THE JOURNAL OF PROSTHETIC DENTISTRY

DENTAL TECHNIQUE

Application of 3D digital smile design based on virtual articulation analysis in esthetic dentistry: A technique

Zhaoguo Yue, MDS,[a] Zhiqiang Luo, MDS,[b] Jianxia Hou, DDS, MS, PhD,[c] and Haidong Zhang, DDS, PhD[d]

ABSTRACT

A technique for the application of a virtual articulation system in 3-dimensional digital smile design (DSD) during esthetic restoration is described. To acquire stable occlusion and a smooth jaw movement pattern without premature contacts or interference, a digital facebow and a virtual articulator were used to collect and analyze a patient's occlusal data and jaw movement information. The original pattern of occlusal contacts and jaw movements were diagnosed as stable and copied to the digital design of the new prostheses. Preparation of the abutments, crown lengthening surgery, and definitive crown fabrication and cementation were performed according to the design. After 9 months, the occlusion remained stable, and the patient was satisfied with the outcome. (J Prosthet Dent 2025;133:24-30)

For all prostheses, a good outcome should be based on proper occlusal design.[1] Although masticatory function may not be considered as the primary role of an esthetic restoration, occlusal stability needs to be achieved for long-term benefits. Incorrect occlusal contacts have been reported to lead to problems. Premature contact of a prosthesis at the maximal intercuspation position would alter the vertical dimension,[2] and improper incisal guidance could interfere with condylar pathways and neuromuscular control patterns.[3] As a result, disregarding occlusion in the design of an anterior prosthesis is likely to lead to abnormal attrition, occlusal trauma, tooth migration, or temporomandibular disorders.[4–6]

Consequently, when patients present with a stable occlusion before esthetic treatment, the occlusal relationship should be transferred to the occlusal contacts and anterior guidance of the definitive restorations. When patients present with an unstable occlusion, occlusal equilibration should be considered.[7] Traditionally, duplicating or correcting the occlusal contact and guidance of anterior teeth has been achieved by mounting diagnostic casts on a mechanical articulator.[8,9] With the development of digital technologies, the use of a virtual articulator has become popular in prosthetic dentistry.[10] They are being used in a wide range of applications because of advantages that include individualized diagnosis, visualization of treatment options, 3-dimensional (3D) simulation, and accurate reproduction.[10–12] Digital smile design (DSD) systems are another advanced technology in esthetic dentistry and have demonstrated efficiency and accuracy.[13] In this technique article, the use of 3D DSD to reconstruct a patient's anterior teeth based on virtual articulation analysis is described. A satisfactory esthetic outcome was achieved with complete consideration for occlusal stability.

Supported by the National Natural Science Foundation of China [#82071117], PR China; and by the Peking University School of Stomatology Science Foundation for Young Scholars [#YS020217], PR China.
The authors report no conflicts of interest related to this case report.
[a]Postgraduate student, Department of Periodontology, Peking University School and Hospital of Stomatology, National Engineering Laboratory for Digital and Material Technology of Stomatology, Research Center of Engineering and Technology for Digital Dentistry of Ministry of Health, Beijing Key Laboratory of Digital Stomatology, Beijing, PR China.
[b]Attending, Private practice, Beijing, PR China.
[c]Professor, Department of Periodontology, Peking University School and Hospital of Stomatology, National Engineering Laboratory for Digital and Material Technology of Stomatology, Research Center of Engineering and Technology for Digital Dentistry of Ministry of Health, Beijing Key Laboratory of Digital Stomatology, Beijing, PR China.
[d]Attending, Department of Periodontology, Peking University School and Hospital of Stomatology, National Engineering Laboratory for Digital and Material Technology of Stomatology, Research Center of Engineering and Technology for Digital Dentistry of Ministry of Health, Beijing Key Laboratory of Digital Stomatology, Beijing, PR China.
[1] Z.Y. and Z.L. contributed equally to this article.

Figure 1. Initial condition. A, Full-face view with natural smile. B, Intraoral view.

Figure 2. Periodontal treatment before esthetic reconstruction. A, Before SRP. B, After SRP. C, Crown margins evaluated with abutment finish line by means of probing and periapical film. SRP, scaling and root planing.

TECHNIQUE

The technique was carried out on a woman who attended the Peking University School of Stomatology with the chief complaint of swollen gingiva around her anterior teeth. Her 4 maxillary incisors had been restored with ceramic crowns 10 years earlier. Her midline diastema had progressively increased (Fig. 1), and she was not satisfied with her esthetics. Therefore, a digital workflow consisting of the following procedures was recommended to reconstruct her maxillary incisors.

1. Enroll the patient into initial periodontal therapy and supportive periodontal therapy, including scaling, root planing, and frequent follow-up visits. With a

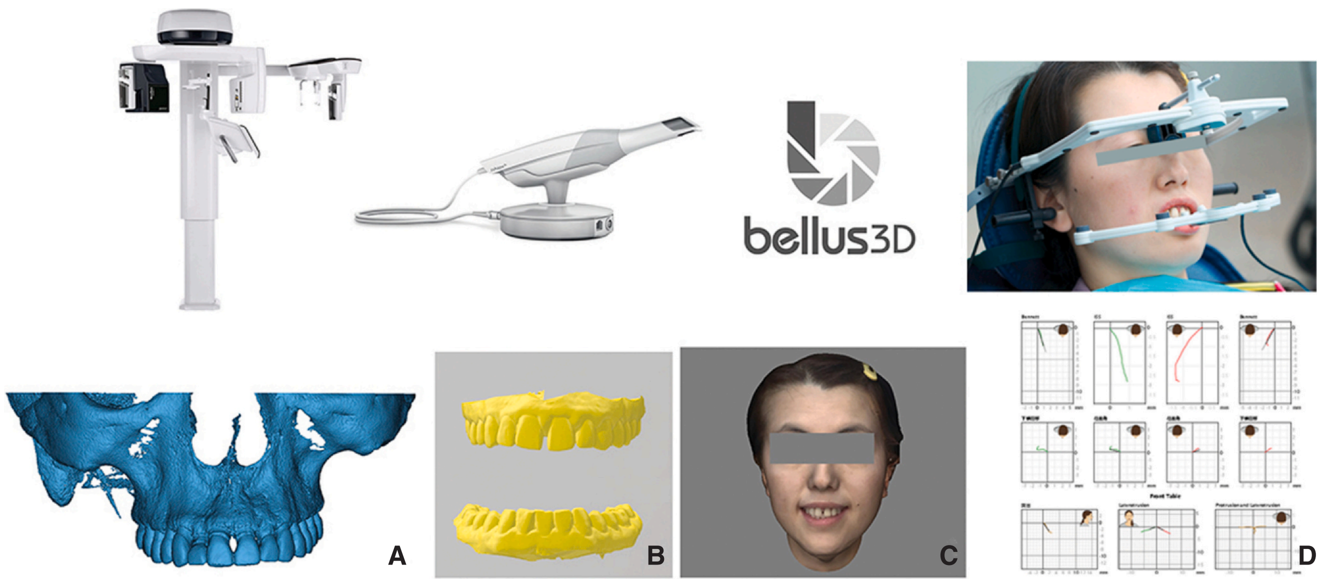

Figure 3. Collection of digital information and creation of virtual patient. A, Bone information acquired by CBCT. B, Tooth and gingival information acquired by intraoral scanning. C, Face and smile information acquired by facial scanning. D, Occlusal information acquired by digital facebow. CBCT, cone beam computed tomography.

stable periodontal status, determine the position of the restoration margins by probing (Fig. 2).

2. Make a cone beam computed tomography (CBCT) scan (Giano HR; NewTom) with a field of view of 16×18 cm to capture both the frontal bone and the chin. Export the data in digital imaging and communications in medicine (DICOM) format and import it into a dental design software program (exocad dental CAD; exocad GmbH) (Fig. 3A).
3. Make intraoral scans (TRIOS 3; 3Shape A/S) of both the maxillary and mandible arches, as well as a buccal scan in maximal intercuspal position. Upload the data to the design software program in standard tessellation language (STL) format (Fig. 3B).
4. Make facial scans (Bellus3D Dental Pro; Bellus3D GmbH) of the patient's laughing, smiling, and resting appearance. Upload the facial data to the design software program in object format (Fig. 3C).
5. Acquire jaw movement information by using a digital dental facebow (JMAnalyser+; zebris Medical GmbH). Record the maximum intercuspation position and eccentric movement in extensible markup language (XML) format and analyze the occlusion and movement pattern by using a virtual articulator (WINJAW+; zebris Medical GmbH). In this patient, the track of her mandible movement was smooth and continuous. The protrusion and laterotrusion tracks of the front table were in accordance with those of the condyle, indicating a stable occlusion (Fig. 3D).[11] Upload the XML file to the design software program as the reference for designing the occlusion of the prostheses.
6. Register the CBCT data and intraoral scan data based on tooth features to create a tooth-jaw virtual model. Register the facial appearance data and a tooth-jaw model based on anterior tooth features to create a static virtual patient model. Align the jaw motion data and patient model based on markers on the facebow fork. Integrate all the data and delete redundancy to create a virtual patient (Fig. 3E).
7. Determine the shape and features of the new restorations for esthetics on the virtual dentition model. Transfer the proper occlusion and guidance pattern determined by the virtual articulator onto the new restorations and determine the morphology of the lingual surfaces. Generate virtual trial restorations and print them (UltraCraft A3D, HeyGears). Make impressions of the printed trial restorations for the interim crowns (Fig. 4). Mark the contour and position of gingiva referring to the smile line and adjacent teeth. Determine whether, or how much, bone removal is needed to reestablish biological width based on the CBCT. Determine the location of the future restoration margin and abutment finish line based on the expected bone level and biological width. Transfer the gingival position and bone removal information to a surgical guide manufacturing machine (UltraCraft A3D, HeyGears) to produce a guide template (Fig. 5).
8. Introduce the treatment plan and expected outcome to the patient with the help of the virtual patient. After obtaining informed consent, remove the existing crowns and complete endodontic therapy as necessary. Make interim crowns from a bis-acryl

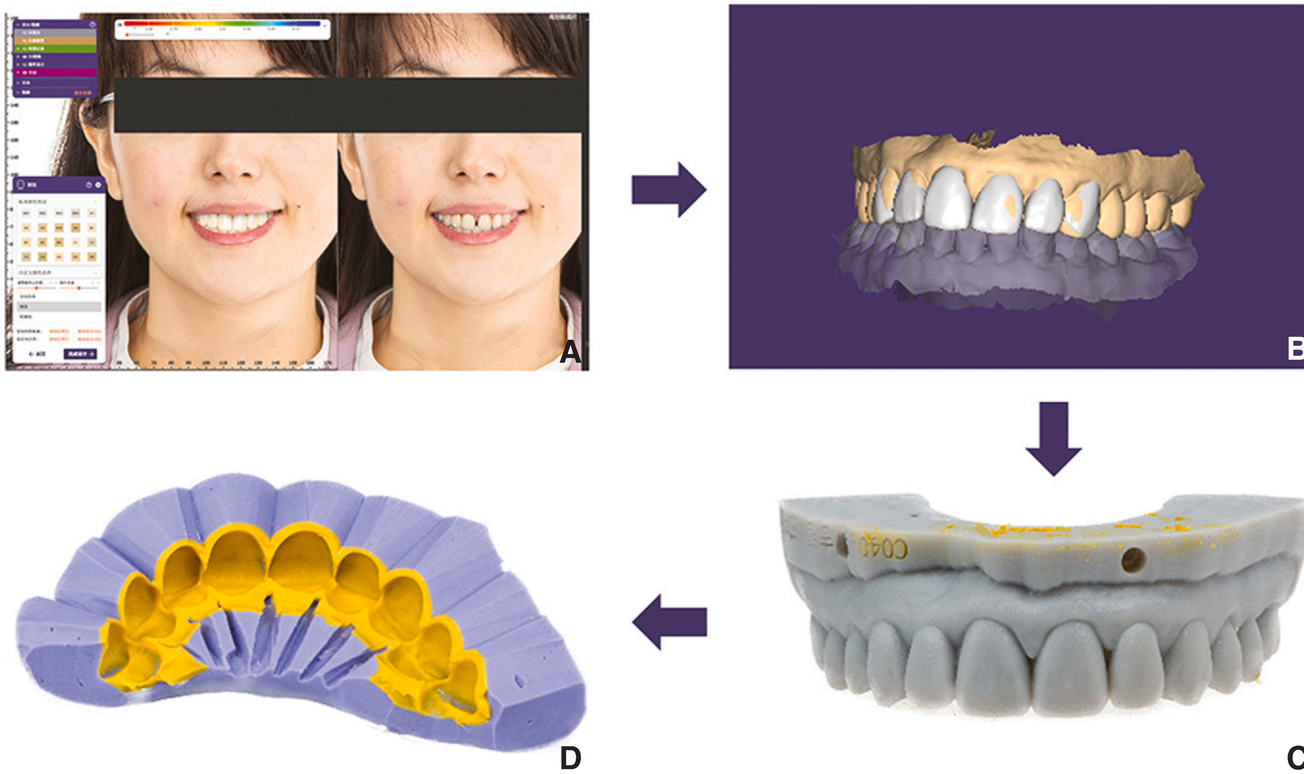

Figure 4. Digital workflow for designing crowns. A, Shape and margin of crowns determined according to facial view and lip position. B, Occlusion adjusted according to jaw motion information. C, Trial restorations printed. D, Impressions based on trial restorations.

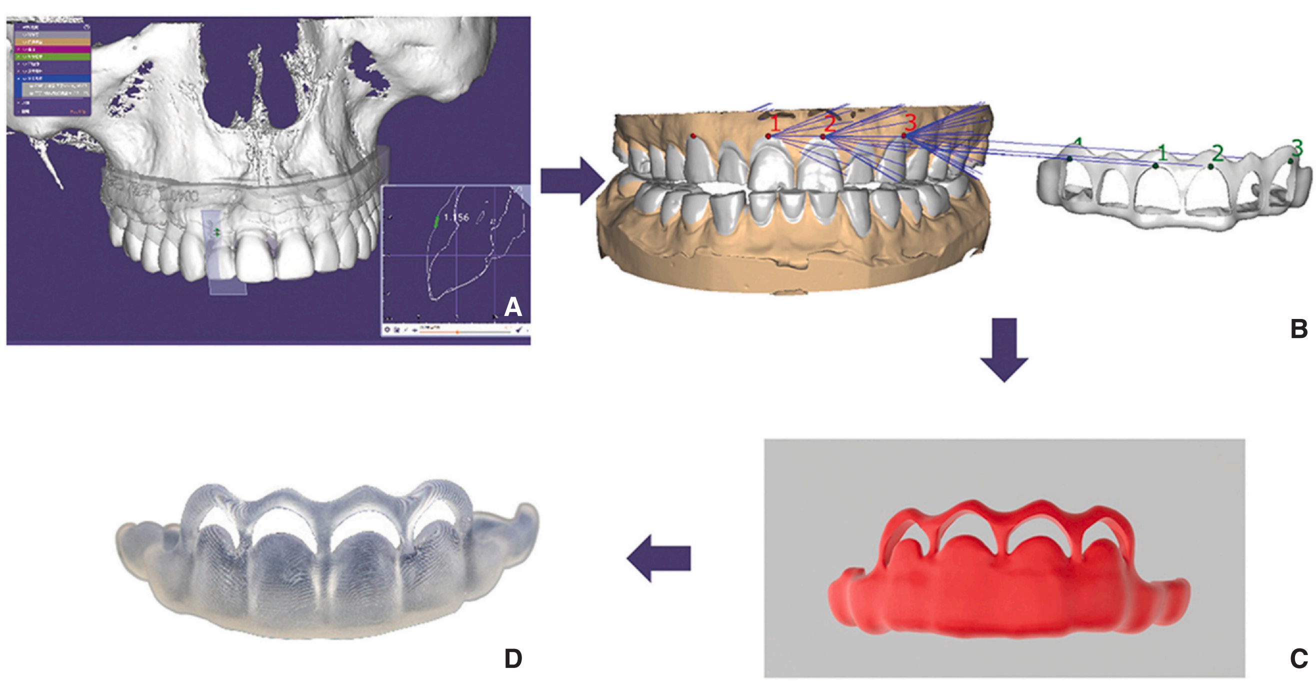

Figure 5. Digital workflow for crown lengthening guide design. A, Whether previous margin violated biological width evaluated. B, Future gingival margin and bone margin determined. C, Digital prototype of surgical guide generated. D, Surgical guide printed.

Figure 6. Crown removal. A, Existing abutment teeth. B, Interim crowns. C, Defective crowns.

material (PROTEMP 4; 3M ESPE) by using the impressions made previously (Fig. 6).

9. Perform crown lengthening surgery according to the surgical guide. Make sure that the gingival incisions comply with the gingiva indicating margins and the alveolar bone levels comply with the bone indicating margin. Prepare the teeth using the biologically oriented preparation technique[14] to correct the previous abutment finish line. Make additional interim crowns to shape the gingival contours (Fig. 7).
10. After 9 months, rescan both arches and align the new cast with the primary design to evaluate the accuracy of the gingival margin and the shape of the crowns. Re-record the mandible movement and evaluate the consistency with the designed incisal tracks. Fabricate definitive restorations as previously digitally designed and seat on the maxillary incisors.
11. Evaluate the shape and margins of the restorations. Record the definitive maximum intercuspation position and eccentric movement. Compare the definitive track with the initial track to confirm consistent occlusal stability. The incisal tracks of protrusion and laterotrusion were smooth, continuous, and coincided well with the original tracks before treatment (Fig. 8). Evaluate the soft tissue contour and its compliance with the smile line. The

Figure 7. Crown lengthening and tooth preparation. A, Surgical crown lengthening. B, Tooth preparation and interim crowns.

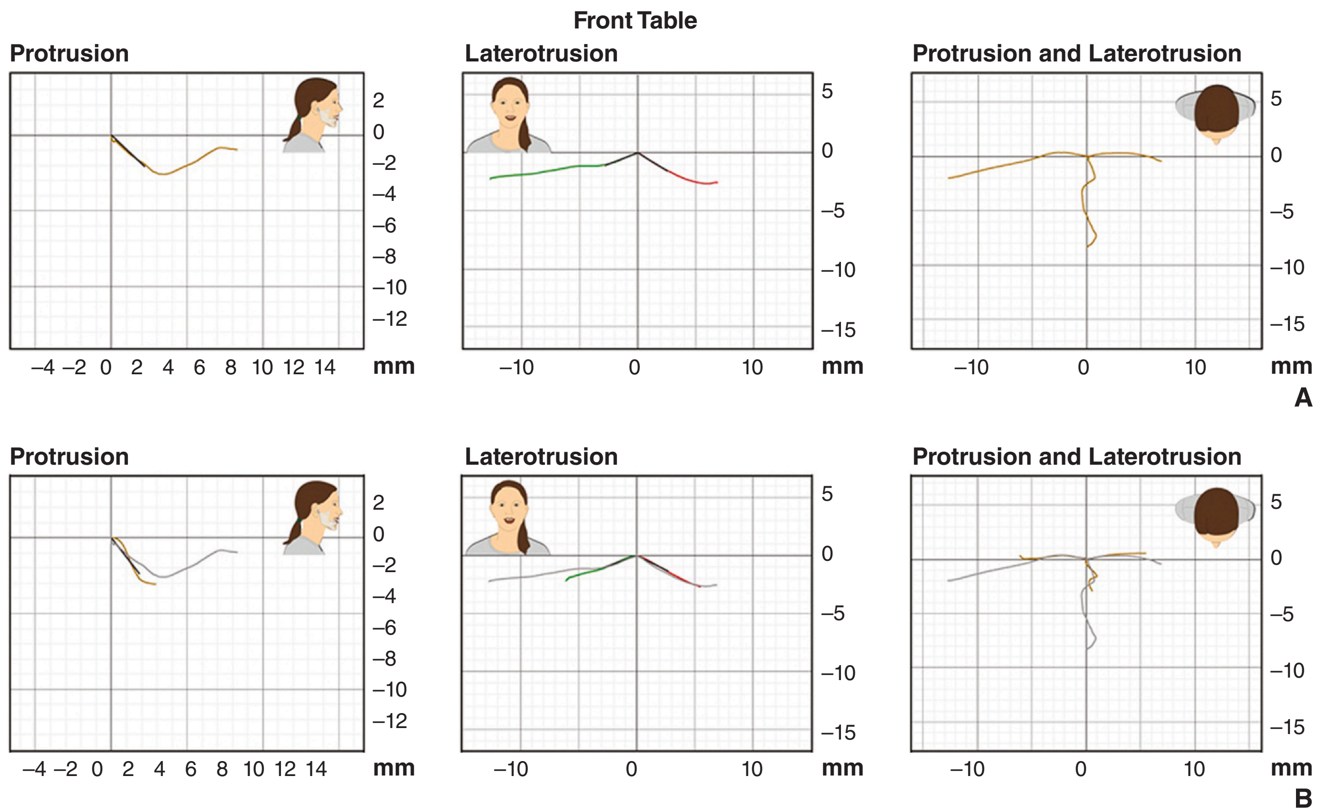

Figure 8. Incisal tracks of protrusion and laterotrusion recorded on virtual articulator after crown delivery. A, Incisal tracks of definitive crowns. B, Comparison of tracks between designed (original) pattern (*red*) and actual pattern (*gray*).

patient was satisfied with the definitive clinical outcome (Fig. 9).

DISCUSSION

The DSD method has become increasingly popular providing satisfactory outcomes.[13] The main advantage of DSD is the ability to dynamically analyze the lip–gingiva–tooth relationship and integrate it into the esthetic design. Thus, comprehensive treatment planning, including design of the crown and the crown lengthening surgical guide, could be acquired before any invasive procedure.[15,16] In addition, complete virtual planning makes the abstract process more

Figure 9. Definitive outcome. A, Full-face view with natural smile. B, Intraoral view. C, Periapical radiographs.

visual and greatly facilitates communication between patient and dentist.[17] In the current clinical situation, the patient was fully involved in the decision-making process. As a result, she was satisfied with the definitive outcome and felt confident with her smile esthetics.

Since articulation is the foundation of successful prostheses, a reliable method of achieving stable occlusion is necessary in DSD.[18] As another useful tool brought by digital technology, the virtual articulator is an ideal complement to DSD. It has been reported to be more accurate and timesaving compared with a mechanical articulator and has the advantage of dynamic and individualized analysis of the occlusal relationship.[11] A virtual articulator can also provide a visualized method of diagnosing occlusal stability as concrete evidence for proper prosthesis occlusion.[19] The occlusion and guidance pattern diagnosed by the virtual articulator was harmonious without occlusal interferences before crown removal in the current patient. Thus, the same pattern of occlusion was duplicated in the definitive restorations, and the consistency was tested by definitive recording. Combining DSD with the virtual articulator improved the esthetic treatment and occlusal stability. However, a fully digital workflow relies heavily on precise devices and software programs, which may greatly increase the treatment cost. The cost-effectiveness dilemma brought by this combined approach may hamper its clinical application. Limitations of this report include the absence of a control group or comparison with conventional approaches. Controlled studies are needed to focus on the cost-effectiveness of the combined approach and determine its repeatability and reproducibility.

SUMMARY

This technique report describes the application of a virtual articulation system in 3D digital smile design during esthetic restoration with a satisfactory outcome.

PATIENT CONSENT

Verbal and written informed consent were obtained for this patient according to the ethics committee and institutional guidelines.

REFERENCES

1. Hagag G, Yoshida K, Miura H. Occlusion, prosthodontic treatment, and temporomandibular disorders: A review. *J Med Dent Sci*. 2000;47:61–66.
2. De Boever JA, Carlsson GE, Klineberg IJ. Need for occlusal therapy and prosthodontic treatment in the management of temporomandibular disorders. Part I. Occlusal interferences and occlusal adjustment. *J Oral Rehabil*. 2000;27:367–379.
3. Sondhi A. Anterior interferences: Their impact on dental health function. *J Indiana Dent Assoc*. 2004;83(4–6):8–17.
4. Watkinson A, Hathorn I. Occlusion in the aetiology and management of upper anterior tooth migration. *Restor Dentistry*. 1986;2:56,58,60–61.
5. Kalladka M, Young A, Thomas D, Heir GM, Quek SYP, Khan J. The relation of temporomandibular disorders and dental occlusion: A narrative review. *Quintessence Int*. 2022;53:450–459.
6. van 't Spijker A, Kreulen CM, Creugers NH. Attrition, occlusion, (dys) function, and intervention: A systematic review. *Clin Oral Implants Res*. 2007;18(Suppl 3):117–126.
7. Wiens JP, Priebe JW. Occlusal stability. *Dent Clin North Am*. 2014;58:19–43.
8. Gross MD, Cardash HS. Transferring anterior occlusal guidance to the articulator. *J Prosthet Dent*. 1989;61:282–285.
9. Abduo J. Safety of increasing vertical dimension of occlusion: A systematic review. *Quintessence Int*. 2012;43:369–380.
10. Koralakunte PR, Aljanakh M. The role of virtual articulator in prosthetic and restorative dentistry. *J Clin Diagn Res*. 2014;8:Ze25–Ze28.
11. Bisler A, Bockholt U, Kordass B, Suchan M, Voss G. The virtual articulator. *Int J Comput Dent*. 2002;5:101–106.
12. Maestre-Ferrín L, Romero-Millán J, Peñarrocha-Oltra D, Peñarrocha-Diago M. Virtual articulator for the analysis of dental occlusion: An update. *Med Oral Patol Oral Cir Bucal*. 2012;17:e160–e163.
13. Cervino G, Fiorillo L, Arzukanyan AV, Spagnuolo G, Cicciù M. Dental restorative digital workflow: Digital smile design from aesthetic to function. *Dent J ((Basel))*. 2019;28:30.
14. Loi I, Di Felice A. Biologically oriented preparation technique (BOPT): A new approach for prosthetic restoration of periodontically healthy teeth. *Eur J Esthet Dent*. 2013;8:10–23.
15. Santos FR, Kamarowski SF, Lopez CAV, Storrer CLM, Neto AT, Deliberador TM. The use of the digital smile design concept as an auxiliary tool in periodontal plastic surgery. *Dent Res J ((Isfahan))*. 2017;14:158–161.
16. Meereis CT, de Souza GB, Albino LG, Ogliari FA, Piva E, Lima GS. Digital smile design for computer-assisted esthetic rehabilitation: Two-year follow-up. *Oper Dent*. 2016;41:E13–E22.
17. Coachman C, Calamita M. Digital smile design: A tool for treatment planning and communication in aesthetic dentistry. *Quintessence Dent Technol*. 2012;35:103–111.
18. Blatz MB, Chiche G, Bahat O, Roblee R, Coachman C, Heymann HO. Evolution of aesthetic dentistry. *J Dent Res*. 2019;98:1294–1304.
19. Lepidi L, Galli M, Mastrangelo F, et al. Virtual articulators and virtual mounting procedures: Where do we stand? *J Prosthodont*. 2021;30:24–35.

Corresponding author:
Dr Haidong Zhang
Department of Periodontology
School and Hospital of Stomatology
Peking University
22 Zhongguancun South Avenue
Haidian District, Beijing, 100081
PR CHINA
Email: siegfriedzhang@126.com

Acknowledgments
The authors thank Mr Xiaoshuai Wang and Beijing WeCare Digital Technology Co., Ltd. for their technical support.

https://doi.org/10.1016/j.prosdent.2023.11.014