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Accuracy of Guided Dual Technique in Esthetic Crown Lengthening: A Prospective Case-Series Study

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ABSTRACT

Objective: This study aimed to evaluate the efficacy and safety of a digitally guided dual technique during esthetic crown lengthening surgery. In addition, patient satisfaction and patient-reported outcomes were assessed.

Materials and Methods: A prospective case series study was conducted. Cone-beam computed tomography and intraoral scans were used to design surgical guides, which were manufactured via 3D printing. The primary outcome was surgical accuracy, assessed by measuring the distance between the planned and final gingival margin positions using overlapping intraoral scans. Secondary outcomes included clinical crown length, gingival margin stability, pain, and patient satisfaction. Statistical analyses were performed using multilevel linear regression models, with significance set at $p < 0.05$.

Results: Ten participants (87 teeth) were treated without complications. The mean duration of surgery was 66.5 min. The overall absolute deviation was 0.56 mm (95% CI: 0.48 to 0.65) at 6 months postoperatively. Clinical crown length increased significantly from baseline to the end of surgery ($p < 0.001$), with minimal reduction at 6 months ($p = 0.479$). Patient-reported outcomes indicated mild postoperative pain and high satisfaction with esthetic results.

Conclusions: The digitally guided dual technique for esthetic crown lengthening surgery is safe and effective, providing highly accurate outcomes. The technique also results in excellent patient satisfaction.

Clinical Significance: The use of digitally guided dual techniques for ACL surgery enhances precision and safety, leading to highly accurate outcomes and improved patient satisfaction. This approach could be beneficial in clinical settings to ensure better esthetic and functional results.

1 | Introduction

Over time, the esthetic expectations of dental patients have evolved in response to the growing understanding of the close relationship between an individual's physical appearance and their self-esteem. In fact, several investigations have stated that a person's face plays a crucial role in determining physical attractiveness [1]. Excessive gingival display (EGD) or gummy smile is a common esthetic problem in dentistry described by the American Academy of Periodontology as a mucogingival deformity around the teeth [2], consisting in the overexposure of the maxillary gingiva while smiling. An exposure of 1–3 mm of gingiva may be considered as normal, and it is unattractive when the exposure is ≥ 4 mm [3]. Several conditions

have been identified as potential causes of EGD, including vertical maxillary excess, hypermobile or short upper lip, dentoalveolar extrusion, gingival overgrowth, and altered passive eruption (APE). Treatment plan is primarily determined by its etiology [4].

In the fully erupted teeth of adults, the gingival margin (GM) should be located at or close to the cementoenamel junction (CEJ) (i.e., anatomical crown). However, in the presence of APE, the margin of the gingiva extends from the CEJ to the incisal edge, resulting in a clinical crown (i.e., the visible portion of the tooth in the oral cavity) that is significantly shorter than normal [5]. In addition to its intrinsic esthetic implications, it has been suggested that an excess of gingival tissue may detrimentally impact oral hygiene practices. This phenomenon is thought to facilitate the accumulation of bacterial plaque, thereby potentially resulting in marginal inflammation and periodontal destruction in susceptible patients [5].

In cases of APE, surgical procedures for crown lengthening should be considered the treatment of choice to enhance smile esthetics by increasing the exposure of the clinical crown and leveling the GMs [6]. Despite the existence of various technical approaches, they uniformly involve the resection of soft (i.e., gingival) and/or hard (i.e., bone) tissues. In fact, as early as 1977, a morphological classification of APE was suggested, which continues to serve as a useful guideline when developing a treatment plan [7].

Obviously, in crown lengthening procedures aimed at meeting high esthetic expectations, it is crucial to achieve a stable and harmonious position of the GMs over the long term. Therefore, it is imperative to conduct a careful evaluation of tissue characteristics, considering the amount of keratinized tissue, the positioning of the gingival margin in relation to the CEJ, and the distance from the CEJ to the bone crest [7–12]. However, the outcome is not always predictable, as a wide range of factors, such as the supracrestal tissue attachment [13, 14], the extent of ostectomy performed [15], the patient's periodontal phenotype [16], the healing time [17], and the surgeon's experience [18] can influence tissue healing and maturation. Moreover, the treatment modality itself may play a significant role in the clinical outcome. Deas et al. [14] found that rebound of the GM position may occur up to 6 months after esthetic crown lengthening (ACL) surgery in many cases; therefore, it is important to keep in mind that if the ACL surgery is planned with a simultaneous restorative treatment; it is recommended to wait at least 6 months to perform it.

Traditionally, the amount of gingiva and alveolar bone removed during ACL was determined by assessing the crown height/width ratio of the teeth and identifying the CEJ position through clinical examination and transgingival probing, respectively [18]. However, this method often leads to suboptimal and unpredictable esthetic results due to the highly technique-sensitive nature of the procedure.

Since its introduction, digital technology has been revolutionary, expanding rapidly, and having an unprecedented impact on dentistry. In the surgical field, static computer-assisted surgery is characterized by the computer-aided design (CAD) and computer-aided manufacturing (CAM) of a customized surgical guide. This guide, which contains all preoperative planning information, is placed in the patient's mouth to guide the operator during the surgical procedure. Consequently, it is possible to implement more precise, safer, faster, and less invasive surgical procedures [19]. Moreover, due to its great versatility, this system has been successfully applied in numerous clinical situations [20–29].

To date, several studies have proposed the use of a double surgical guide in ACL to reduce the risk of errors during gingival incision and improve visualization of the bone crest level during bone resection [30]. However, despite the promising results, most of these studies are based on clinical cases with insufficient follow-up time and do not consider the patient's perspective [31, 32]. Hence, the aim of this study was to determine the efficacy and safety of a digitally guided dual technique for both gingival and bone resection during ACL surgery in the immediate postoperative, 8 weeks and 6 months of follow-up. Secondarily, the patient satisfaction and patient-reported outcomes measurement were also assessed.

2 | Materials and Methods

A prospective case-series study was conducted in a total of 10 patients who were treated consecutively between October 2023 and March 2024 in a private dental clinic. The study design adhered to the STROBE guidelines for observational studies [33]. The protocol was developed in accordance with the tenets of the Helsinki Declaration and was approved by the Ethics Committee (CEIm) (Protocol number 40-2023).

Patients were provided with comprehensive information about the surgical procedures and treatment alternatives, and informed consent was obtained in all cases. In the case of a patient under the age of 18, consent was also obtained from their legal guardian in accordance with the prevailing local legislation.

2.1 | Patient Selection

Candidates had to meet the following eligibility criteria:

- Female and male patients over the age of 16 seeking an ACL procedure due to APE type 1B [7].
- Full-mouth plaque score < 20% and full-mouth bleeding score < 15%.
- Full mental capacity to comprehend and authorized the informed consent before the beginning of the study.
- Patients willing to undergo all the visits and procedures schedule in the study as required by the protocol.

On the other hand, exclusion criteria were:

- General contraindications to ACL surgery, radiotherapy in the head and neck area, uncontrolled diabetes, and alcohol abuse.
- Smokers > 10 cigarettes/day.
- Candidates for crown lengthening procedure for functional purposes.

- History of any disease or condition that, by the researcher's opinion, may presume a risk to the patient or confound the efficacy and safety results of the study.
- Current pregnancy or lactation.
- Being participant in other clinical studies in the previous 4 weeks.

2.2 | Preparation Phase

All participants were provided with individualized professional oral hygiene instructions, in addition to comprehensive full-mouth supragingival scaling and polishing. Furthermore, intraoral and extraoral photographic records were taken using a digital camera (Nikon D90; Nikon, Tokyo, Japan) equipped with a 100 mm macro lens and twin flash illumination, with the intention of facilitating the visual analysis of smile esthetics. The resulting images are presented in Figure 1.

2.3 | Surgical Guide Design and Manufacturing

The Digital Imaging and Communication in Medicine files obtained from the cone-beam computed tomography (CBCT) (NewTom GiANO HR; Quantitative Radiology, Verona, Italy; 0.2 mm/voxel, 110 kV, 64.6 mAs, 4.3 s) scan of the patient were converted to Standard Tessellation Language (STL) format and then superimposed with STL files acquired from the intraoral scan (Trios 3; 3Shape, Copenhagen, Denmark) (T_0, baseline) using Exocad DentalCAD software (exocad GmbH, Darmstadt, Germany). With this design software, the level of the CEJ of each tooth to be treated was marked to guide the gingivectomy incision line. In addition, a second line was positioned 3 mm apical to the CEJ line to guide the bone resection to respect the supracrestal tissue attachment and the gingival sulcus [13]. After completing the virtual design, surgical guides with a thickness of 2 mm and a 0.03 mm guide-to-teeth offset were printed using the Formiga P110 (EOS, Munich, Germany) that employs selective laser sintering technology with a layer thickness of 60–120 μm. The postprocessing of the surgical guide included sandblasting with glass microbeads, technician quality and technical control, cleaning in ultrasonic baths, and cleaning with a thermodisinfection machine. Finally, the surgical guide was subjected to a steam sterilization process at 134°C and a pressure of 2 bar. For further details, refer to Figure 2.

2.4 | Surgical Protocol

The surgical technique employed was analogous to that previously described elsewhere [4]. First, the polyamide CAD/CAM

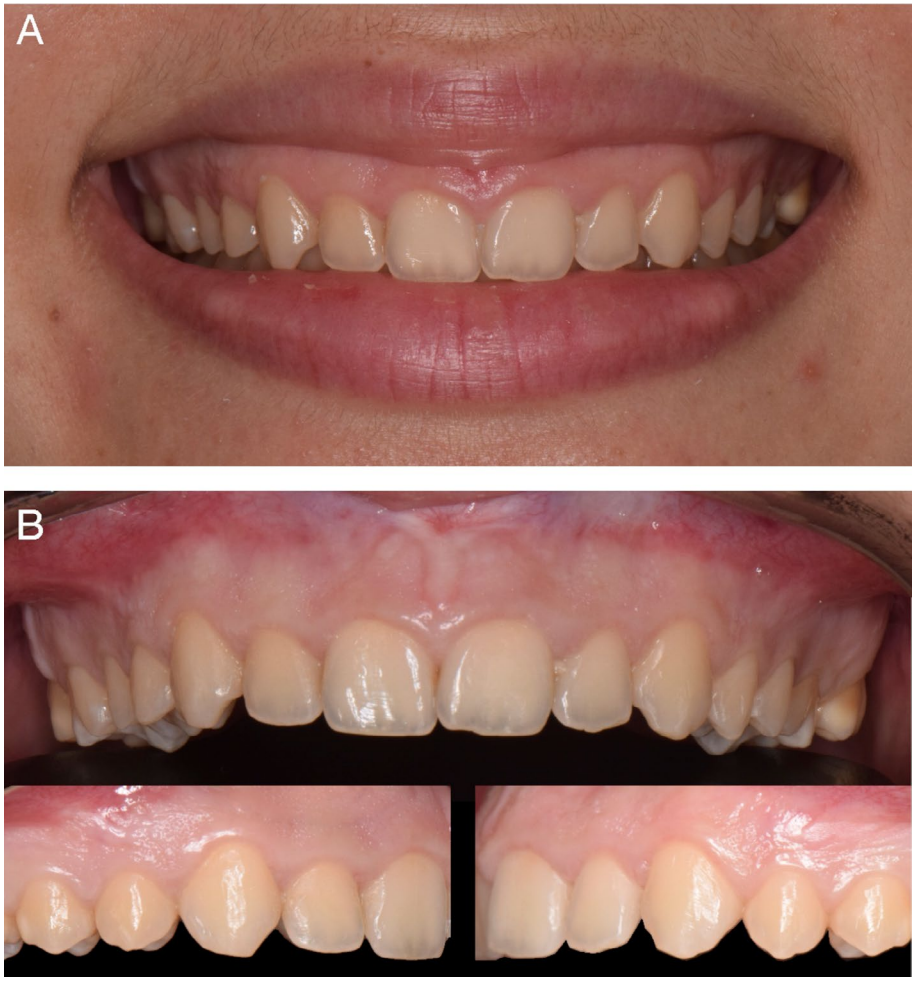

FIGURE 1 | Patient's photographs before surgery. (A) Extraoral photographs, (B) intraoral photographs.

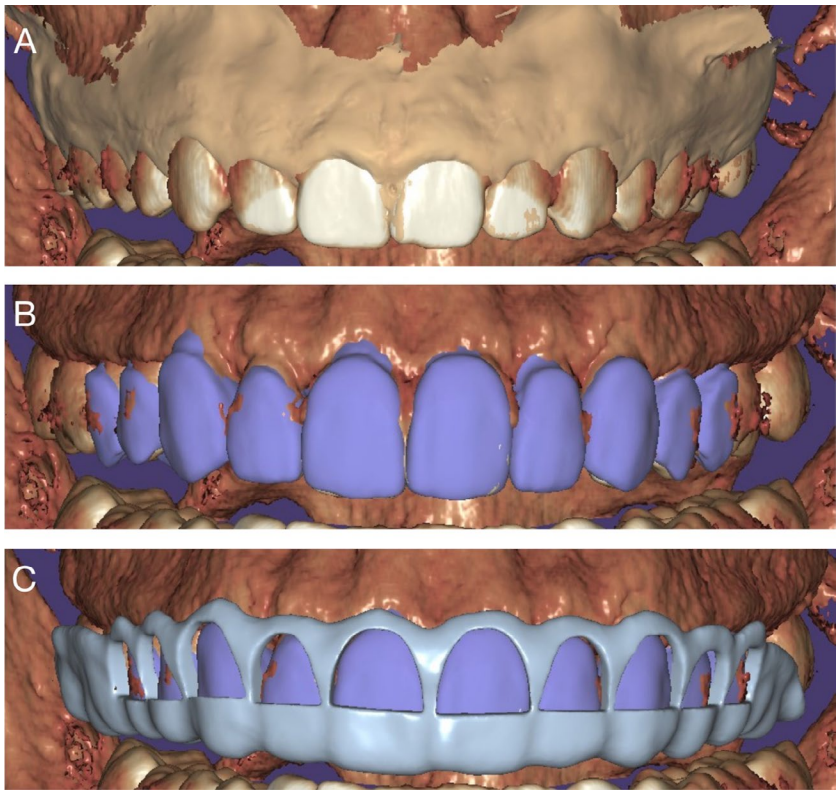

FIGURE 2 | Steps for the surgical guide confection. (A) CBCT superimposed to the STL model, (B) CEJ level marked, (C) surgical guide design.

FIGURE 3 | Surgical sequence. (A) Surgical guide try-in, (B) gingivectomy, (C) soft tissue removal and check of the gingival margin position with the gingival margin, (D) gingival margin position without the surgical guide, (E) full-thickness flap elevation, (F) checking the bone level after ostectomy, (G) suture at the end of the surgery, (H) 15 days postoperative appointment, (I) 8 weeks follow-up appointment.

surgical guide was placed on the patient's maxilla, and its stability and proper fitting was assessed clinically. An adequate fit between the surgical guide and patient dental arch was considered a pre-requisite to continue with the surgery. Local anesthesia was then administered using articaine 4% with 1:100,000 epinephrine (Artinibsa 4% 1:100,000; Laboratorios Inibsa S.A., Lliçà de Vall, Spain). Using a 15c blade, an internal bevel incision was made along the lower border of the guide window, extending from the right to the left teeth planned for treatment. The guide was then removed, and a second sulcular incision was made. The secondary flap was excised using a 13/14 universal curette to reveal the new crown lengths. Next, a full-thickness mucoperiosteal flap was elevated beyond the mucogingival junction. Subsequently, the surgical guide was repositioned to ascertain the extent of ostectomy needed, and the bone was marked with a P24 periosteal elevator (Hu-Friedy, Chicago, USA). Once the limit of the ostectomy was marked, the surgical guide was removed to complete the ostectomy with a high-speed round diamond bur, and its extent was regularly checked by placing it and removing it during the procedure. After completing the ostectomy, osteoplasty was carried out to remove the buccal bone buttressing. The guide was reinserted for a final verification before internal vertical mattress sutures (5-0 poliamide; Supramid, Aragó, Barcelona, Spain) were placed in the papillary region of each tooth. Finally, once hemostasis was ensured, an intraoral scan was taken (T_1). Figure 3 depicts the surgical technique described above.

After the surgery, a non-steroidal anti-inflammatory drug (ibuprofen 600 mg orally every 8 h), and a rescue analgesic (paracetamol 1 g orally every 8 h, if needed) were prescribed to use in case of pain. In addition, a mouth rinse (0.12% chlorhexidine digluconate 15 mL every 12 h for 15 days) was prescribed to control postoperative pain and reduce the risk of surgical site infection. In addition, oral and written information with recommendations were provided to the patients. A follow-up appointment was scheduled for 7 days after the surgical procedure, and the sutures were removed at 15 days postsurgery. Patients also received oral hygiene instructions and were recalled at 8 weeks (T_2) and 6 months (T_3) for data collection (Figure 4).

2.5 | Data Sampling

2.5.1 | Primary Outcome

The primary outcome measure of this study was the deviation of the GMP between the planned position and the actual position at the immediate postoperative (T_1) and follow-up appointments at 8 weeks (T_2) and 6 months (T_3) after surgery. Absolute and signed (i.e., positive for apical and negative for coronal) surgical accuracy (expressed in mm) was evaluated by the same trained examiner (M.E.P.), who compared the zenith of the planned gingival margin position (GMP) of each intervened tooth with the final position determined from the STL files taken at each timepoint, using a vertical linear

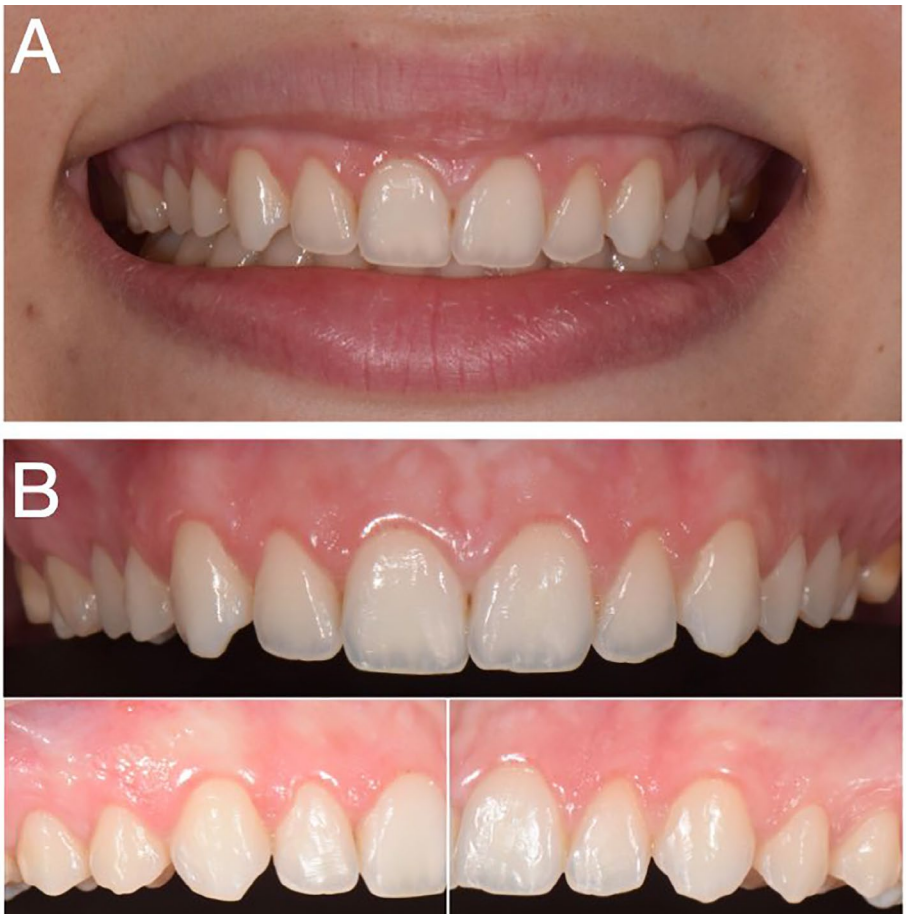

FIGURE 4 | Patient's photographs at 6 months follow-up appointment. (A) Extraoral photographs, (B) intraoral photographs.

measurement. The overlapping and postoperative processing of the STL files was made manually using Real GUIDE 5 software (3Diemme Bioimaging Technologies, Cantù, Italy) (Figure 5).

To test intraexaminer reliability, an assessment of 30 randomly selected measurements was repeated after 4 weeks. The intraclass correlation coefficient was 0.84 (95% CI: 0.69 to 0.92; $p < 0.001$) for absolute agreement.

2.5.2 | Secondary Outcomes

Any undesirable medical event, unforeseen illness or injury, or unwanted clinical signs associated with the ACL surgery were recorded. The clinical crown length (distance between the incisal edge and gingival margin (expressed in mm) along the long axis of the tooth in clinical examination) was measured at T_0, T_1, T_2, and T_3. The gingival margin stability was also assessed, recording changes in the position of the GMP (expressed in mm) during the 6 months follow-up period by overlapping the intraoral scans taken at T_1, T_2, and T_3, using Real GUIDE 5 software (3Diemme Bioimaging Technologies, Cantù, Italy) (Figure 5). Finally, several patient-reported outcome measures were also registered. Subjective pain at the end of the surgical procedure, then at 2, 6, 12, and 24 h, and daily until the 7th postoperative day was recorded on a 100-mm visual analogue scale (VAS), with 0 meaning "no pain" and 100 meaning "worst pain imaginable." Patients were also asked to record their analgesic intake (Ibuprofen 400 mg and Paracetamol 1 g) during the first 7 postoperative days. Participants completed surveys (using a Likert scale) at baseline and at the end of the follow-up period to evaluate satisfaction with smile, gingiva and tooth features, and experience with the ACL procedure [34]. In addition, patients rated their overall satisfaction with the treatment outcomes on a 100-mm VAS at these same timepoints.

2.5.3 | Sample Size Calculation

Sample size was calculated using the software G*Power v.3.1.3 (Heinrich-Heine Universität, Dusseldorf, Germany) based the assumption that an absolute discrepancy of 1 mm at T_3 would be clinically significant. Considering a common standard deviation (SD) of 0.6 mm [19], a risk of 0.05, a power of 80%, and a 10% exclusion rate, three patients were required. Because the teeth were not independent due to the two-level data structure (patient and tooth), the number of patients needed to be corrected. Assuming an intrasubject correlation of 0.5 (moderate) and that each subject will need esthetic crown lengthening in 6 teeth, 10 patients were treated.

2.5.4 | Statistical Analysis

Statistical analyses were conducted using SPSS software version 29 (SPSS Inc., Chicago, IL, USA). Categorical outcomes were presented as absolute and relative frequencies. The normality of scale variables was explored using the Shapiro–Wilk test and through visual analysis of the P–P plot and box plot. The interquartile range (IQR) and median were calculated for non-normal distributions, while the mean and SD were used for distributions compatible with normality. Two levels of analyses were taken into consideration: patient and tooth.

At the patient level, simple linear regression models were employed to explore the homogeneity of scale and categorical variables. Crude regression coefficients with their respective 95% CI were obtained. At the tooth level, multilevel linear regression models were conducted to evaluate absolute GMP discrepancy using the generalized linear mixed model (GLMM) method. The GLMM method was utilized to account for the fact that a single patient may have more than one tooth treated. Tooth type (I, C, and PM) and time were included as predictor variables. In

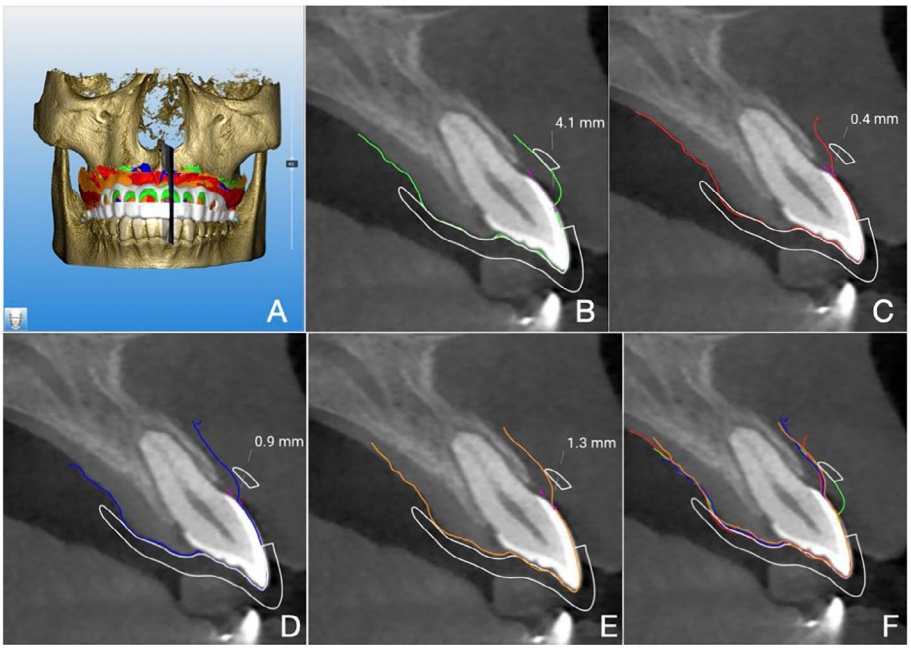

FIGURE 5 | Measurements with Real GUIDE 5 software. (A) General view, (B) CCL measurements, (C) T1 measurements, (D) T2 measurements, (E) T3 measurements, (F) overlapping of T1, T2, and T3.

addition, to analyze the changes in GMP over time among the three tooth type groups, the interaction between tooth type, and time was added. Adjusted beta coefficients and 95% CIs were obtained from the *t*-statistic.

To analyze the influence of the procedure on the evolution of pain over time, a Friedmann test used for longitudinal analysis. For satisfaction surveys, the questionnaire data was evaluated using Wilcoxon's signed-rank test.

The level of significance was set at $p < 0.05$, using the Bonferroni correction for multiple comparisons. The assumptions underlying the statistical analyses were checked in all cases.

3 | Results

Ten patients (87 teeth) with APE type 1B [7], aged 30.42 years (SD = 18.42), were recruited and treated without registering any protocol deviation nor dropouts. Tables 1 and 2 show the main demographic and clinical variables of the sample. Table 2 shows the mean length of the clinical crowns at the baseline and the expected GMP change from the baseline to the planned GMP.

ACL surgery took an average of 57.12 min (SD = 23.02) from anesthesia to the last suture. No intraoperative or postoperative complications were recorded. Furthermore, the surgeon rated the fit of the surgical guide as excellent or very good in 7 (70%) and 3 (30%) cases, respectively.

3.1 | Primary Outcome

3.1.1 | Accuracy Analysis

Accuracy analysis revealed an overall absolute deviation from the planned GMP of 0.62 mm (95% CI: 0.45 to 0.80), 0.59 mm (95% CI: 0.39 to 0.78), and 0.56 mm (95% CI: 0.48 to 0.65) at T_1, T_2, and T_3.

TABLE 1 | Main demographic characteristics of patients.

Case	Age	Sex	Systemic disease	Smoking (cig/day)	N° of teeth treated
1	50.04	Female	Hypertension	No	10
2	19.70	Male	None	No	10
3	18.32	Female	None	No	10
4	22.80	Male	None	No	10
5	72.74	Female	Hypothyroidism	No	6
6	36.27	Female	None	5	3
7	16.84	Male	None	No	8
8	18.65	Female	None	10	10
9	32.38	Female	None	No	10
10	16.43	Female	None	No	10

TABLE 2 | Main clinical characteristics of patients.

	Baseline clinical crown length (range)			Expected gingival margin position change (range)		
Case	Incisor	Canine	Premolar	Incisor	Canine	Premolar
1	8.1 (7.4 to 8.7)	7.45 (7.2 to 7.7)	6.3 (5.6 to 7.6)	1.00 (0.70 to 1.50)	0.90 (0.80 to 1.00)	0.80 (0.40 to 1.10)
2	5.35 (4.5 to 6.1)	5.3 (4.9 to 5.7)	6.1 (5.6 to 6.6)	1.92 (1.30 to 2.30)	2.10 (1.10 to 3.10)	0.70 (0.40 to 1.10)
3	6.85 (5.2 to 8)	6.7 (5.8 to 7.6)	6.7 (5.9 to 7.5)	4.22 (3.20 to 4.90)	3.50 (2.80 to 4.20)	2.97 (2.30 to 3.70)
4	8.0 (6.4 to 8.9)	8.05 (7.8 to 8.3)	6.5 (5.4 to 7.1)	2.42 (1.50 to 3.20)	2.25 (2.00 to 2.50)	1.52 (1.30 to 1.90)
5	7.9 (6.3 to 9.5)	9.75 (9.5 to 10.0)	—	1.70 (1.10 to 2.60)	0.90 (0.60 to 1.20)	—
6	8.7 (8.2 to 9.1)	—	—	0.73 (0.50 to 0.90)	—	—
7	7.15 (6.3 to 8.4)	8.25 (8.2 to 8.3)	6.95 (6.8 to 7.1)	3.50 (2.70 to 4.00)	2.85 (2.70 to 3.00)	1.40 (0.80 to 2.00)
8	7.0 (6.5 to 8.3)	6.65 (5.5 to 7.8)	5.7 (5.4 to 6.6)	1.33 (0.80 to 2.10)	0.95 (0.60 to 1.30)	1.32 (1.00 to 1.80)
9	8.65 (7.6 to 9.8)	8.05 (7.8 to 8.3)	6.2 (5.9 to 6.5)	1.68 (1.30 to 1.90)	1.60 (1.40 to 1.80)	0.92 (0.50 to 1.40)
10	6.85 (5.5 to 8.1)	6.15 (5.7 to 6.6)	6.0 (5.5 to 6.8)	3.27 (2.80 to 3.70)	3.85 (3.80 to 3.90)	2.20 (1.70 to 2.60)

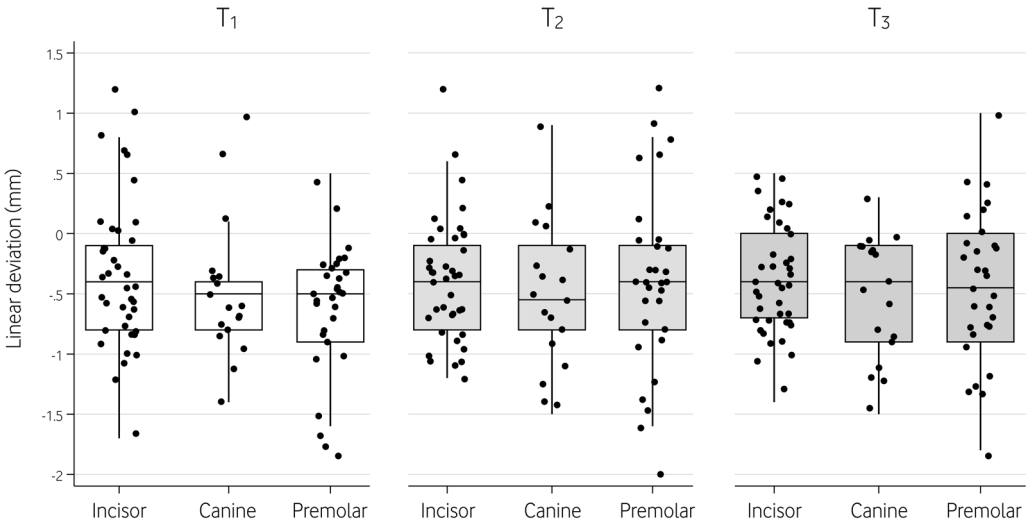

FIGURE 6 | Boxplot of the accuracy results by tooth type. For each box, the interior line in bold shows the median, and the edges of the box are estimates of the lower and upper quartiles. Negative values represent undercorrection (GM over the planned position) and positive values represent overcorrection (GM under the planned position).

The magnitude of change (deviation versus 1 mm reference value) was <1 mm for both timepoints (all $p<0.001$). Similar accuracy results were observed after stratifying by tooth type (Figure 6).

After analyzing the signed deviations at T_3, it was found that 77.01% of the teeth (95% CI: 67.14 to 84.60) exhibited a slight undercorrection compared to the planned GMP (mean: −0.66 mm; 95% CI: −0.75 to −0.56). In contrast, in 17.23% of cases (95% CI: 10.74 to 26.52), the gingival margin was positioned more apically than planned (mean: 0.33 mm; 95% CI: 0.21 to 0.46). Among these cases, gingival recession was observed in one tooth (risk = 1.15%; 95% CI: 0.20 to 6.23).

3.2 | Secondary Outcomes

3.2.1 | Clinical Crown Length

The mean CCL for all the treated maxillary teeth at baseline was 7.18 mm (SD = 2.48) and increased significantly to 8.64 mm (SD = 2.57) at T_1 (MD: 1.47 mm; 95% CI: 0.92 to 1.92; $p<0.001$). In comparison to T_1, the mean CCL showed a minimally significant reduction after 6 months (MD: −0.04 mm; 95% CI: −0.14 to 0.07; $p=0.479$).

3.2.2 | Gingival Margin Stability After Esthetic Crown Lengthening Procedure (T_1 to T_3)

Univariate analyses revealed that none of the variables assessed, whether at the patient or tooth level, influenced the gingival margin stability from T_1 to T_3 (all $p>0.05$) (Table 3).

The multivariate GLMM for repeated measures did not yield statistically significant differences for any of the independent covariates introduced. Similarly, the interaction effect between time and tooth type was not significant (F [2167] = 0.07; $p=0.930$) (Table 4 and Figure 1).

3.2.3 | Participant-Reported Outcomes

The postoperative VAS pain scores varied significantly over time ($Q=71.72$; df = 10; $p<0.001$). Interestingly, all patients experienced mild pain (i.e., VAS < 40 mm) throughout the entire follow-up period. Nevertheless, the peak of pain occurred between 6- and 12-h post-intervention, with a progressive decrease observed thereafter (Figure 7A). Similarly, analgesic consumption followed a comparable pattern ($Q=51.19$; df = 6; $p<0.001$) (Figure 7B).

In terms of VAS esthetic scale, a statistically significant difference was found between baseline (mean: 52.8 mm; SD = 18.51) and 6 months postoperatively (mean: 93 mm; SD = 6.60) ($p=0.005$). Likewise, in the satisfaction questionnaire (Table 5), differences in responses of questions 1 to 6 were observed between T_0 and T_3 (all $p<0.05$). Moreover, 70% of the participants rated the results of the procedure as extremely satisfactory.

4 | Discussion

The present prospective study aimed to evaluate the ACL procedure using a computer-assisted surgery approach, demonstrating high accuracy in the final GMP compared with the planned position and high patient-reported satisfaction. This study focusses in the efficacy of an ACL in terms of accuracy in the positioning of the GM after the surgery regarding the virtually planned position. For answering this purpose, the main timepoint to take into consideration would be the inmmediate postoreaptive measurement (T_1) because this timepoint is not affected by tissues healing and maturation. Also, we aimed to include two follow-up timepoints at 2 (T_2) and 6 months (T_3) to evaluate if the treatment outcome of an ACL in a static computer-assisted approach is stable over time and determine the magnitude of a possible rebound.

Computer-assisted surgery is already well stablished in dental implantology [35], but it has potential use in other surgical

TABLE 3 | Univariate analyses for absolute GMP change (mm) from T_1 to T_3.

	Category	Coeff. (95% CI)	*p*
Patient level ($n = 10$)			
Age (years)		0.01 (−0.00 to 0.29)	0.081
Gender	Female	0	0.089
	Male	−0.51 (−1.12 to 1.00)	
Systemic disease	No	0	0.376
	Yes	0.32 (−0.47 to 1.12)	
Smoking	No	0	0.479
	Yes	0.26 (−0.55 to 1.08)	
Number of teeth treated	< 10	0	0.150
	10	−0.44 (−1.08 to 0.20)	
Tooth level ($n = 261$)			
Tooth type	Incisor	0	0.652
	Canine	0.06 (−0.07 to 0.19)	
	Premolar	0.06 (−0.09 to 0.20)	
Expected GMP change (mm)		0.02 (−0.03 to 0.07)	0.451

Abbreviations: Coeff: coefficient; GMP: gingival margin position; 95% CI: 95% confidence interval.

TABLE 4 | Gingival margin stability after esthetic crown lengthening (T_1 to T_3).

	Category	Coeff. (95% CI)	*p*
Tooth type	Incisor	0	0.471
	Canine	0.09 (−0.06 to 0.23)	
	Premolar	0.10 (−0.09 to 0.29)	
Time	End of surgery (T_1)	0	0.130
	6 months postsurgery (T_3)	−0.07 (−0.19 to 0.05)	
Expected GMP change (mm)		0.06 (−0.01 to 0.13)	0.087
Time × Tooth type			0.930
T_3 × Incisor		0	
T_3 × Canine		−0.03 (−0.21 to 0.16)	
T_3 × Premolar		0.02 (−0.18 to 0.23)	

Abbreviations: Coeff: coefficient; GMP: gingival margin position; 95% CI: 95% confidence interval.

procedures to achieve more predictable and accurate outcomes. Computer-guided ACL procedures have been introduced to enhance clinical results, reduce the risk of errors and ensure rigorous accuracy on the results [36]. Several authors have demonstrated that employing a digital workflow is a reliable method for ensuring an accurate diagnosis and a predictable, safe ACL procedure. This approach reduces the risk of surgical errors such as over or under cuts and minimizes trauma to the surrounding gingival tissue and bone. As a result, patients experience less pain and inflammation, and shorter surgical and recovery times, increasing the level of patient acceptance and satisfaction [4, 32, 37, 38].

The methodology used in this case report aligns with previous case studies [39–41]. CBCT imaging and a digital intraoral scan were utilized for diagnosis and surgical planning. A surgical guide was created using a 3D printer, and the surgical procedure was performed similarly to the aforementioned case report, yielding comparable outcomes. Nevertheless, various surgical guide designs have been described. In this study, the design left a 3 mm acrylic stripe between the gingivectomy and the ostectomy line [39]. Other authors [19] used a different design with an empty space between these reference lines. In the same way, an in vitro study compared the precision of this alternative design with others, but the design used in this study was not included in

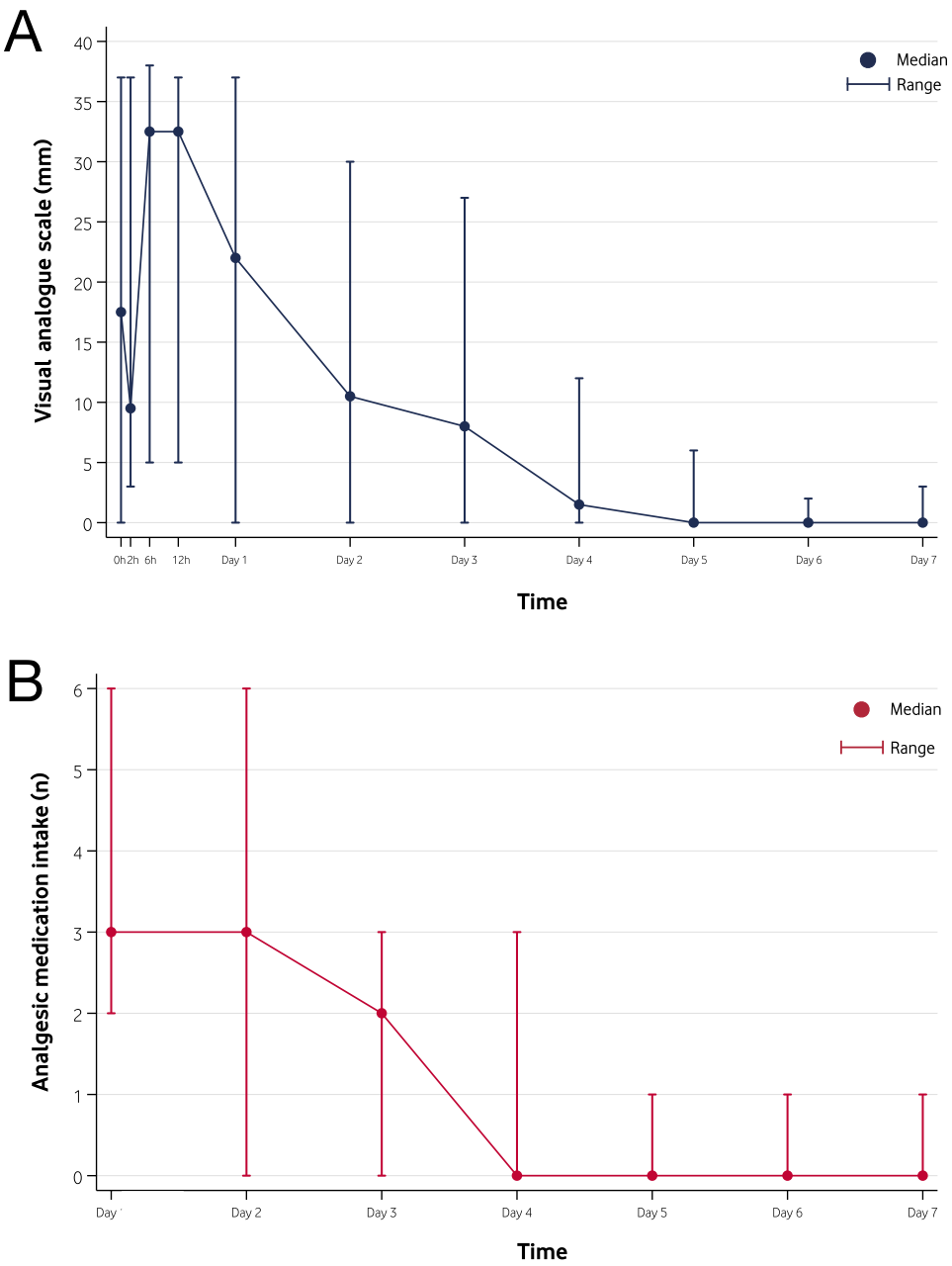

FIGURE 7 | (A) Pain experienced by the patients measured with VAS over time, (B) analgesic medication intake by the patients over time.

the comparison [42]. Thus, a comparative study is needed to determine which design is more precise. When the design used in this study is employed, the surgical guide is very useful to mark and check the limit of the ostectomy, but it is recommended to remove it during its performance to avoid an over-extension or surgical guide modification with the bur. Moreover, removing it can help to avoid root damage with the round bur as it permits more visual control. Using alternative burs, such as end-cutting burs, can also prevent root damage during ACL.

This study found that the absolute deviation of the planned gingival margin was less than 1 mm at T_1, T_2, and T_3, indicating high precision and stability over at least 6 months. These results are consistent with other investigations, who observed similar stability [43]. In addition, previous research observed that GMP remained stable and showed no significant difference when compared with freehand surgery, despite a statistically significant change from the initial assessment to the follow-up [39]. Nevertheless, it has been argued that even both techniques show comparable gingival margin stability, the guided dual technique may offer additional advantages in certain scenarios [19].

Our results indicated a slight under correction in 77.01% of the teeth, suggesting the technique is consistently precise but tends to slightly underestimate gingival margin correction. In cases where ostectomy is required, the appropriate amount is debated among authors. One recommendation is an ostectomy of 3 mm behind the CEJ [39]. However, some suggest considering the flap margin instead the CEJ, while others advocated

TABLE 5 | Patient satisfaction survey.

Question	Timepoint	Satisfied					*p*
		Not at all	Slightly	Somewhat	Very	Extremely	
1	Baseline	3 (30%)	5 (50%	2 (20%)	0 (0%)	0 (0%)	< 0.001
	6 months	0 (0%)	0 (0%)	0 (0%)	5 (50%)	5 (50%)	
2	Baseline	6 (60%)	4 (40%)	0 (0%)	0 (0%)	0 (0%)	< 0.001
	6 months	0 (0%)	0 (0%)	0 (0%)	2 (20%)	8 (80%)	
3	Baseline	2 (20%)	5 (50%)	3 (30%)	0 (0%)	0 (0%)	< 0.001
	6 months	0 (0%)	0 (0%)	0 (0%)	3 (30%)	7 (70%)	
4	Baseline	1 (10%)	2 (20%)	4 (40%)	2 (20%)	1 (10%)	0.029
	6 months	0 (0%)	0 (0%)	2 (20%)	6 (50%)	2 (20%)	
5	Baseline	2 (20%)	0 (0%)	3 (30%)	3 (30%)	2 (20%)	0.032
	6 months	0 (0%)	0 (0%)	2 (20%)	3 (30%)	5 (50%)	
6	Baseline	2 (20%)	3 (30%)	2 (20%)	1 (10%)	2 (20%)	0.008
	6 months	0 (0%)	0 (0%)	1 (10%)	2 (20%)	7 (70%)	
7	Baseline	2 (20%)	2 (20%)	4 (40%)	2 (20%)	0 (0%)	0.798
	6 months	2 (20%)	2 (20%)	5 (50%)	1 (10%)	0 (0%)	
8	Experience	0 (0%)	2 (20%)	4 (40%)	4 (40%)	0 (0%)	NA
	Outcome	0 (0%)	0 (0%)	0 (0%)	2 (20%)	8 (80%)	

Note: Question 1: Are you satisfied with your smile?; Question 2: Are you satisfied with the amount of gum you show when you smile?; Question 3: Are you satisfied with the amount of gum you show when you talk?; Question 4: Are you satisfied with the amount of teeth you show when you smile or talk?; Question 5: Are you satisfied with the size of the upper front teeth?; Question 6: Are you satisfied with the shape of the upper front teeth?; Question 7: Are you satisfied with the color of the upper front teeth?; Question 8: Are you satisfied with the procedure experience and outcome?
Abbreviation: NA: not applicable.

for maintaining at least 2 mm distance from the CEJ to bone crest, adjusting as necessary [4, 10]. Similarly, findings indicate that a distance of ≤ 2 mm from the alveolar crest to the flap margin can cause rebound, whereas an ostectomy of ≥ 4 mm may lead to gingival margin recession [43]. Therefore, careful planning and execution of the necessary ostectomy are essential to minimize the risk of both gingival rebound and recession. In this context, using a computer-assisted approach in which the levels of ostectomy and gingivectomy are preoperatively planned and executed using the surgical guide could minimize the rebound and the dimensional changes during follow-up because the distance between bone level and gingival margin will be the ideal dimension for the supracrestal tissue attachment.

To avoid over or underestimations, one study proposed a two-stage ACL approach: first, performing osseous surgery, and second, conducting gingivectomy if needed [44]. This protocol can also be executed with a computer-assisted surgery method using a surgical guide for both stages. In the first stage, ostectomy is performed with the guide and the second stage is significantly simplified by merely placing the guide and trimming the excess gingiva.

The mean duration of the procedure is closely related with the patient's satisfaction and postoperative pain. Using a digital workflow, the surgery took an average of 66.5 min (IQR = 19), a reasonable time given the procedure's complexity. In contrast, another study reported a duration of 92.75 min (SD = 16.73) [19], with surgeries using a surgical guide being quicker than those performed freehand [45, 46]. Our study also reported consistently low postoperative pain scores, well-managed with analgesics, which decreased over time. Moreover, in line with previous investigations [19], patients also reported high esthetic satisfaction scores. Specifically, at the end of the follow-up period, in addition to a significant improvement in most of the analyzed parameters, all the participants were very or extremely satisfied with the procedure experience and outcome (Table 5).

Regarding the length of the follow-up period, while some studies assert that tissue maturation and stabilization occur within 8–12 weeks [31, 47], others recommend a follow-up period of at least 6 months for a comprehensive evaluation of ACL outcomes [19, 43, 48]. In this study, no statistically significant differences have been found in terms of gingival margin stability between the two timepoint evaluations at 8 weeks (T_2) and 6 months (T_3), showing a discrepancy of 0.59 mm (95% CI: 0.39 to 0.78) and 0.56 mm (95% CI: 0.48 to 0.65), respectively from the planned GMP. In terms of clinical crown length, the observed trend has been toward a slight reduction of −0.04 mm (95% CI: −0.14 to 0.07) on its size from the immediate postsurgical timepoint (T_1)

to the 6 months follow-up evaluation (T_3); however, this reduction is non-statistically significant ($p = 0.479$), and therefore, its clinical implication might be unappreciable.

This study has some limitations that need to be addressed. First, the case study design and the inclusion of only 10 patients limit the ability to draw broad conclusions and make comprehensive comparisons. Furthermore, all 10 patients were classified as 1B [7], which provides a uniform sample but limits the generalizability of the results to other clinical situations. Patients classified as 1A or 2B APE could also benefit from surgical guides, but their design might differ. For example, 1A patients require gingivectomy without ostectomy, whereas 2B patients would need ostectomy without gingivectomy. Finally, although the intra-examiner reliability of the evaluator was almost perfect, the fact that the measurements were taken manually using the zenith as a reference may have led to a subjective interpretation. Therefore, future research on this topic should implement automatic postoperative processing methods to minimize these errors.

5 | Conclusions

Within the limitations of this study, it was concluded that guided esthetic crown lengthening procedures seem to be safe and effective, providing highly accurate outcomes with a gingival margin shift of less than 1 mm from the planned position. In addition, this technique results in an excellent patient satisfaction.

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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. G. L. Patzer, "Self-Esteem and Physical Attractiveness," *Journal of Esthetic and Restorative Dentistry* 7, no. 6 (1995): 274–276.

2. G. C. Armitage, "Development of a Classification System for Periodontal Diseases and Conditions," *Annals of Periodontology* 4, no. 1 (1999): 1–6.

3. V. O. Kokich, Jr., H. A. Kiyak, and P. A. Shapiro, "Comparing the Perception of Dentists and Lay People to Altered Dental Esthetics," *Journal of Esthetic Dentistry* 11, no. 6 (1999): 311–324.

4. A. Alhumaidan, F. Al-Qarni, M. AlSharief, et al., "Surgical Guides for Esthetic Crown Lengthening Procedures: Periodontal and Prosthetic Aspects," *Journal of the American Dental Association (1939)* 153, no. 1 (2022): 31–38.

5. F. Alpiste-Illueca, "Morphology and Dimensions of the Dentogingival Unit in the Altered Passive Eruption," *Medicina Oral, Patología Oral y Cirugía Bucal* 17, no. 5 (2012): 814–820.

6. S. C. S. Pinto, C. Higashi, E. Bonafé, et al., "Crown Lengthening as Treatment for Altered Passive Eruption: Review and Case Report," *World Journal of Dentistry* 6, no. 3 (2015): 178–183.

7. J. G. Coslet, R. Vanarsdall, and A. Weisgold, "Diagnosis and Classification of Delayed Passive Eruption of the Dentogingival Junction in the Adult," *Alpha Omegan* 70, no. 3 (1977): 24–28.

8. A. W. Gargiulo, F. M. Wentz, and B. Orban, "Dimensions and Relations of the Dentogingival Junction in Humans," *Journal of Periodontology* 32, no. 3 (1961): 261–267.

9. B. Nugala, B. S. Kumar, S. Sahitya, and P. M. Krishna, "Biologic Width and Its Importance in Periodontal and Restorative Dentistry," *Journal of Conservative Dentistry* 15, no. 1 (2012): 12–17.

10. P. M. Camargo, P. R. Melnick, and L. M. Camargo, "Clinical Crown Lengthening in the Esthetic Zone," *Journal of the California Dental Association* 35, no. 7 (2007): 487–498.

11. D. A. Garber and M. A. Salama, "The Aesthetic Smile: Diagnosis and Treatment," *Periodontology 2000* 11, no. 1 (1996): 18–28.

12. R. A. Levine and M. McGuire, "The Diagnosis and Treatment of the Gummy Smile," *Compendium of Continuing Education in Dentistry* 18, no. 8 (1997): 756–766.

13. S. K. Lanning, T. C. Waldrop, J. C. Gunsolley, and J. G. Maynard, "Surgical Crown Lengthening: Evaluation of the Biological Width," *Journal of Periodontology* 74, no. 4 (2003): 468–474.

14. D. E. Deas, S. A. Mackey, R. S. Sagun, R. H. Hancock, S. Gruwell, and C. Campbell, "Crown Lengthening in the Maxillary Anterior Region: A 6-Month Prospective Clinical Study," *International Journal of Periodontics & Restorative Dentistry* 34, no. 3 (2014): 365–373.

15. D. E. Deas, A. J. Moritz, H. T. McDonnell, et al., "Osseous Surgery for Crown Lengthening: A 6-Month Clinical Study," *Journal of Periodontology* 75, no. 9 (2004): 1288–1294.

16. R. Arora, S. C. Narula, R. K. Sharma, and S. Tewari, "Evaluation of Supracrestal Gingival Tissue After Surgical Crown Lengthening: A 6-Month Clinical Study," *Journal of Periodontology* 84, no. 7 (2013): 934–940.

17. R. Pontoriero and G. Carnevale, "Surgical Crown Lengthening: A 12-Month Clinical Wound Healing Study," *Journal of Periodontology* 72, no. 7 (2001): 841–848.

18. F. Herrero, J. B. Scott, P. S. Maropis, and R. A. Yukna, "Clinical Comparison of Desired Versus Actual Amount of Surgical Crown Lengthening," *Journal of Periodontology* 66, no. 7 (1995): 568–571.

19. T. M. I. Carrera, A. E. N. Freire, G. J. P. L. de Oliveira, et al., "Digital Planning and Guided Dual Technique in Esthetic Crown Lengthening: A Randomized Controlled Clinical Trial," *Clinical Oral Investigations* 27, no. 4 (2023): 1589–1603.

20. M. Hultin, K. G. Svensson, and M. Trulsson, "Clinical Advantages of Computer-Guided Implant Placement: A Systematic Review," *Clinical Oral Implants Research* 23, no. S6 (2012): 124–135.

21. F. Altieri and M. Cassetta, "The Impact of Tooth-Borne vs Computer-Guided Bone-Borne Rapid Maxillary Expansion on Pain and Oral Health-Related Quality of Life: A Parallel Cohort Study," *American Journal of Orthodontics and Dentofacial Orthopedics* 158, no. 5 (2020): 83–90.

22. U. Kim, S. Kim, and E. Kim, "The Application of "Bone Window Technique" Using Piezoelectric Saws and a CAD/CAM-Guided Surgical Stent in Endodontic Microsurgery on a Mandibular Molar Case," *Restorative Dentistry & Endodontics* 45, no. 3 (2020): 27.

23. J. Kostunov, P. Rammelsberg, A. L. Klotz, A. Zenthöfer, and F. S. Schwindling, "Minimization of Tooth Substance Removal in Normally

Calcified Teeth Using Guided Endodontics: An In Vitro Pilot Study," *Journal of Endodontia* 47, no. 2 (2021): 286–290.

24. F. C. Yogui, F. R. Verri, J. M. de Luna Gomes, C. A. A. Lemos, R. S. Cruz, and E. P. Pellizzer, "Comparison Between Computer-Guided and Freehand Dental Implant Placement Surgery: A Systematic Review and Meta-Analysis," *International Journal of Oral and Maxillofacial Surgery* 50, no. 2 (2021): 242–250.

25. N. Zhu, J. Liu, T. Ma, Y. Zhang, and Y. Lin, "Fully Digital Versus Conventional Workflow for Horizontal Ridge Augmentation With Intraoral Block Bone: A Randomized Controlled Clinical Trial," *Clinical Implant Dentistry and Related Research* 24, no. 6 (2022): 809–820.

26. O. Gibreal, Y. Al-Modallal, G. Mahmoud, and A. Gibreal, "The Efficacy and Accuracy of 3D-Guided Orthodontic Piezocision: A Randomized Controlled Trial," *BMC Oral Health* 23, no. 1 (2023): 181.

27. E. Lucas-Taulé, M. Llaquet, J. Muñoz-Peñalver, J. Somoza, M. Satorres-Nieto, and F. Hernández-Alfaro, "Fully Guided Tooth Autotransplantation Using a Multidrilling Axis Surgical Stent: Proof of Concept," *Journal of Endodontia* 46, no. 10 (2020): 1515–1521.

28. O. Camps-Font and J. Vilarrasa, "Computer-Guided Surgical Exposure of Palatally Displaced Canines: A Technical Note," *International Journal of Computerized Dentistry* 26, no. 4 (2023): 339–346.

29. F. Altieri, G. Padalino, R. Guarnieri, E. Barbato, and M. Cassetta, "Computer-Guided Palatal Canine Disimpaction: A Technical Note," *International Journal of Computerized Dentistry* 23, no. 3 (2020): 219–224.

30. X. Liu, J. Yu, J. Zhou, and J. Tan, "A Digitally Guided Dual Technique for Both Gingival and Bone Resection During Crown Lengthening Surgery," *Journal of Prosthetic Dentistry* 119, no. 3 (2018): 345–349.

31. S. O. Alazmi, "Three Dimensional Digitally Designed Surgical Guides in Esthetic Crown Lengthening: A Clinical Case Report With 12 Months Follow Up," *Clinical, Cosmetic and Investigational Dentistry* 14 (2022): 55–59.

32. B. Alresheedi, "Digitally Guided Workflow for the Esthetic and Prosthetic Oral Rehabilitation of a Patient With Excessive Gingival Display: A Case Report," *Clinical, Cosmetic and Investigational Dentistry* 14 (2022): 281–287.

33. E. von Elm, D. G. Altman, M. Egger, et al., "The Strengthening the Reporting of Observational Studies in Epidemiology (STROBE) Statement: Guidelines for Reporting Observational Studies," *Journal of Clinical Epidemiology* 61, no. 4 (2008): 344–349.

34. C. O. Silva, J. M. Soumaille, F. C. Marson, et al., "Aesthetic Crown Lengthening: Periodontal and Patient-Centred Outcomes," *Journal of Clinical Periodontology* 42, no. 12 (2015): 1126–1134.

35. J. D'haese, J. Ackhurst, D. Wismeijer, et al., "Current State of the Art of Computer-Guided Implant Surgery," *Periodontology 2000* 73, no. 1 (2017): 121–133.

36. N. T. Cong, P. H. Nam, H. Viet, and A. Marya, "Digitally Planned Surgical Crown Lengthening: A Novel Bone Reduction Strategy to Correct a Gummy Smile," *Journal of Surgical Case Reports* 2024, no. 4 (2024): 202.

37. T. M. Deliberador, S. G. Weiss, A. T. D. Neto, et al., "Guided Periodontal Surgery: Association of Digital Workflow and Piezosurgery for the Correction of a Gummy Smile," *Case Reports in Dentistry* 2020 (2020): 7923842.

38. P. Tack, J. Victor, P. Gemmel, and L. Annemans, "3D-Printing Techniques in a Medical Setting: A Systematic Literature Review," *Biomedical Engineering Online* 15, no. 1 (2016): 115.

39. E. Borham, H. A. Abuel-Ela, I. S. Mohamed, and Y. A. Fouad, "Treatment of Excessive Gingival Display Using Conventional Esthetic Crown Lengthening Versus Computer Guided Esthetic Crown Lengthening: A Randomized Clinical Trial," *BMC Oral Health* 24, no. 1 (2024): 317.

40. L. Passos, F. P. Soares, I. G. G. Choi, and A. R. G. Cortes, "Full Digital Workflow for Crown Lengthening by Using a Single Surgical Guide," *Journal of Prosthetic Dentistry* 124, no. 3 (2020): 257–261.

41. I. Pedrinaci, J. Calatrava, J. Flores, A. Hamilton, G. O. Gallucci, and M. Sanz, "Multifunctional Anatomical Prototypes (MAPs): Treatment of Excessive Gingival Display due to Altered Passive Eruption," *Journal of Esthetic and Restorative Dentistry* 35, no. 7 (2023): 1058–1067.

42. Y. Li, M. Liu, T. Zhou, J. Lyu, J. Tan, and X. Liu, "Accuracy of Three Types of Digital Guides for Crown Lengthening Surgery: An In Vitro Study," *Journal of Dental Sciences* 19, no. 1 (2024): 39–45.

43. E. Domínguez, A. Pascual-La Rocca, C. Valles, et al., "Stability of the Gingival Margin After an Aesthetic Crown Lengthening Procedure in the Anterior Region by Means of a Replaced Flap and Buccal Osseous Surgery: A Prospective Study," *Clinical Oral Investigations* 24, no. 10 (2020): 3633–3640.

44. O. González-Martín, G. Carbajo, M. Rodrigo, E. Montero, and M. Sanz, "One-Versus Two-Stage Crown Lengthening Surgical Procedure for Aesthetic Restorative Purposes: A Randomized Controlled Trial," *Journal of Clinical Periodontology* 47, no. 12 (2020): 1511–1521.

45. D. H. Ballard, P. Mills, R. Duszak, et al., "Medical 3D Printing Cost-Savings in Orthopedic and Maxillofacial Surgery: Cost Analysis of Operating Room Time Saved With 3D Printed Anatomic Models and Surgical Guides," *Academic Radiology* 27, no. 8 (2020): 1103–1113.

46. M. Colombo, C. Mangano, E. Mijiritsky, M. Krebs, U. Hauschild, and T. Fortin, "Clinical Applications and Effectiveness of Guided Implant Surgery: A Critical Review Based on Randomized Controlled Trials," *BMC Oral Health* 17, no. 1 (2017): 150.

47. E. S. Rosenberg, S. C. Cho, and D. A. Garber, "Crown Lengthening Revisited," *Compendium of Continuing Education in Dentistry* 20, no. 6 (1999): 527–542.

48. C. G. Benítez, L. H. Azevedo, I. L. S. da Silva, et al., "Use of Both the Diode and er: YAG Lasers in Esthetic Crown Lengthening With the Aid of Digitally Guided Dual Technique: 3 Years Follow-Up," *Journal of Esthetic and Restorative Dentistry* 36, no. 5 (2024): 695–701.