients who presented for unscheduled denture adjustments, n (%)	16 (22)	7 (21)	.94

CAD-CAM, computer-aided design and computer-aided manufacturing.

Table 2. Data regarding unscheduled denture-adjustment visits

Characteristic	Patients Who Presented for Unscheduled Denture Adjustments, N=23	Patients Who Did Not Return for Unscheduled Denture Adjustments, N=83	*P*
Median edentulous years (range)	12 (1-50)	7 (1-60)	.12
Male gender, n (%)	7 (30)	33 (40)	.41
Patients who returned for scheduled postinsertion visits, n (%)	18 (78)	38 (54)	.006

opportunity to return for adjustments. The experimental variable was the number of unscheduled, postinsertion adjustments, providing a realistic objective and quantitative data that were straightforward to record. Other clinical factors that influence patient adaptation to complete dentures include palatal vault depth, muscle attachments, ridge classification, quantified measurements of denture retention/stability, and Prosthodontic Diagnostic Index (PDI) classifications. PDI classifications were not recorded in this study because of inconsistent record keeping. PDI classifications would have assisted readers in comparing clinical results between the 2 groups.

A consensus regarding the clinical significance of CAD-CAM–fabricated dentures compared with that of conventional dentures is lacking. In this study, no difference was found in the number of postinsertion visits with either denture protocol. The author of this study anticipated a decrease in the number of postinsertion visits for participants treated following the CAD-CAM denture protocol when compared with that for participants treated with dentures fabricated with an injection molding process. The

Table 3. Range and number of patients seen for unscheduled postinsertion-adjustment visits

Metric	CAD-CAM Dentures	Conventional Dentures
Treatment range (wk)	1-42	2-28
Average time (wk) for first unscheduled visit after insertion	8.6, 10 patients	4.8, 14 patients
Average time (wk) for second unscheduled visit after insertion	6.3, 4 patients	12.4, 9 patients
Average time (wk) for third unscheduled visit after insertion	6.8, 4 patients	9, 3 patients
Average time (wk) for fourth unscheduled visit after insertion	11.8, 4 patients	6.5, 2 patients

CAD-CAM, computer-aided design and computer-aided manufacturing.

results of this clinical study did not validate this concept and failed to reject the null hypothesis.

CONCLUSIONS

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

1. No differences in the number of unscheduled, postinsertion visits for participants treated with dentures made following either a CAD-CAM or injection molding protocol were detected.
2. Further research is indicated to detect clinical differences, if any, regarding methods of denture fabrication.

REFERENCES

1. Felton DA. Edentulism and comorbid factors. J Prosthodont 2009;18:88-96.
2. Zarb GA, Bolender CL, Carlsson GE. Boucher's prosthodontic treatment for edentulous patients. 11th ed. St Louis: Mosby/Elsevier; 1997. p. 141-82.
3. Felton D, Cooper L, Scurria M. Predictable impression procedures for complete dentures. Dent Clin North Am 1996;40:39-51.
4. Chaffee NR, Cooper LF, Felton DA. A technique for border molding edentulous impressions using vinyl polysiloxane material. J Prosthodont 1999;8:129-34.
5. Ye Y, Sun J. Simplified complete denture: a systematic review of the literature. J Prosthodont 2017;26:267-74.
6. Jo A, Kanazawa M, Sato Y, Iwaki M, Akiba N, Minakuchi S. A randomized controlled trial of the different impression methods for the complete denture fabrication: patient reported outcomes. J Dent 2015;43:989-96.
7. Thean HP, Chew CL, Goh KI. Shear bond strength of denture teeth to base: a comparative study. Dent Dig 1996;27:425-8.
8. Estafan D, David A, David S, Calamia J. A new approach to restorative dentistry: fabricating ceramic restorations using CEREC CAD/CAM. Compend Contin Educ Dent 1999;20:555-60.
9. Kurbad A. The integration of Cerec Scan into the treatment process. Int J Comput Dent 2000;3:61-6.
10. Inokoshi M, Kanazawa M, Minakuchi S. Evaluation of a complete denture trial method applying rapid prototyping. Dent Mater J 2012;31:40-6.
11. Bilgin M, Erdem A, Aglarci O, Dilber E. Fabricating complete dentures with CAD/CAM and RP technologies. J Prosthodont 2015;24:576-9.
12. Matsuda T, Goto T, Yagi K, Kashiwabara T, Ichikawa T. Part-digitizing system of impression and interocclusal record for complete denture fabrication. J Prosthodont 2016;25:503-9.
13. Kanazawa M, Inokoshi M, Minakuchi S, Ohbarashi N. Trial of a CAD/CAM system for fabricating complete dentures. Dent Mater J 2011;30:93-6.
14. Goodacre C, Garbacea A, Naylor W, Daher T, Marchack C, Lowry J. CAD/CAM fabricated complete dentures: concepts and clinical methods of obtaining required morphological data. J Prosthet Dent 2012;107:34-46.
15. Goodacre B, Goodacre C, Baba N, Kattadivil M. Comparison of denture base adaptation between CAD-CAM and conventional fabrication techniques. J Prosthet Dent 2016;116:249-56.
16. Bidra AS, Farrell K, Burnham D, Dhingra A, Taylor TD, Kuo CL. Prospective cohort pilot study of 2-visit CAD/CAM monolithic complete dentures and implant-retained overdentures: clinical and patient-centered outcomes. J Prosthet Dent 2016;115:578-86.
17. Ettinger RL, Qian F. Longitudinal assessment of denture maintenance needs in an overdenture population. J Prosthodont 2019;28:22-9.
18. Komagamine Y, Kanazawa M, Sasaki Y, Sato Y, Minakuchi S. Prognoses of new complete dentures from the patient's denture assessment of existing dentures. Clin Oral Investig 2017;21:1495-501.
19. Saponaro PC, Yilmaz B, Heshmati RH, McGlumphy EA. Clinical performance of CAD-CAM-fabricated complete dentures: a cross-sectional study. J Prosthet Dent 2016;116:431-5.
20. Kobayashi N, Komiyama O, Kimoto S, Kawara M. Reduction of shrinkage on heat-activated acrylic denture base resin obtaining gradual cooling after processing. J Oral Rehabil 2004;31:710-6.
21. Keenan P, Radford D, Clark R. Dimensional change in complete dentures fabricated by injection molding and microwave processing. J Prosthet Dent 2003;89:37-44.
22. Lechner S, Lautenschlager E. Processing changes in maxillary complete dentures. J Prosthet Dent 1984;52:20-4.
23. Lechner S, Thomas G. Changes caused by processing complete mandibular dentures. J Prosthet Dent 1994;72:606-13.
24. Takamata T, Setcos J. Resin denture bases: review of accuracy and methods of polymerization. Int J Prosthodont 1989;2:555-62.

Corresponding author:
Dr Carl Drago
W238N2325 Kestrel Drive
Waukesha, WI 53188
Email: carl.drago@gmail.com

Acknowledgments
The authors gratefully acknowledge Nathaniel Farley DDS, MS, FACP as the second clinician and the assistance of Jessica Kotek, Brittany Deml, Heather Brown, and Nikki Knutson (prosthodontic staff, Gundersen Health System, LaCrosse, WI) for clinical assistance, data collection, and chart reviews.

https://doi.org/10.1016/j.prosdent.2018.10.030