Journal of Esthetic and Restorative Dentistry

WILEY

CLINICAL ARTICLE OPEN ACCESS

Digital Approach Provides Predictability in Increasing the VDO in Erosive Wear: Clinical Technique and 9-Year Follow-Up

Fady Ibrahim[1] | Udo Plaster[2] | Petra C. Gierthmuehlen[1]

[1]Department of Prosthodontics, Medical Faculty and University Hospital Düsseldorf, Heinrich-Heine-University, Düsseldorf, Germany | [2]Plaster Dental Technology, Nürnberg, Germany

Correspondence: Fady Ibrahim (fady.ibrahim@med.uni-duesseldorf.de)

Received: 31 July 2024 | **Revised:** 2 October 2024 | **Accepted:** 19 October 2024

Funding: The authors received no specific funding for this work.

Keywords: CAD/CAM | digital workflow | full-mouth rehabilitation | minimally invasive dentistry | vertical dimension of occlusion

ABSTRACT

Objective: This clinical case describes a digital workflow using face scans and CAD/CAM technology for a full-mouth rehabilitation with increased vertical dimension of occlusion (VDO) with adhesive lithium disilicate restorations after 9 years.

Clinical Considerations: A healthy, 46-year-old man displaying severe tooth wear, underwent an extensive full-mouth rehabilitation involving an increase of the VDO through laminate veneers and adhesive partial coverage lithium disilicate restorations. Anatomical landmarks of the face and reference planes were captured using a digital face scanning system. The anatomical position of the maxilla was registered with a transfer device. Digital data sets of the intraoral situation combined with a facial scan enabled precise virtual planning, guiding minimally invasive preparations. Long-term provisional restorations, milled from high-performance polycarbonate, were used to test the novel VDO before the final lithium disilicate restorations were fabricated. This approach provided a time- and cost-efficient treatment solution. No failures were observed at the 9-year follow-up.

Conclusions: Utilizing face scans and design software enable a virtual visualization and comprehensive quality control for patients with dental wear, resulting in significant time savings and increased predictability for the dental technician, dentist and patient.

Clinical Significance: The described digital workflow optimizes the planning and implementation of a comprehensive adhesive full-arch rehabilitation with an increase of the VDO. The clinical long-term follow up result of CAD/CAM assisted minimally invasive lithium disilicate restorations after 9 years demonstrates to clinicians a reliable treatment concept for patients with dental wear.

1 | Introduction

Patients with severely compromised dentition often necessitate the restoration of their vertical dimension of occlusion (VDO) owing to factors such as tooth wear, tooth loss, supra-eruption or alterations in existing prostheses. The process of adjusting the VDO is inherently intricate, characterized by a comprehensive approach that integrates clinical assessment of facial and dental esthetics, functional aspects such as phonetics and occlusion as well as anatomical landmarks [1]. Numerous studies indicate a prevalent trend toward increased erosive tooth wear with advancing age [2]. The globally reported prevalence of tooth wear exhibits a considerable variability, with estimates ranging from 29% to 60% of the worldwide population [3].

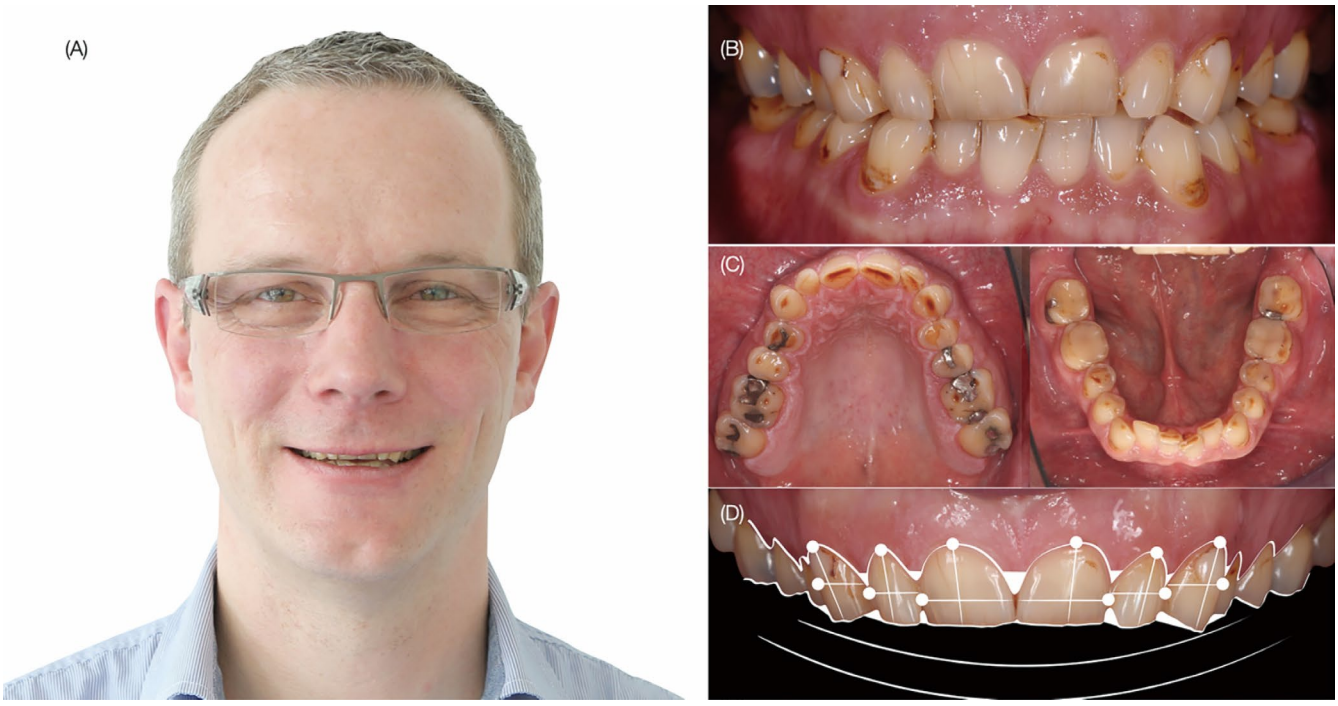

FIGURE 1 | Initial photographs. (A) Full-face view (B–D) oral situation of the case (B) frontal (C) maxillary and mandibular occlusal view (D) esthetic analysis: zenith, tooth axis, contact point, and smile line.

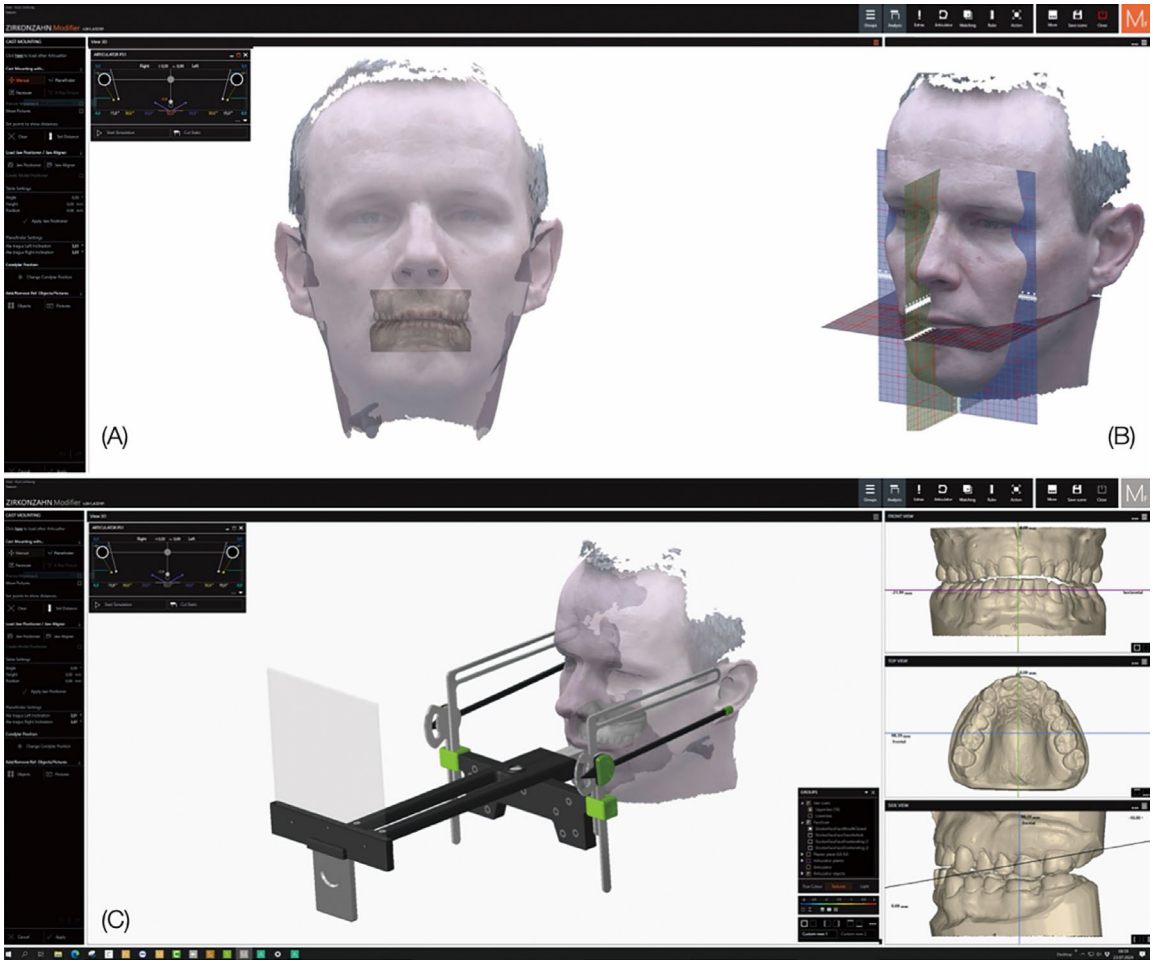

FIGURE 2 | (A) Frontal view face scan (B) sagittal, frontal, and horizontal plane visualized (C) digital data of maxillary and mandibular models merged with facial scans. Visualization used to determine the novel VDO.

FIGURE 3 | (A) Superimposition of face scan on jaw position in side profile (B) digital models with the novel VDO (C) digital design of the mandibular splint for evaluation of the increased VDO.

It is paramount for oral health professionals to effectively identify the initial signs of tooth wear, arising from a myriad of factors including periodontal disease, functional disorders, dental caries, intrinsic contributors like gastroesophageal reflux disease (GERD), or extrinsic erosive tooth wear induced by the escalating consumption of acidic foods and beverages, alongside lifestyle alterations, medications or drugs [4, 5]. Complications associated with erosive tooth wear, encompass hypersensitivity, pulpal inflammation, and periapical pathology [6, 7]. Advanced tooth wear frequently correlates with a reduction in the VDO, discernible in the patient's facial appearance [1]. Vertical alterations in the maxilla-mandible relationship carry significant biological, biomechanical, esthetic, and three-dimensional (3D) functional implications. In cases of severe erosive decay, there is often a necessity to augment the VDO, traditionally achieved through conventionally manufactured wax-ups by dental technicians. However, this process of transferring the desired diagnostic tooth arrangement to mock-ups, provisionals, and permanent restorations can be labor-intensive, costly, and prone to inaccuracies. Traditional facial analysis methods, such as two-dimensional (2D) photography, combined with vernier caliper measurements, primarily focus on assessing facial distances and angles in a 2D plane [8]. However, with the continuous advancements in optical scanning and design technologies, the field has shifted toward 3D workflows [9]. Digital manufacturing technologies, along with millable polymer and wax blocks for computer-aided design and manufacturing (CAD/CAM), are being increasingly utilized due to their high predictability. When combined with face scans, mock-ups can be digitally aligned with the patient's smile line and facial profile. If deemed successful, these mock-ups serve as a blueprint for the fabrication of ceramic restorations, ensuring precise esthetic and functional outcomes [10, 11].

Novel treatment strategies for the rehabilitation of extended erosive lesions evolved and prioritize minimally invasive approaches, aiming to conserve maximal tooth structure [12]. Advancements in ceramic materials and adhesive technologies have spurred the development of defect-oriented treatment concepts for restoring compromised dentition. Modified onlay, partial coverage and occlusal veneer preparation geometries have emerged as viable alternatives to conventional full-coverage crowns [13]. Non-retentive preparation designs, coupled with reduced restoration thickness, enable minimally invasive treatment strategies [14].

Monolithic ceramic restorations have gained popularity as means to mitigate chipping concerns. Lithium disilicate ceramics can be manufactured through traditional methods involving waxing and heat pressing, or alternatively, via CAD/CAM technology. These restorations have been subjected to extensive research and evaluation in long-term clinical studies, especially for single-tooth restorations [15]. Promising long-term clinical data for the application of lithium disilicate restorations, using conventional workflows for the rehabilitation of severe tooth were also reported [16]. It is now necessary to obtain evidence on the clinical long-term behavior of lithium disilicate restoration for the increase of VDO with severe wear in combination with digital workflows. Therefore, the aim of this clinical case is to show a full-mouth rehabilitation in a severely worn dentition with a minimally invasive approach and to present the 9-year follow-up. In addition, this report describes the use of digital technologies for analysis, planning, designing, fabricating and illustrates the detailed treatment steps in clinical and laboratory procedures.

2 | Case

2.1 | Initial Findings

A male patient aged 46 years, with an unremarkable medical history, sought evaluation due to severely worn dentition leading to compromised occlusal function. His primary concerns included dissatisfaction with the esthetics of his smile and severe hypersensitivity in multiple teeth. Due to extensive erosive decay, the VDO was substantially reduced (Figure 1). Clinical examination revealed insufficient amalgam and composite fillings, attrition and erosion affecting most teeth, accompanied by a pronounced loss in VDO with a BEWE score of 17 across all sextants [17].

Periodontal assessment indicated the absence of bleeding on probing or clinical attachment loss. Radiographic

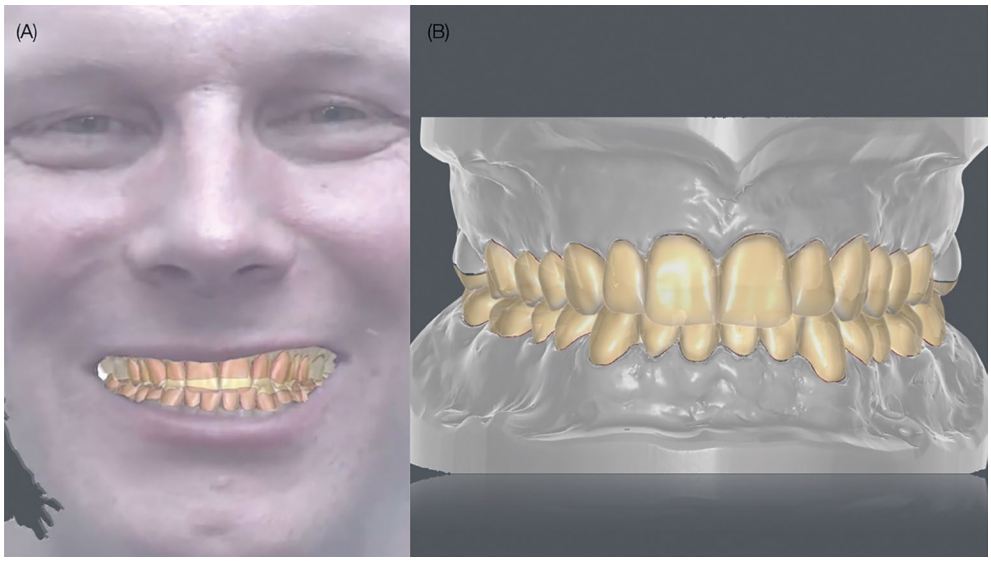

FIGURE 4 | (A) Digital design of the mock-up with the novel VDO referenced by the face scan of the patient and the smile line (B) mock-up design at the novel VDO.

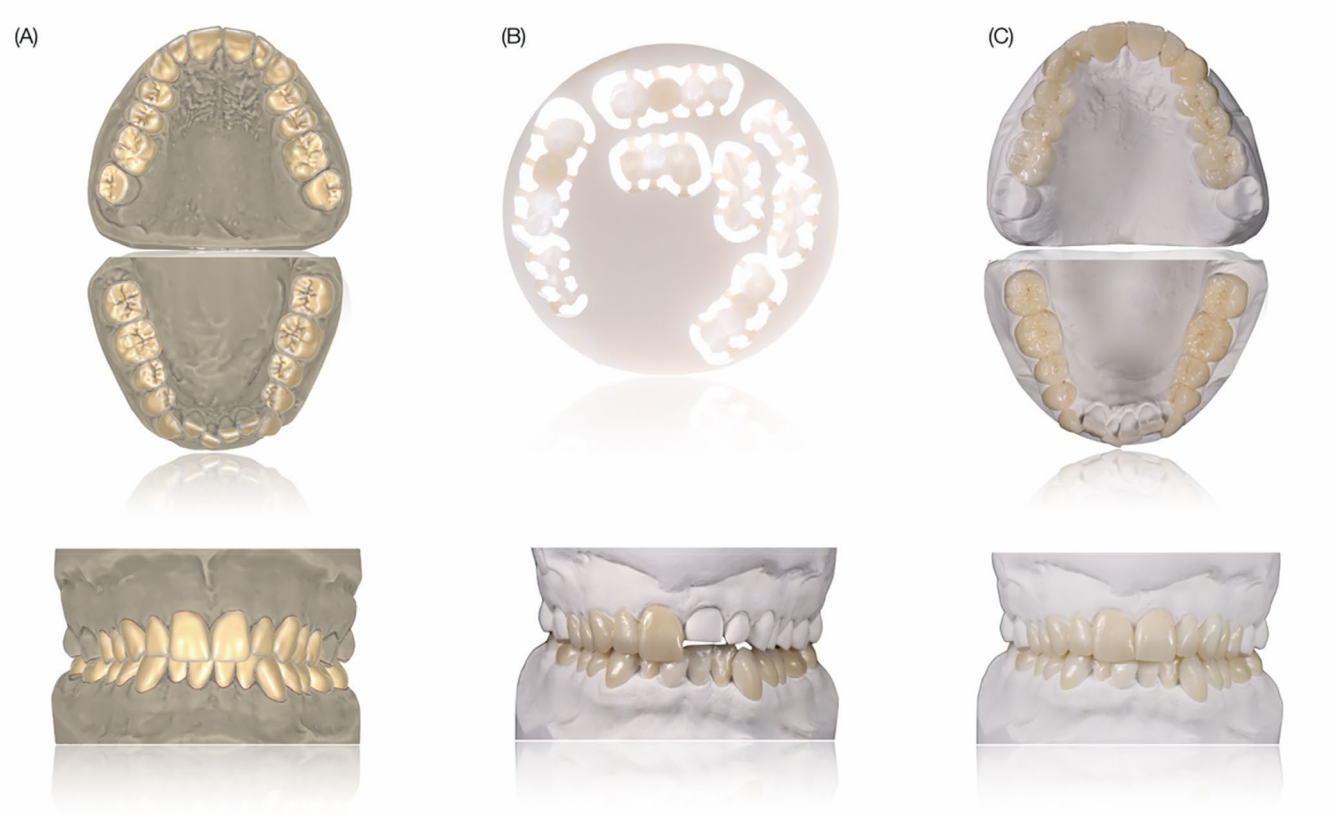

FIGURE 5 | (A) digital design of the mock-up with the increased VDO (B) the milled mock-up displays the increase of VDO (C) the final CAD/CAM fabricated mock-up.

evaluations revealed the absence of periapical or periodontal lesions. Furthermore, the patient exhibited no indications of pain or tenderness in the head or neck region, nor did he report any clicking or tenderness in the temporomandibular joint (TMJ).

A treatment plan for a full-mouth rehabilitation with adhesive minimally invasive high-strength glass ceramic restorations completed in a digital workflow was presented to the patient and accepted.

3 | Treatment Planning and Clinical Procedures

An esthetic analysis was performed to assess various aspects of dental esthetics and to guide the treatment planning for

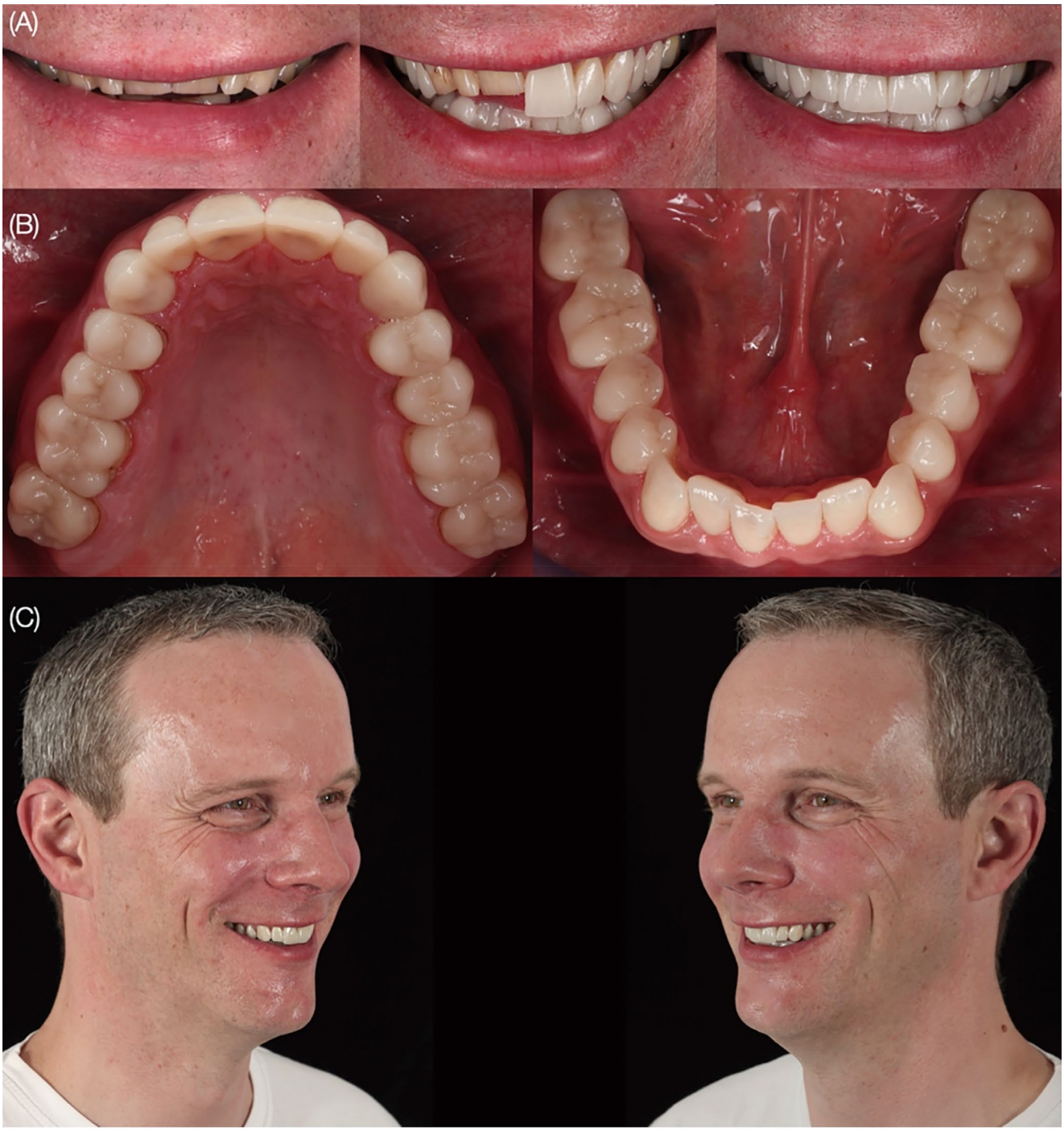

FIGURE 6 | Clinical try in of the mock-up restorations. (A) Smile line improvement, evident in comparison of the mock-up with the initial situation, and in the inserted mock-up with the novel VDO (B) maxillary and mandibular occlusal view of the mock-up (C) full face view in side profile with mock-up in situ.

achieving an optimal outcome (Figure 1). After conventional impressions (Impregum, 3M ESPE) obtained models were scanned (S600 Arti Zirkonzahn, Zirkonzahn, Gais, Italy). Anatomical landmarks of the face and reference planes were captured using a digital face scanning system (Face Hunter, Zirkonzahn, Gais, Italy). The anatomical position of the maxilla was registered with a transfer device (Planefinder, Zirkonzahn, Gais, Italy). This data was uploaded and merged in a design software (Zirkonzahn.Modifier software; Zirkonzahn, Gais, Italy) to visualize the initial situation comprehensively and to determine the novel VDO. Initially, a temporary disposable diagnostic splint (Aqualizer, Dentrade International, Cologne, Germany) was inserted to facilitate the maxilla-mandibular registration in a centric position. Following this, a jig (Futar D fast, Kettenbach, Eschenburg, Germany) was placed on the maxillary central incisors. The elaborated, novel VDO, with the jig in place, was recorded using a registration material (Greenbite Apple, Detax, Ettlingen, Germany) and a facial

FIGURE 7 | Defect oriented, minimally invasive preparation. (A) Occlusal view maxilla and mandible. (B) Buccal view maxilla and mandible.

FIGURE 8 | Virtual articulation enabled a precise transfer of the elaborated VDO from the initial analysis to the digital design of the mock-up and definitive restorations.

scanner (Face Hunter, Zirkonzahn, Gais, Italy). The data sets of the face scan and scanned models were uploaded into the design software (Zirkonzahn.Modifier software; Zirkonzahn, Gais, Italy) to visualize the updated facial proportions (Figure 2). At first a mandibular splint (Therapon Transpa; Zirkonzahn, Gais, Italy) was digitally designed (Figure 3), and provided to the patient to evaluate the functional aspects of the increased VDO. After using the splint for 6 weeks, the patient reported no issues. The dental technician then proceeded to digitally design the mock-up at the increased VDO (Heroes Collection, Zirkonzahn, Gais, Italy) (Figure 4). The digitally designed mock-up restorations (TempBasic, Zirkonzahn, Gais, Italy), were then milled (M2 Teleskoper milling unit, Zirkonzahn, Gais, Italy) (Figure 5). This full-arch mock-up arrangement was then provided to the patient (Figure 6). Upon the patient's approval of the mock-up, a minimally invasive preparation technique was employed. Minimally invasive full-coverage crowns were performed for maxillary anterior teeth and veneer preparation for the mandibular incisors. The extension of the posterior partial coverage restorations was defect oriented. The palatal and lingual aspects of all posterior teeth were preserved (Figure 7). Sharp edges on the occlusal surfaces resulting from erosive tooth decay were carefully rounded, while a shallow buccal chamfer preparation (0.5 mm) was performed on the anterior, premolar, and molar teeth. The abutment teeth were provisionally restored utilizing the underlined CAD/CAM-generated polymer-based mock-up restorations. Due to the availability of limited data regarding the precision of full-arch scans [18, 19] at the time the case was inserted, conventional impressions (Identium, Kettenbach Co, Eschenburg, Germany) of all abutment teeth were acquired. A cross-mounting bite registration was executed, and the mounted models were subsequently digitized using a laboratory scanner. The final restorations were designed based on the approved and tested

mock-up design (Zirkonzahn.Modifier software; Zirkonzahn, Gais, Italy). Integrating the three-dimensional face scan, allowed for precise visualization. The virtual articulator module (Zirkonzahn.Modifier software; Zirkonzahn, Gais, Italy) was used to analyze the functional movements. The increase of the VDO for the definitive restorations was identical with the design of the provisionals (Figure 8). All restorations were then milled utilizing CAD wax (CAD wax Zirkonzahn; Zirkonzahn, Gais, Italy) in a 5+1-axis milling unit and then pressed in a lithium disilicate glass ceramic (IPS e.max Press, Ivoclar, Schaan, Liechtenstein) (Figure 9). A thin application of veneering material (IPS e.max Ceram; Ivoclar, Schaan, Liechtenstein), was limited to maxillary anterior teeth. All lithium disilicate glass–ceramic restorations were adhesively cemented with a dual-polymerizing composite cement (Variolink Esthetic DC, Ivoclar, Schaan, Liechtenstein) according to the manufacturer's instruction (Adhese Universal, Ivoclar, Schaan, Liechtenstein). The presented digital approach facilitated the establishment of a stable static and dynamic occlusion with incisal/canine guidance, attributed to the solid foundation provided by CAD/CAM planning (Figure 10). The patient was then provided with a CAD/CAM fabricated maxillary occlusal guard (Temp Premium Flexible Transpa, Zirkonzahn, Gais, Italy) to ensure long term success of the definitive restorations. At the 9-year post-treatment evaluation, a stable occlusion, healthy periodontal status, and absence of plaque accumulation was confirmed.

FIGURE 9 | Fabrication of minimally invasive lithium disilicate restorations with CAD wax milling and subsequent heat-pressing technique.

FIGURE 10 | Post-operative result. (A) Smile line, (B) intraoral frontal view, (C) maxillary and mandibular occlusal view, (D) esthetic analysis: zenith, tooth axis, contact point, and smile line.

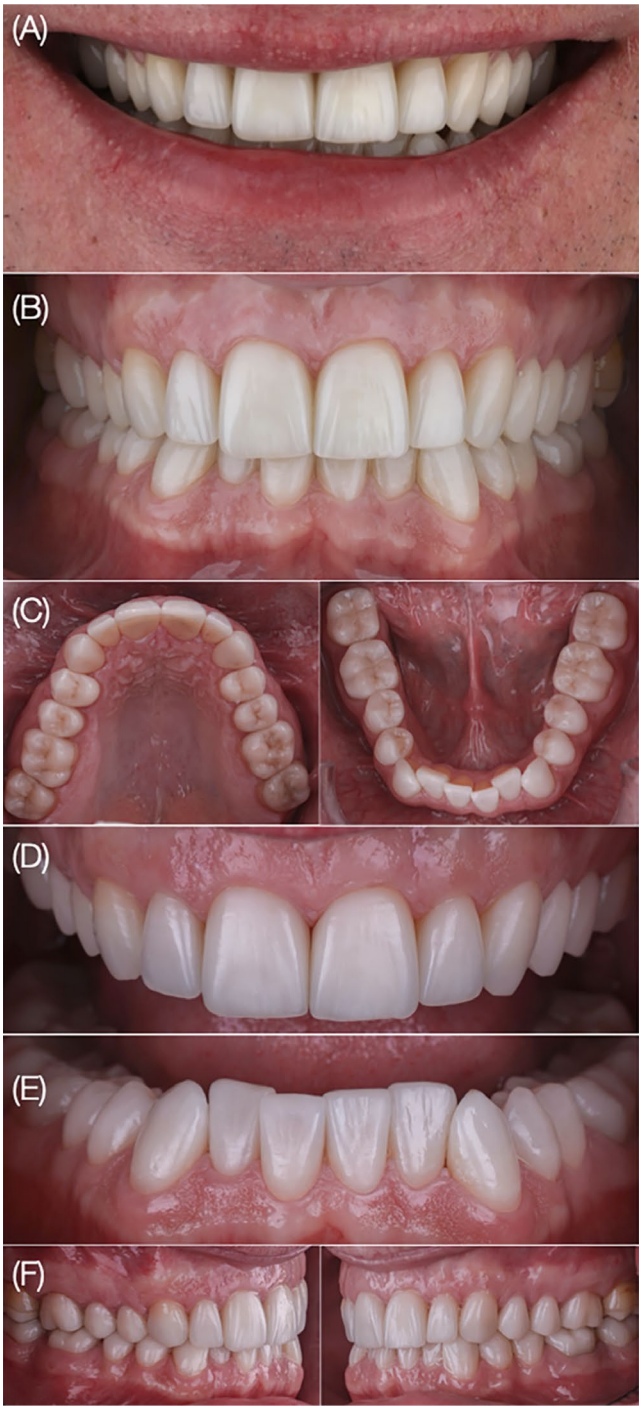

FIGURE 11 | 9-year post-treatment result. (A) Smile line, (B) intraoral frontal view, (C) maxillary and mandibular occlusal view, (D) maxillary frontal view, (E) mandibular frontal view, and (F) lateral view left and right.

No evidence of caries at the restoration margins or signs of fractures within the restorations were observed (Figure 11). An IOS was performed at the 9-year follow-up, utilizing the Primescan (Sirona Dental System GmbH, Bensheim, Germany). Very limited surface wear was observed at the lithium disilicate restorations. Marginal discolorations were observed at the buccal aspect of the partial coverage restorations of the maxillary molars. Figure 12 provides an overview of the digital workflow and displays the change of the VDO.

4 | Discussion

This clinical case reports the full-mouth rehabilitation of a patient with severe tooth wear and loss of VDO in a digital workflow with adhesive minimally invasive ceramic restorations. The presented 9-year follow-up showed that restorations fabricated with CAD/CAM support resulted in clinically acceptable marginal fit and reliable long-term behavior. The application of a face scan and a software that created a smile design with all functional aspects allowed the clinician to explain the treatment plan to the patient and to show the anticipated treatment outcome at a very early stage. Today, 3D printing of a digital wax-up is available and can be used for the fabrication of precise dental preparation guides and mock-ups as well as provisional restorations [20–22]. Recently many CAD systems that combine facial and intraoral photo and/or scan data have been introduced. These advancements enable the analysis of facial proportions, tooth design, functional aspect and display of esthetic outcomes. The obtained predictability and reproducibility emphasize the advantages of digital workflows compared to conventional approaches. A thorough understanding of the physiognomic map is essential, as it plays a critical role in the diagnostic process. Key frontal landmarks include the Trichion, Nasion, Subnasale, Stomion, and Pogonion. With the near-photorealistic quality of digitized facial renderings, the patient's facial physiognomy can be precisely considered. These data provide validation and reference values that enhance diagnostic accuracy [23]. The reference points or lines analyzed in the presented system (PlaneSystem, Zirkonzahn, Gais, Italy) are not based on the skull but are established in 3D space, relative to two consistent zero lines: the true vertical and the true horizontal. The first molar (6-year molar) acts as a stable reference point for spatial orientation. This approach ensures that the parameters used in digitally designing and fabricating restorations precisely correspond to the patient's individual conditions. Furthermore, the reference positions are perfectly synchronized between the patient's mouth and the dental technician's workstation, allowing for data comparisons grounded in objective measurements [24].

This aspect is important in the present case, where the VDO was altered. Determining and establishing the VDO is still considered to be challenging and as one of the dogmas in dentistry [1]. With the help of the described digital workflow the increase of VDO could be determined at certain anatomical landmarks and was used as a reliable objective guide during the entire treatment process of re-establishing a novel VDO [1]. The patient adapted very well to the increased VDO, which meets well with the relevant literature. For a VDO increase in the range of 1.8–6.00 mm the patient's adaptation is reported to be high [1].

Over the past decades, significant improvements have led to intraoral scanners playing a leading role in modern dentistry, offering clinicians similar accuracy, efficiency, and patient comfort compared to conventional impression techniques [25–27]. However, conventional impressions were utilized for this full-arch case due to the controversial discussion surrounding the precision and accuracy of intraoral scans at the time the case was treated, 9 years ago. Laboratory studies have reported inaccuracies, distortions, and horizontal deviations, particularly in the distal regions of the data sets in full-arch cases [18, 28].

FIGURE 12 | Overview of digital workflow and evolution of the VDO. (A) Initial situation, (B) digital design of the Mock-up and the simulated novel VDO, showing the increase at the following reference points: The maxillary and mandibular zeniths of the cementoenamel junctions of the canine and first molar on the right and left side, (C) mock-up with the novel VDO, (D) post-operative result, and (E) 9-year- follow up, with an intraoral scan.

CAD/CAM technology is versatile, enabling the fabrication of a wide range of materials including lithium disilicate, polymer-infiltrated ceramics, and various polymer-based materials as well as zirconia and its various translucent modifications [29]. Encouraging results have been documented for the use of monolithic zirconia crowns in the restoration of carious lesions [30–33]. Minimally invasive lithium disilicate ceramic restorations for patients with moderate or severe wear demonstrated a remarkable survival rate of 100% even after up to 13 years of observation [16]. Another clinical investigation examined the survival rates of ultrathin bonded CAD/CAM occlusal veneers applied to posterior teeth impacted by erosive wear. The findings showcased substantial patient satisfaction and favorable outcomes in terms of performance with a survival rate of 100% for lithium disilicate and 84.7% for composite resin restorations after 3 years [11].

After 9 years of follow-up no fractures of the lithium disilicate ceramic material, no debonding failures and only minor marginal discoloration at the buccal margins of the maxillary molars were observed in the present case. This contributes to clinically support the scientific evidence that shows the success of minimally invasive adhesive lithium disilicate restorations. CAD wax milling and subsequent heat pressing technique enabled the manufacturing of thin margins of minimally invasive restorations and could overcome the challenging machinability of glass ceramics in CAD/CAM milling devices, at the time when the case was performed. Nowadays, the difference between heat pressing and CAD/CAM milling is considered clinically acceptable and shows no significant difference [34].

Multilayer translucent zirconia ceramics have also gained significant popularity owing to its capability to replicate the color gradient from the incisal area to the cervical region [35, 36]. The current evidence of zirconia materials for minimally invasive treatment concepts of severe tooth wear is however limited to case reports [37].

5 | Conclusion

Based on the clinical result of the present case after a nine-year follow-up in which no failures occurred, the authors consider the digital workflow a predictable treatment concept. The digital design of the mock-up referenced by the face scan determined the novel VDO, served as a blueprint for the entire treatment concept and guided the minimally invasive preparation designs. The novel VDO that was elaborated based on this digital design, was tested and approved by the patient, first with the splint, then with the mock-up and interim restorations. Hence a reliable long-term outcome of minimally invasive lithium disilicate restorations for the indication of extended tooth wear was achieved.

In contrast to traditional 2D photography, the integration of face scans with virtual diagnostic tooth arrangement tools enables comprehensive quality control, ensuring precision in transferring all information from temporary to permanent restorations, particularly in complex cases involving an increase in the VDO.

Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

The data that support the findings of this study are available from the corresponding author upon reasonable request.

References

1. A. L. Pissiotis, S. N. Kamalakidis, Y. Kirmanidou, et al., "EPA Consensus Project Paper: The Vertical Dimension of Occlusion. How to Determine and How to Alter? A Systematic Review," *European Journal of Prosthodontics and Restorative Dentistry* (2023).

2. A. Van't Spijker, J. M. Rodriguez, C. M. Kreulen, et al., "Prevalence of Tooth Wear in Adults," *International Journal of Prosthodontics* 22, no. 1 (2009): 35–42.

3. D. Bartlett and S. O'Toole, "Tooth Wear: Best Evidence Consensus Statement," *Journal of Prosthodontics* 30 (2020): 20–25.

4. M. E. Barbour and A. Lussi, "Erosion in Relation to Nutrition and the Environment," *Monographs in Oral Science* 25 (2014): 143–154.

5. A. Lussi, T. Jaeggi, and D. Zero, "The Role of Diet in the Aetiology of Dental Erosion," *Caries Research* 38, no. Suppl 1 (2004): 34–44.

6. N. X. West, M. Sanz, A. Lussi, D. Bartlett, P. Bouchard, and D. Bourgeois, "Prevalence of Dentine Hypersensitivity and Study of Associated Factors: A European Population-Based Cross-Sectional Study," *Journal of Dentistry* 41, no. 10 (2013): 841–851.

7. C. Ganss and A. Lussi, "Diagnosis of Erosive Tooth Wear," *Monographs in Oral Science* 25 (2014): 22–31.

8. Y. J. Zhao, Y. X. Xiong, and Y. Wang, "Three-Dimensional Accuracy of Facial Scan for Facial Deformities in Clinics: A New Evaluation Method for Facial Scanner Accuracy," *PLoS One* 12, no. 1 (2017): e0169402.

9. W. Piedra-Cascón, J. Fountain, W. Att, and M. Revilla-León, "2D and 3D patient's Representation of Simulated Restorative Esthetic Outcomes Using Different Computer-Aided Design Software Programs," *Journal of Esthetic and Restorative Dentistry* 33, no. 1 (2021): 143–151.

10. A. Skorulska, P. Piszko, Z. Rybak, M. Szymonowicz, and M. Dobrzyński, "Review on Polymer, Ceramic and Composite Materials for CAD/CAM Indirect Restorations in Dentistry-Application, Mechanical Characteristics and Comparison," *Materials* 14, no. 7 (2021): 1592.

11. L. H. Schlichting, T. H. Resende, K. R. Reis, et al., "Ultrathin CAD-CAM Glass-Ceramic and Composite Resin Occlusal Veneers for the Treatment of Severe Dental Erosion: An up to 3-Year Randomized Clinical Trial," *Journal of Prosthetic Dentistry* 128, no. 2 (2022): 158.e1–158.e12.

12. B. Loomans, N. Opdam, T. Attin, et al., "Severe Tooth Wear: European Consensus Statement on Management Guidelines," *Journal of Adhesive Dentistry* 19, no. 2 (2017): 111–119.

13. M. Alghauli, A. Y. Alqutaibi, S. Wille, and M. Kern, "Clinical Outcomes and Influence of Material Parameters on the Behavior and Survival Rate of Thin and Ultrathin Occlusal Veneers: A Systematic Review," *Journal of Prosthodontic Research* 67, no. 1 (2023): 45–54.

14. P. C. Gierthmuehlen, A. Jerg, J. B. Fischer, E. A. Bonfante, and F. A. Spitznagel, "Posterior Minimally Invasive Full-Veneers: Effect of Ceramic Thicknesses, Bonding Substrate, and Preparation Designs on Failure-Load and -Mode After Fatigue," *Journal of Esthetic and Restorative Dentistry* 34, no. 1 (2022): 145–153.

15. K. A. Malament, M. Margvelashvili-Malament, Z. S. Natto, V. Thompson, D. Rekow, and W. Att, "Comparison of 16.9-Year Survival of Pressed Acid Etched e.Max Lithium Disilicate Glass-Ceramic Complete and Partial Coverage Restorations in Posterior Teeth: Performance and Outcomes as a Function of Tooth Position, Age, Sex, and Thickness of Ceramic Material," *Journal of Prosthetic Dentistry* 126, no. 4 (2021): 533–545.

16. D. Edelhoff, K. J. Erdelt, B. Stawarczyk, and A. Liebermann, "Pressable Lithium Disilicate Ceramic Versus CAD/CAM Resin Composite Restorations in Patients With Moderate to Severe Tooth Wear: Clinical Observations up to 13 Years," *Journal of Esthetic and Restorative Dentistry* 35, no. 1 (2023): 116–128.

17. D. Bartlett, C. Ganss, and A. Lussi, "Basic Erosive Wear Examination (BEWE): A New Scoring System for Scientific and Clinical Needs," *Clinical Oral Investigations* 12 Suppl 1, no. Suppl 1 (2008): S65–S68.

18. A. Ender and A. Mehl, "In-Vitro Evaluation of the Accuracy of Conventional and Digital Methods of Obtaining Full-Arch Dental Impressions," *Quintessence International* 46, no. 1 (2015): 9–17.

19. H. Khraishi and B. Duane, "Evidence for Use of Intraoral Scanners Under Clinical Conditions for Obtaining Full-Arch Digital Impressions Is Insufficient," *Evidence-Based Dentistry* 18, no. 1 (2017): 24–25.

20. M. Sancho-Puchades, V. Fehmer, C. Hämmerle, and I. Sailer, "Advanced Smile Diagnostics Using CAD/CAM Mock-Ups," *International Journal of Esthetic Dentistry* 10, no. 3 (2015): 374–391.

21. C. Porto, R. F. de Freitas, A. L. Carneiro Pereira, and A. da Fonte Porto Carreiro, "CAD/CAM Technology for Fabrication of Reduction Guide for RPD Parallel Guiding Planes Preparation: A Dental Technique," *Primary Dental Journal* 11, no. 4 (2022): 66–70.

22. A. O. Abdullah, E. A. Tsitrou, and S. Pollington, "Comparative In Vitro Evaluation of CAD/CAM vs Conventional Provisional Crowns," *Journal of Applied Oral Science* 24, no. 3 (2016): 258–263.

23. M. Srinivasan, F. Berisha, I. Bronzino, P. Kamnoedboon, and C. R. Leles, "Reliability of a Face Scanner in Measuring the Vertical Dimension of Occlusion," *Journal of Dentistry* 146 (2024): 105016.

24. U. Plaster, "Transfer of the patient's Oral Situation to the Articulator and Synchronizing the Articulated Models," *Journal of Craniomandibular Function* 11, no. 2 (2019): 163–184.

25. M. Hasanzade, M. Aminikhah, K. I. Afrashtehfar, and M. Alikhasi, "Marginal and Internal Adaptation of Single Crowns and Fixed Dental Prostheses by Using Digital and Conventional Workflows: A Systematic Review and Meta-Analysis," *Journal of Prosthetic Dentistry* 126, no. 3 (2021): 360–368.

26. M. Hasanzade, M. Shirani, K. I. Afrashtehfar, P. Naseri, and M. Alikhasi, "In Vivo and in Vitro Comparison of Internal and Marginal Fit of Digital and Conventional Impressions for Full-Coverage Fixed Restorations: A Systematic Review and Meta-Analysis," *Journal of Evidence-Based Dental Practice* 19, no. 3 (2019): 236–254.

27. O. N. Bandiaky, P. Le Bars, A. Gaudin, et al., "Comparative Assessment of Complete-Coverage, Fixed Tooth-Supported Prostheses Fabricated From Digital Scans or Conventional Impressions: A Systematic Review and Meta-Analysis," *Journal of Prosthetic Dentistry* 127, no. 1 (2022): 71–79.

28. S. B. Patzelt, A. Emmanouilidi, S. Stampf, et al., "Accuracy of Full-Arch Scans Using Intraoral Scanners," *Clinical Oral Investigations* 18, no. 6 (2014): 1687–1694.

29. F. A. Spitznagel, J. Boldt, and P. C. Gierthmuehlen, "CAD/CAM Ceramic Restorative Materials for Natural Teeth," *Journal of Dental Research* 97, no. 10 (2018): 1082–1091.

30. M. Waldecker, R. Behnisch, P. Rammelsberg, and W. Bömicke, "Five-Year Clinical Performance of Monolithic and Partially Veneered Zirconia Single Crowns-a Prospective Observational Study," *Journal of Prosthodontic Research* 66, no. 2 (2022): 339–345.

31. A. Mikeli, M. H. Walter, S. A. Rau, M. Raedel, and M. Raedel, "Three-Year Clinical Performance of Posterior Monolithic Zirconia Single Crowns," *Journal of Prosthetic Dentistry* 128, no. 6 (2022): 1252–1257.

32. Z. Tang, X. Zhao, H. Wang, and B. Liu, "Clinical Evaluation of Monolithic Zirconia Crowns for Posterior Teeth Restorations," *Medicine* 98, no. 40 (2019): e17385.

33. M. F. Solá-Ruiz, M. Baixauli-López, A. Roig-Vanaclocha, J. Amengual-Lorenzo, and R. Agustín-Panadero, "Prospective Study of Monolithic Zirconia Crowns: Clinical Behavior and Survival Rate at a 5-Year Follow-Up," *Journal of Prosthodontic Research* 65, no. 3 (2021): 284–290.

34. I. B. Sanches, T. C. Metzker, R. Kappler, M. V. Oliveira, A. O. Carvalho, and E. M. Castor Xisto Lima, "Marginal Adaptation of CAD-CAM and Heat-Pressed Lithium Disilicate Crowns: A Systematic Review and Meta-Analysis," *Journal of Prosthetic Dentistry* 129, no. 1 (2023): 34–39.

35. N. Kolakarnprasert, M. R. Kaizer, D. K. Kim, and Y. Zhang, "New Multi-Layered Zirconias: Composition, Microstructure and Translucency," *Dental Materials* 35, no. 5 (2019): 797–806.

36. M. Inokoshi, H. Liu, K. Yoshihara, et al., “Layer Characteristics in Strength-Gradient Multilayered Yttria-Stabilized Zirconia,” *Dental Materials* 39, no. 4 (2023): 430–441.

37. C. R. Luna-Domínguez, J. H. Luna-Domínguez, and M. Blatz, “Full-Mouth Rehabilitation in a Completely Digital Workflow Using Partially Adhesive Monolithic Zirconia Restorations,” *Journal of Esthetic and Restorative Dentistry* 35, no. 7 (2023): 1050–1057.