Case Report

Gingival Contouring and Smile Makeover Through Digital Planning and 3D Guidance

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Abstract

Background: Gingivectomy plays a vital role in restorative dentistry, especially for patients with uneven gingival architecture. Traditional techniques often present challenges in achieving precision and symmetry. This case report demonstrates the effectiveness of a fully digital workflow for planning and performing gingivectomy, aiming to improve clinical accuracy and esthetic outcomes. A mock-up was also fabricated post-surgery to visualize the expected final result and assist in guiding subsequent treatment.

Methods: A comprehensive digital workflow was implemented, starting with an Artificial Intelligence (AI)-based smile simulation to preview the esthetic outcome. A digital smile design was used to fabricate a combined tooth and gingival reduction guide through Computer-Aided Design and Manufacturing (CAD/CAM). The guide was stored under controlled conditions to maintain dimensional stability. Provisional restorations were milled from Mono Polymethylmethacrylate (PMMA), a dedicated CAD/CAM temporary material and also served as the mock-up. Laser-assisted gingivectomy was then performed using the three-Dimensional (3D)-printed guide, followed by placement of the provisional restorations.

Results: The digital workflow enabled precise gingival contouring, accurate guide fit and harmonious integration between gingival margins and restorative contours. The mock-up provided clear visualization of the esthetic improvements, with minimal invasiveness and high patient satisfaction. The PMMA provisionals exhibited excellent esthetics and biological compatibility.

Conclusion: This case underscores the advantages of integrating AI-driven planning and CAD/CAM technology in periodontal and restorative dentistry. The digital approach facilitated precise surgical execution, predictable outcomes, and effective communication with the patient. The high-quality mock-up not only enhanced patient acceptance but also served as a reliable template for subsequent esthetic treatment phases.

Keywords: 3D Guides; Artificial Intelligence; CAD/CAM; Digital Dentistry; Digital Planning; Gingivectomy, Guided Surgery; Minimally Invasive; Provisional Restoration; Smile Simulation

Introduction

Patient need for perfect smile has increased considerably in recent years, influenced not only by concerns over tooth color and shape but also by the demand to improve function and biology, often requiring a multidisciplinary approach involving restorative, periodontal, orthodontic and surgical interventions [1-3]. Moreover, the increasing impact of social media has significantly contributed to the growing interest in dental treatments focused on smile enhancement [2]. A prior study found that among social media users, the most requested esthetic procedures were teeth whitening (54.7%), smile makeovers (17%), dental veneers (11.9%) and clear aligners (10.4%), reflecting a growing desire for the ideal smile [4].

Excessive Gingival Display (EGD), commonly referred to as a "gummy smile" or a "high smile line", is a prevalent esthetic concern, particularly in the maxillary anterior region [5,6]. It is typically defined by the exposure of more than 3 mm of gingival tissue during smiling [7]. It was stated that the occurrence of EGD has been reported in approximately 7% of men and 14% of women between the ages of 20 and 30 years [8]. EGD can be attributed to various factors, including vertical maxillary excess, anterior dentoalveolar extrusion, lip length and activity, gingival hyperplasia and over compensatory eruption. While these causes may vary, it is often the result of a multifactorial effect, with Altered Passive Eruption (APE) being one of the primary dental contributors [6,9]. APE occurs when the gingival margin fails to migrate apically following tooth eruption, leading to short clinical crowns and a more coronal gingival positioning [10,11]. The harmonious relationship between the teeth and surrounding gingival architecture plays a crucial role in smile esthetics, as societal standards often emphasize symmetry, proper tooth alignment and a balanced gingival display as key components of an attractive smile [12].

An accurate differential diagnosis is essential for determining the appropriate treatment for a gummy smile, as therapeutic options include facial surgery, periodontal surgery, laser treatment and botulinum toxin injections. More recently, digital workflows and flapless procedures, such as piezosurgery, have been integrated into treatment planning [8,13-16]. Dental lasers present multiple benefits in soft tissue procedures compared to traditional surgical methods, including enhanced coagulation, reduced or no need for anesthesia and sutures, and faster postoperative healing. These advantages contribute to favorable clinical outcomes. However, to prevent complications such as gingival recession or bone damage, a comprehensive understanding of laser-tissue interaction is essential for predictable and safe results [17,18].

Digital dentistry has transformed the management of complex cases by enhancing diagnostic accuracy and treatment planning [19]. The integration of digital planning tools not only improves procedural accuracy but also reduces chair time and surgical trauma, ultimately leading to enhanced esthetic and functional outcomes [20]. In the context of gingivectomy, a digital workflow enables clinicians to assess anatomical landmarks with greater precision and to plan surgical interventions more predictably. Cone-Beam Computed Tomography (CBCT) is used to evaluate the position of the Cemento-Enamel Junction (CEJ) in relation to the alveolar bone crest [16]. The CBCT-derived data are exported in Digital Imaging and Communications in Medicine (DICOM) format and then converted into Standard Tessellation Language (STL) files. These STL files are superimposed with those obtained from intraoral scans to construct a precise three-dimensional (3D) virtual model. Based on this model, a customized surgical guide is digitally designed and fabricated using 3D printing technology [21].

Further, digital technologies have transformed the planning and execution of such procedures, offering clinicians greater control and predictability [22]. In this context, Digital Smile Design (DSD) has emerged as a revolutionary tool. Originally introduced by Coachman, et al., in 2007, DSD allows clinicians to design the ideal smile using facially guided analysis based on extraoral photographs and dynamic video documentation. This methodology enables a patient-centered approach, where Artificial Intelligence (AI) -powered software can create accurate two-dimensional (2D) simulations of potential outcomes, which are then transformed into 3D models to guide treatment planning [23]. The use of mock-ups based on DSD further enhances communication between clinician and patient, allowing the patient to visualize and approve the proposed result prior to treatment [1]. These mock-ups also serve a critical clinical role, acting as physical guides for soft tissue procedures and references for tooth preparations [24]. There are several programs that can be used for the DSD such as Photoshop software from Adobe Systems (San Jose, CA, USA), Keynote (Apple Inc., Cupertino, CA, USA), PowerPoint (Microsoft Corp., Redmond, WA, USA), Digital Smile Design App (DSD app) and other applications and softwares combining digital photography and imaging software [25].

In the present case, a digital approach was used to simplify a complex gingivectomy procedure and a mock-up was created to help the patient visualize the potential final project and to support a guided, outcome-driven methodology. The patient presented with challenging gingival architecture, requiring precise planning and execution. The treatment process began with AI-driven smile simulation, followed by the creation of a digital gingivectomy guide and a milled provisional restoration used as a mock-up. These digital tools enhanced visualization, ensured precise guide placement, and facilitated a more predictable clinical outcome. The fully integrated digital workflow enabled a minimally invasive approach, improved procedural efficiency, and produced a high-quality milled mock-up that served as a provisional restoration, optimizing both esthetic and functional results.

Ethical Statement

The project did not meet the definition of human subject research under the purview of the IRB according to federal regulations and therefore, was exempt.

Case Presentation

A 28-year-old male in apparent good health presented with dissatisfaction regarding his smile. Intraoral and extraoral evaluation revealed a gummy smile (Fig. 1), short anterior teeth (confirmed by the Chu esthetic gauge) (Fig. 2-4) and composite restorations with overhangs and discoloration on the anterior teeth, affecting the esthetic appearance. No periodontal issues were noted even with the presence of the moderate oral hygiene and no bleeding on probing was observed.

Figure 1: Initial portrait photograph showing the patient's gummy smile prior to treatment.

Figure 2: Initial buccal view of the maxillary anterior teeth.

Figure 3: Initial 12 o'clock buccal view of the maxillary anterior teeth, highlighting excessive gingival display and defective composite restoration.
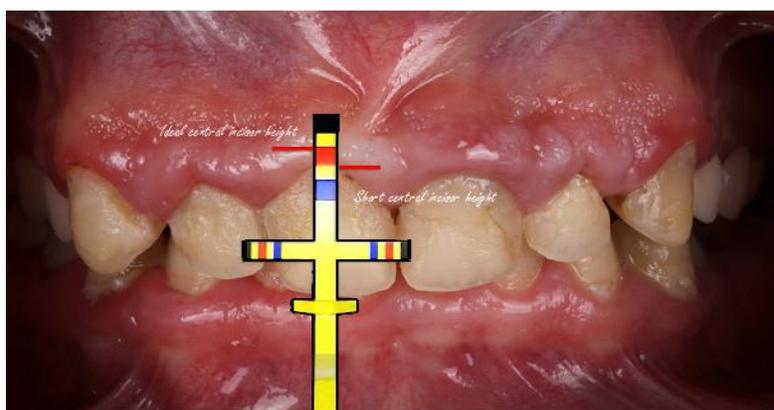

Figure 4: Clinical evaluation using the Chu proportion gauge, indicating reduced height of the maxillary central incisor relative to ideal proportions.

A comprehensive clinical, radiographic examination and digital photos were conducted as part of the treatment planning. CBCT was performed to assess the distance between the bone crest and the CEJ. The results indicated that the bone crest was away from the CEJ, suggesting no need for bone resection. Clinical examination revealed non-ideal gingival and dental architecture (Fig. 1-4).

Initially, three sessions of deep cleaning were performed to ensure that the gingival tissues were in optimal condition prior to commencing the procedure. The proposed treatment plan involved a gingivectomy procedure, without bone removal, using a digital approach for precise planning and execution. The patient agreed to the treatment plan and signed an informed consent prior to the initiation of treatment. The approach employed advanced digital solutions for enhanced precision and predictable outcomes in this complex case.

Digital Planning
The digital treatment planning process began with the analysis of digital photographs. The patient's extraoral photograph was captured using a smartphone device (Samsung Galaxy S24, Samsung, Suwon, South Korea) and imported into the SmileFy application (SmileFy Inc., Hallandale Beach, FL, USA). This application facilitated the 2D smile design by analyzing key facial features, such as the interpupillary and commissural lines, which were found to be in harmony with the maxillary occlusal plane. The facial midline was also automatically detected by the software [26]. The before and after 2D smile design simulations were clearly shown in Fig. 5, providing a visual representation of the potential outcome. This helped both the clinician and patient assess the proposed changes efficiently and accurately. The newly created 2D smile design was presented to the patient, who approved it to proceed with the project.

Figure 5: Before and after 2D smile design simulation using SmileFy software, based on a frontal facial photograph for esthetic analysis and planning.

In addition to the 2D smile design generated with SmileFy software (SmileFy Inc., Hallandale Beach, FL, USA), which provided four build-in templates from which one was chosen according to the patient's facial features, another 2D design was created for the patient using the SmileCloud program (SmileCloud SRL, Timișoara, Romania). This software also incorporates AI and a virtual cloud platform. The AI-powered tool suggests a tooth shape library with more templates based on the patient's facial features when compared to the SmileFy software, allowing for a more personalized and accurate result. SmileCloud offers a cloud-based solution for smile design that is flexible and scalable, enabling dental professionals to adjust and create highly tailored smile designs. Moreover, SmileCloud enables real-time collaboration between clinicians and dental technicians, supports facially driven design protocols and offers realistic tooth morphologies derived from natural tooth libraries-factors that enhance diagnostic accuracy and esthetic predictability. A main advantage of SmileCloud is its ability to include gingival contouring in the planning phase, which is crucial for cases requiring periodontal adjustments to achieve ideal esthetic outcomes. The before and after results of the 2D smile design using SmileCloud are presented in Fig. 6.

Figure 6: Before and after 2D smile design simulation using Smilecloud software, showcasing the AI-powered customization based on the patient's facial features.

This additional design provided a second perspective on the patient's smile, offering more possibilities for customization and refinement. The use of both SmileFy and SmileCloud tools allowed for a comprehensive and collaborative approach to smile design, ensuring that the final outcome would meet both the patient's esthetic desires and functional requirements.

All in all, the 2D smile design was presented to the patient, who accepted it to proceed with the project. While 2D smile design is a powerful tool for visualization and patient communication, it has limitations. One primary constraint is that it only shows

the patient a simulated representation of the final result, allowing for a better understanding and confirmation of the proposed changes. The selected 2D tooth template can be downloaded as its corresponding natural tooth libraries in the STL file format, which can then be imported into 3D design software programs to facilitate the esthetic project and to provide a more realistic view of the final situation [27].

A significant limitation of 2D Computer-Aided Design (CAD) systems is that smile design is created in a 2D format using the patient's photographs, without incorporating 3D virtual diagnostic casts. This restricts the ability to visualize the design in a 3D environment, limiting its ability to account for factors such as occlusion and overall dental architecture. Additionally, 2D dental CAD programs often do not allow modifications in the software programming, which may limit customization options for more complex treatment plans [28-30].

Thus, while 2D smile design is a valuable initial step, the transition to a 3D workflow offers a more comprehensive, accurate and adaptable approach to the final smile design. To address this, a 3D smile design was initiated. An intraoral scan was performed using the Helios 500 (Eighteeth Company, Changzhou, Jiangsu Province, China) to visualize both the upper and lower arches. The Polygon File Format (PLY) file of the upper jaw was imported into Exocad software (Exocad GmbH, Darmstadt, Germany) revealing increased gingival volume and suboptimal architecture of both teeth and gingival tissues (Fig. 7).

Figure 7: PLY file of the upper scan showcasing the excessive gingival volume and the initial tissue architecture (View from the Exocad software).

Facial scanners have the potential to digitize and replace conventional extraoral records, such as analog facebows, occlusal analysis tools and traditional diagnostic wax-ups. While routine digital radiography and photography continue to provide essential diagnostic data, the integration of 3D facial scanning enables the acquisition of additional extraoral soft tissue and facial structure details. These data can be superimposed to create a comprehensive 3D virtual model of the patient, enhancing diagnostic precision and treatment planning [31]. To complement the existing records, a 3D facial scan was performed using the MetiSmile facial scanner (Shining 3D Tech. Co., Ltd., Hangzhou, China), providing detailed morphological data of the patient's facial anatomy for alignment with intraoral scans and further integration into the digital workflow (Fig. 8).
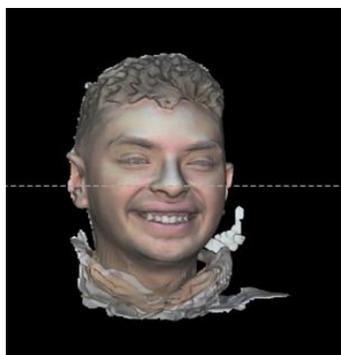

Figure 8: 3D facial scan of the patient acquired using the MetiSmile scanner (Shining 3D Tech. Co., Ltd., Hangzhou, China), serving as supplementary data for comprehensive digital treatment planning.

Subsequently, the initial intraoral scan and the CBCT data were superimposed using SmileCloud software (SmileCloud SRL, Timișoara, Romania) to generate a 3D smile design. This integration allowed for precise alignment of skeletal, dental and soft tissue structures, facilitating a comprehensive and accurate virtual treatment plan (Fig. 9).
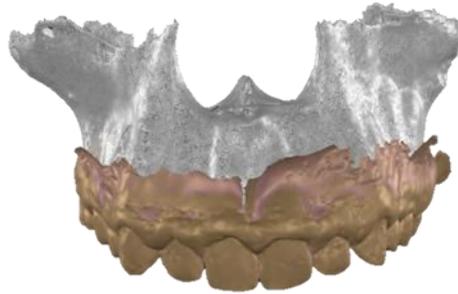

Figure 9: Superimposition of the initial intraoral scan and CBCT data using SmileCloud software to generate a comprehensive 3D smile design integrating dental, skeletal and soft tissue structures.

After the superimposition of the initial intraoral scan and CBCT data in SmileCloud software, the digital design was adjusted to ensure optimal dental and gingival harmony. The software allowed for precise modifications in tooth alignment, shape and gingival contour. The 3D visualization facilitated a comprehensive face-guided intraoral planning process by considering key facial landmarks such as the interpupillary line, midline and the smile zenith curve.

The correction of the teeth and gingival margins was achieved by adjusting the incisal line, which was aligned parallel to the interpupillary line and gingival contour, ensuring a balanced, esthetically pleasing smile. The gingival margin was refined to create a harmonious transition between the teeth and the surrounding soft tissues. The position of the interdental papillae was also adjusted, ensuring that the papillae rested beyond the interproximal contact point to close any gaps and promote an esthetically balanced smile. The correction also involved ensuring that the canine teeth were positioned 0.5 to 1 mm higher than the central incisors and the lateral incisors were positioned 0.5 to 1 mm lower, following the smile zenith curve principles. Additionally, the esthetic aspect ratio of the teeth, such as the height and width of the central incisors, was assessed to maintain an ideal proportion for a visually appealing smile. Based on this face-guided analysis, a digital design was prepared, correlating the patient's facial shape with the optimal tooth morphology (square, ovoid or triangular), ensuring the final 3D project aligned with the patient's desires, physical features and personality (Fig. 10).
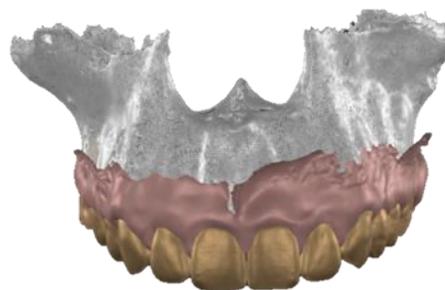

Figure 10: 3D smile design showcasing the ideal correction of tooth alignment and gingival harmony, with adjustments made for an esthetically balanced smile. The design includes the refinement of the gingival margin, correction of tooth position and alignment of the smile zenith curve to ensure optimal facial and dental esthetics.

The 3D smile design was then printed using Asiga Max (Asiga, Sydney, Australia) and the DentaMODEL 3D print material (Asiga, Sydney, Australia), to have a physical reference for further evaluation and refinement. This allows the clinician to assess the esthetics and functionality of the design in a more tangible form before proceeding with the final treatment (Fig. 11).

Figure 11: 3D-printed smile design model used as a reference for evaluating tooth alignment, gingival harmony and overall esthetic outcome prior to final treatment implementation.

3D-printed Guides and Laser Treatment
After completing the 3D smile design, two 3D surgical guides were created and designed for the gingivectomy procedure using different software programs. The first guide was designed using Exocad software (Exocad GmbH, Darmstadt, Germany), which provided precise geometry to ensure accurate seating during surgery (Fig. 12). This guide incorporated three key windows to facilitate proper alignment and positioning for the gingivectomy.
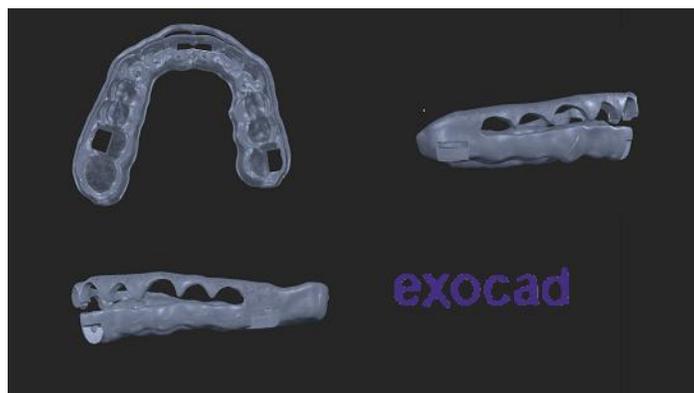

Figure 12: Surgical guide designed using Exocad software, featuring three key windows to ensure proper seating during the gingivectomy procedure.

The second guide was designed using CoDiagnostiX software (Straumann, Basal, Switzerland), which featured open and parallel scalloped lines to delineate the incision line for the coronal gingivectomy procedure (Fig. 13).
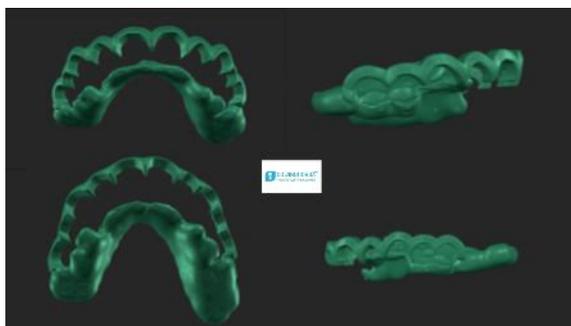

Figure 13: Surgical guide designed using CoDiagnostiX software, with parallel scalloped lines delineating the incision line for the coronal gingivectomy procedure.

The use of these two guides offers several advantages. First, increased accuracy and precision: Each guide was optimized for different aspects of the treatment, providing better overall precision during the gingivectomy. Second, redundancy for increased confidence: The integration of guides from two distinct software platforms introduced an added level of safety, contributing to a more controlled and predictable outcome (Fig. 14).

Figure 14: Two 3D guides for the gingivectomy procedure.

From the frontal (Fig. 15) and lateral views (Fig. 16) of the gingivectomy project, it was clear that the guides were positioned correctly, with the guide away from the bone, eliminating the need for a crown lengthening procedure. The guides ensured the appropriate relationship between the CEJ and the alveolar crest.
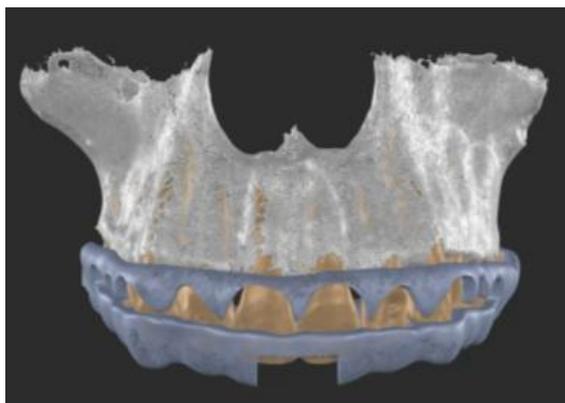

Figure 15: Frontal view of the guide superimposed on the 3D model, demonstrating that the gingival margin is safely positioned away from the underlying bone. Confirming that a crown lengthening procedure was not necessary.
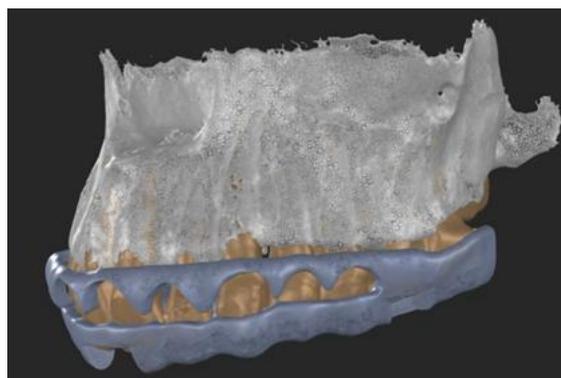

Figure 16: The lateral view of the superimposed guides reveals a clear distance between the planned gingival incision line and the alveolar crest, ensuring a conservative and biologically safe gingivectomy.

The two surgical guides, developed using Exocad and CoDiagnostiX software, were fabricated through 3D printing to aid in the esthetic gingivectomy procedure. Once printed using the open printer Asiga Max (Asiga, Sydney, Australia) and the DentaGUIDE 3D print material (Asiga, Sydney, Australia), both guides were tested on the initial 3D model to ensure proper adaptation and fit. This verification step was essential to confirm that each guide seated accurately, providing reliable reference points during surgery. The Exocad-designed guide featured three precise windows to aid in seating verification (Fig. 17), while

the CoDiagnostiX guide employed open, scalloped designs to delineate the planned incision line. Next, the guides were stored in a dark environment to prevent any potential errors during the gingivectomy procedure and to preserve the dimensional stability of both guides, as previously demonstrated in the literature [32]. Additionally, to maintain precision, guides should be used within 7 days and stored in a dry environment to prevent any alteration in their dimensional stability [33].

Figure 17: Visualization of the 3D-printed surgical guides designed using Exocad software.

The clear and stable adaptation of both guides on the model reinforced their clinical applicability and helped eliminate the need for crown lengthening, as they remained well above the bone level (Fig.18).

Figure 18: Visualization of the two 3D-printed surgical guides-designed using CoDiagnostiX and Exocad software-adapted accurately onto the initial 3D model, confirming proper fit and stability before clinical application.

The Exocad-designed surgical guide was carefully positioned intraorally to assess its adaptability and ensure a precise fit within the patient's soft tissue contours (Fig. 19).

Figure 19: Intraoral positioning of the Exocad-designed guide to assess its fit and adaptability.

Once in place, the guide's stability and alignment were confirmed using key anatomical landmarks. To validate the accuracy of the planned gingival correction, reference lines were drawn on the gingiva through the guide's windows. These markings indicated the exact amount of soft tissue to be removed, ensuring that the clinical execution would correspond precisely with the previously approved DSD. This step served as a crucial verification phase to guarantee that the gingivectomy procedure would align with both functional and esthetic expectations (Fig. 20).
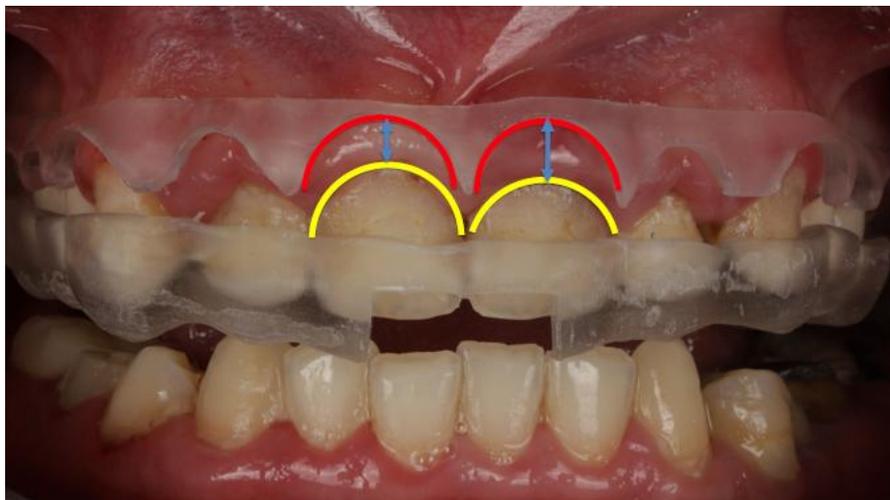

Figure 20: Reference lines drawn through the guide to outline the gingival tissue to be removed, confirming alignment with the 3D smile design.

The CoDiagnostiX-designed surgical guide was also placed in the patient's mouth to evaluate its adaptation and stability (Fig. 21). The guide demonstrated a precise fit, conforming closely to the gingival contours. Its open design with scalloped incisal margins clearly delineated the planned gingival incision line, enabling the clinician to visualize and verify the extent of gingival reshaping needed. This intraoral verification confirmed the feasibility of the gingivectomy procedure as digitally planned, reinforcing the reliability of the CoDiagnostiX guide for esthetic soft tissue management.

Figure 21: Semi lateral view showing the intraoral adaptation of the CoDiagnostiX-designed surgical guide, with clear visualization of the gingival contour line.

Once the correct seating of the guide was verified intraorally, the gingivectomy procedure was performed using an erbium-doped yttrium aluminum garnet (Er:YAG) laser (Fotona; wavelength: 2940 nm), with a power setting of 2 watts, frequency of 10 Hz, and pulse width of 100 microseconds. The procedure utilized the R02 handpiece with a chisel quartz tip, 0% water (cooling was achieved using gauze soaked in cold water), and 4% air spray. This advanced laser technology enabled precise cutting and coagulation of the gingival tissues, resulting in minimal bleeding and improved intraoperative visibility. The use of this minimally invasive technique contributed to shorter healing duration, reduced postoperative discomfort and a predictable esthetic outcome. The surgical procedure strictly followed the contours defined by the predesigned 3D-printed guide, ensuring symmetry and harmony in the final gingival architecture (Fig.22).

Figure 22: Gingivectomy performed using the Fotona Er: YAG laser following the guided contours.

Following the laser-assisted gingivectomy procedure, the patient reported zero discomfort and zero pain, underscoring the minimally invasive nature and patient-friendly advantage of using the Er: YAG laser. The precise guidance provided by the predesigned 3D-printed surgical guide, combined with the effective hemostasis and tissue-sparing action of the laser, contributed significantly to patient comfort and satisfaction during and after the procedure (Fig. 23).

Figure 23: Lateral view of the surgical guide positioned intraorally during the gingivectomy procedure with the Fotona Er: YAG laser.

Milled Provisional

According to the previously finalized 3D smile design and digital wax-up, the provisional restorations were milled with palatal support to ensure proper fit and enhanced mechanical properties (Fig. 24,25). Milling was selected over conventional techniques and 3D printing due to its higher fracture resistance, better marginal accuracy and superior surface finish. These advantages make milled provisionals more durable and reliable, particularly when used in cases requiring long-term temporization or significant functional and esthetic demands [34].

Figure 24: Milled provisional restorations with palatal support, designed according to the finalized 3D smile plan, ensuring strength and fit for esthetic and functional evaluation.

Figure 25: Different views of the milled provisional restorations with palatal support, designed according to the digital smile design and fabricated for enhanced fracture resistance.

Afterwards, the milled provisional restorations by the milling unit (Zirkonzahn M1, Zirkonzahn, GAIS, Germany), fabricated using Mono Polymethylmethacrylate (PMMA) discs (98.5 mm x 20 mm, A1 shade) from Aidite (Qinhuangdao Technology Co., Ltd., Qinhuangdao, Hebei Province, China)-a specialized CAD/ Computer-Aided Manufacturing (CAM) temporary material composed of 99% PMMA were inserted into the patient's mouth (Fig. 26). This material is recognized for its exceptional mechanical strength, flexibility, shade and structural stability and esthetic properties, including high gloss and natural translucency. These qualities make Mono PMMA an ideal solution for long-term provisional restorations that closely mimic natural dentition. Before cementation, immediate dentin sealing was performed on the prepared dentin using OptiBond FL (Kerr Corporation, Orange, CA, USA), applied with ZerofloX™ (MIXPAC Dental, Medmix AG, Baar, Switzerland), a fiber-free micro applicator featuring flexible elastomer bristles that allow precise and clean delivery without the risk of fiber contamination on the surface. This step aimed to protect the dentin and reduce post-operative sensitivity. The temporary luting agent was then applied and the restorations were seated in place. After placement, the restorations were carefully finished and polished using multi-step polishing protocols to enhance surface smoothness and luster, ensuring both patient comfort and optimal esthetic integration.
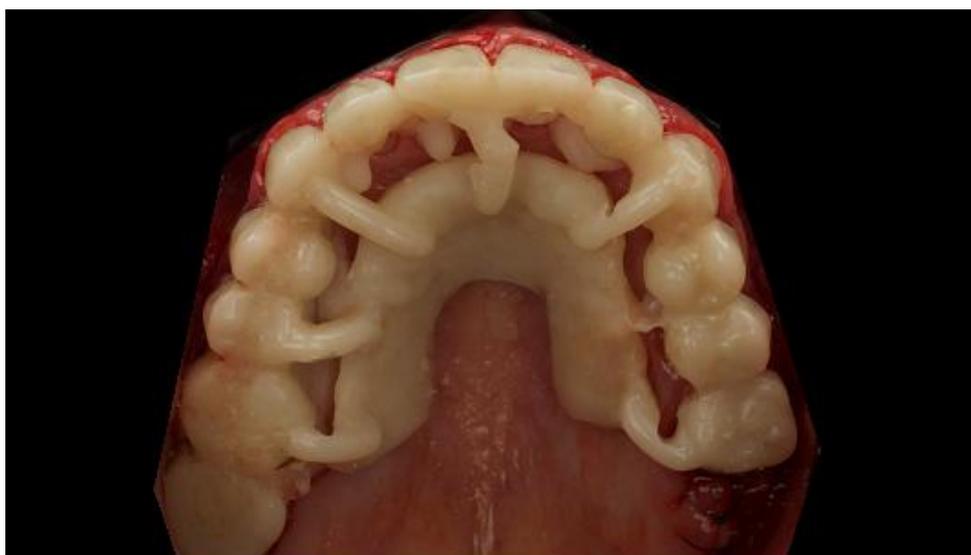

Figure 26: Occlusal view of the milled CAD/CAM provisional restorations in the patient's mouth, showcasing the palatal support and the harmonious curvature of the anterior teeth for optimal esthetic and functional integration.

After delivering the project in the patient's mouth, a clear esthetic transformation was observed. The patient expressed great satisfaction with the outcome and the fully digital workflow, which allowed for precise planning, predictable execution and efficient delivery of the provisional restorations (Fig. 27).

Figure 27: Before and after provisional placement: noticeable esthetic transformation following full digital workflow and insertion of milled CAD/CAM provisional restorations.

In a digital dentistry solution, complete cases can be resolved with enhanced efficiency, precision and patient satisfaction-from initial diagnosis and planning to guided gingivectomy and the delivery of esthetic restorations-by integrating intraoral scanners, software used for design manufacturing, facial scanners, 3D printers and milling units in a seamless workflow (Fig. 28).

Figure 28: One-week follow-up after full digital treatment showing retracted intraoral view in occlusion and full smile of the patient, demonstrating stable gingival contour and optimal esthetic integration of provisional restorations.

Discussion

In this case, the treatment was performed using a fully digital workflow, incorporating laser technology for the gingivectomy procedure. The patient presented with a gummy smile caused by excess gingival tissue and the treatment was focused on reshaping the gingiva without the need for bone removal. Laser-assisted gingivectomy was selected due to its precision, minimal invasiveness and ability to provide excellent esthetic results with faster recovery times.

The digital workflow began with the use of Intraoral Scanning (IOS), which provided highly accurate digital impressions of the patient's dentition. These digital models were then printed for further evaluation and treatment planning. The analysis of the

patient's facial features and gingival architecture was performed using a combination of AI-driven design tools. Initially, a 2D smile design was created using AI software, which provided a clear visual representation of the expected esthetic outcome. The 2D design allowed both the clinician and patient to quickly assess the esthetic changes [25,27].

Following the 2D design, a 3D smile design was developed using different software tools, which helped create a more detailed and realistic representation of the desired result [26,35]. These digital designs were essential in ensuring that the final outcome would meet the patient's esthetic goals. Based on these designs, two surgical guides were then printed and designed digitally, ensuring precise control during the gingivectomy procedure. The laser-assisted gingivectomy was guided by a 3D-printed guide, which minimized the risk of error and ensured that the gingival margins were sculpted with high accuracy [17,18].

The digital planning process enabled the practitioner to visualize the final result before the procedure, ensuring alignment with the patient's esthetic expectations and allowing for more accurate diagnoses. This approach offered several advantages, including precise treatment planning, improved communication, visualization of the treatment and reduced error risks, while saving time. Additionally, digital planning facilitated comprehensive facial analysis, considering clinical factors that might be overlooked during a conventional visual examination [22,25]. It is recommended, especially for younger clinicians, to perform the procedure with a gingivectomy guide [36]. The laser's precision was further enhanced by this digital workflow, leading to controlled tissue removal and optimal results in both function and esthetics [25]. The laser also helped minimize bleeding, reduce post-operative discomfort and expedite healing [37].

Following the laser gingivectomy, a milled provisional restoration was created. Ensuring that a provisional restoration maintains both esthetic qualities (such as color) and biological integrity (including marginal adaptation) is crucial for patient satisfaction and oral health until the final restoration is placed. Despite the availability of various provisional materials, there is a lack of direct comparisons regarding their color stability and marginal adaptation over a clinically relevant period [38].

Since the introduction of CAD/CAM technology in dentistry, marking a significant shift in the field, a variety of digital scanners and milling machines have been developed. The growing use of CAD/CAM systems in dentistry is primarily driven by their operational speed and the consistent high quality of the fabricated materials [39,40]. Looking ahead, some anticipate a "second revolution" in dentistry as 3D printing techniques advance to the point where they can match the results of traditional fabrication methods [40]. It was shown in a study that the marginal fit and internal adaptation of 3D-printed provisional crowns outperformed those made using CAD/CAM milling [41]. While CAD/CAM-milled crowns may have superior physical properties, 3D-printed crowns excel in terms of mechanical performance [42]. However, milled restorations are known for their superior fracture resistance compared to 3D-printed or conventional options. The milling process produces a more homogenous material structure, which enhances the mechanical properties, offering better durability and wear resistance [34]. This was especially important during healing, as the stable milled provisional preserved and protected the gingival margin.

The combination of laser technology, a fully digital workflow and the use of a milled provisional provided a highly predictable, efficient and minimally invasive solution to address the patient's gummy smile. The integration of IOS, DSD, 3D-printed surgical guides, laser assistance and milled mock-up ensured an optimal outcome with minimal downtime. This full digital approach resulted in a harmonious, natural smile that met the patient's functional and esthetic goals while avoiding the need for more invasive procedures such as osteotomy or crown lengthening.

Conclusion

The integration of digital solutions, including AI for smile simulation and the use of digital guides, significantly simplified the treatment process for a complex gingivectomy case. The use of digital technologies not only enhanced the precision of the gingivectomy procedure but also ensured an optimized fit for the milled mock-up which can serve as a provisional restoration. This approach highlights the transformative potential of digital dentistry in addressing challenging clinical scenarios, offering both improved patient outcomes and greater efficiency in treatment planning and execution.

Conflict of Interest

The authors declared no potential conflicts of interest with respect to the research, authorship and/or publication of this article.

Informed Consent Statement

Written informed consent has been obtained from the patient(s) to publish this paper.

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Data Availability

Data sharing is not applicable. No new data were created or analyzed in this study.

Author's Contribution

Conceptualization, R.B.; methodology, H.T., M.Q., L.H., R.B., K.C., N.K. and Y.H.; software, R.B., M.Q., K.C. and N.K.; validation, N.K., Y.H., M.Q. and R.B.; formal analysis, R.B., S.A.I. and H.T.; investigation, R.B., S.A.I., K.C., M.Q. and N.N.; resources, R.B., S.A.I., N.K., L.H., R.B., E.A.D. and H.T.; data curation, R.B., N.K. and N.N.; writing-original draft preparation, R.B. and L.H.; writing-review and editing, R.B., N.K., L.H., E.A.D., N.N., Y.H. and H.T.; visualization, R.B., L.H., Y.H. and N.K.; supervision, Y.H.; project administration, Y.H.; funding acquisition, Y.H. All authors have read and agreed to the published version of the manuscript.

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