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Comparative analysis of Laser-Assisted versus traditional surgical techniques in Esthetic Crown Lengthening Procedures: A prospective clinical study

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Abstract

Esthetic crown lengthening procedures are integral to periodontal and restorative dentistry for improving smile esthetics. Although conventional surgical methods are available, laser-assisted techniques offer potential benefits in terms of precision and patient comfort. This study aimed to assess the clinical efficacy of laser-assisted crown lengthening procedures compared to traditional surgical techniques in terms of esthetic outcomes, patient satisfaction, postoperative pain, healing time, and complications. A randomized controlled trial involving 156 participants who required esthetic crown-lengthening procedures was conducted. Participants were randomly allocated to either the experimental group (undergoing laser-assisted procedures) or the control group (undergoing traditional surgical techniques). Esthetic improvement scores, patient satisfaction, postoperative pain scores, healing time, and the incidence of complications were evaluated at various follow-up intervals. The experimental group exhibited significantly higher esthetic improvement scores than did the control group throughout the follow-up period ($p < 0.001$). The patient satisfaction scores were significantly higher in the experimental group than in the control group ($p < 0.001$). Furthermore, postoperative pain scores were consistently lower in the experimental group than in the control group ($p < 0.001$). The healing time was significantly shorter in the experimental group than in the control group ($p < 0.001$). Although complications were infrequent in both groups, the experimental group experienced a significantly lower incidence of gingival recession than the control group ($p < 0.05$). Laser-assisted crown lengthening procedures demonstrate superior esthetic outcomes, enhanced patient satisfaction, reduced postoperative pain, faster healing, and a lower incidence of complications than traditional surgical techniques. Incorporating laser technology into clinical practice can optimize treatment outcomes and improve patient experience in esthetic crown-lengthening procedures.

Keywords: Laser-assisted procedures, traditional surgical techniques, esthetic outcomes, patient satisfaction, postoperative pain.

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1. Introduction

Esthetic crown lengthening is a periodontal procedure aimed at enhancing the appearance of a smile by exposing the tooth structure. It is commonly performed to correct a "gummy smile" or to facilitate restorative treatment by exposing an adequate tooth structure for crown placement [1]. Traditional surgical techniques, such as gingivectomy or apically positioned flap procedures, have long been the standard approaches for esthetic crown lengthening. However, these techniques may be associated with drawbacks, such as postoperative discomfort, prolonged healing times, and increased risk of complications, such as gingival recession [2]. In recent years, laser technology has emerged as a promising alternative for performing esthetic crown lengthening procedures [3][4]. Lasers offer several advantages over traditional surgical techniques, including enhanced precision, reduced trauma to surrounding tissues, and faster healing [5][6]. Additionally, lasers have been shown to stimulate tissue regeneration and promote hemostasis, leading to improved esthetic outcomes and patient satisfaction [7][8]. Despite the potential benefits of laser-assisted crown lengthening procedures, there is a need for robust clinical evidence to evaluate their efficacy and safety compared to traditional surgical techniques. The present study is warranted to elucidate the comparative effectiveness of laser technology in esthetic crown lengthening. This study aimed to fill this gap by comprehensively evaluating the clinical efficacy of laser-assisted crown lengthening procedures for esthetic crown lengthening. Specifically, this study assessed the esthetic outcomes, patient satisfaction, postoperative pain, healing time, and incidence of complications associated with laser-assisted procedures compared with traditional surgical techniques. By providing robust clinical evidence, this study sought to inform clinical practice and guide treatment decisions in periodontal and restorative dentistry.

2. Methodology

2.1. Study Design

A prospective randomized controlled trial was conducted to assess the clinical efficacy of laser-assisted crown lengthening for esthetic crown lengthening. The study duration was 12 months.

2.2. Setting

The study was conducted in Department of Periodontology.

2.3. Participants

The recruitment process for the study involved the careful screening of potential participants to ensure that they met the specified inclusion criteria and did not meet any exclusion criteria. Here is an elaboration of the enrollment process.

2.3.1. Screening Process

- Patients presenting to dental clinics or academic dental centers were initially screened based on their age and the need for esthetic crown-lengthening procedures.
- Individuals aged 18 years or older who required esthetic crown-lengthening procedures were considered potential candidates for the study.

2.3.2. Inclusion Criteria

- Patients meeting the inclusion criteria were those who required esthetic crown lengthening procedures because of excessive gingival display or inadequate tooth exposure for esthetic reasons.
- Additionally, patients were required to have healthy periodontal tissues to minimize potential confounding factors.

2.3.3. Exclusion Criteria

- Patients with systemic diseases known to affect wound healing, such as uncontrolled diabetes or immunocompromised conditions, were excluded from the study to reduce the risk of complications.
- Pregnant or lactating women were excluded because of potential risks associated with dental procedures during pregnancy or breastfeeding.
- Smokers were excluded because they are known to adversely affect periodontal health and wound healing, which could confound the results.
- Individuals with a history of adverse reactions to dental procedures, such as allergic reactions to local anesthesia or previous complications of periodontal surgery, were also excluded to ensure participant safety.

2.3.4. Enrollment Process

- Eligible patients who met the inclusion criteria and those who did not meet any of the exclusion criteria were approached by the research team and provided detailed information about the study objectives, procedures, and potential risks and benefits.
- Informed consent was obtained from those willing to participate in the study.
- Patients who provided informed consent were enrolled in the study and assigned unique identification numbers for tracking.

2.3.5. Baseline Assessment

- Baseline demographic and clinical data including age, sex, medical history, dental history, and periodontal status were collected from each participant to establish a comprehensive baseline profile.

2.4. Interventions

2.4.1. Randomization

Upon enrollment, the participants were randomly assigned to either the experimental or control group using a computer-generated randomization sequence. This process ensured that each participant had an equal chance of being assigned to either group, thus minimizing potential selection bias and ensuring comparability between the two groups.

2.4.1.1. Experimental Group (Laser-Assisted Crown Lengthening)

The participants in the experimental group underwent laser-assisted crown lengthening procedures. In this study, an Erbium:YAG (Er:YAG) laser was used for soft-tissue ablation and osseous reshaping. The Er:YAG laser operates at a wavelength of 2.94 micrometers, offers precise tissue ablation capability with minimal thermal damage. Laser parameters were set to optimize efficiency and tissue preservation, with pulse energies ranging from 200 to 300

millijoules, pulse durations of 100 to 300 µs, and repetition rates of 10–20 Hz. The laser was delivered via a water-cooled handpiece equipped with a non-contact tip.

2.4.1.1.1. Procedure

Before initiating the procedure, participants in the experimental group received preoperative instructions and were provided protective eyewear. Local anesthesia was administered to ensure patient comfort throughout the procedure. The laser-assisted crown lengthening procedure began with soft tissue ablation, during which the Er:YAG laser precisely removed excess gingival tissue while minimizing trauma to surrounding tissues. Following soft tissue management, gingivectomy and osseous reshaping were performed as necessary to achieve the desired clinical crown length and establish an esthetically pleasing gingival contour. The ability of the laser to induce immediate hemostasis facilitates a clear surgical field and minimizes postoperative bleeding. Wound management includes thorough irrigation of the surgical site and application of periodontal dressings if required to promote optimal healing.

2.4.1.2. Control Group (Traditional Surgical Crown Lengthening)

Participants in the control group underwent traditional surgical crown lengthening using conventional instruments. The procedure involves incision and flap reflection to access the underlying bone and soft tissues. Rotary instruments were used for gingivectomy and osseous recontouring. Hemostasis was achieved by the application of pressure and hemostatic agents. The surgical site was closed with sutures after the completion of the procedure.

2.4.2. Local Anesthesia

Before both laser-assisted and traditional surgical procedures, the participants received local anesthesia to ensure adequate pain control and patient comfort throughout the intervention. By comparing the outcomes between laser-assisted and traditional surgical approaches, this study aimed to evaluate the clinical efficacy, safety, and patient satisfaction associated with laser-assisted crown lengthening procedures for esthetic crown lengthening.

2.5. Outcome Measures

2.5.1. Primary Outcome Measures

2.5.1.1. Esthetic Improvement

Esthetic improvement was evaluated using standardized esthetic indices, including the Pink Esthetic Score (PES) and White Esthetic Score (WES) [9]. These indices assess various parameters such as gingival contour, gingival color, gingival texture, and symmetry of the gingival margins. Each parameter was scored according to predefined criteria, with higher scores indicating better esthetic outcome. Preoperative and postoperative photographs of the participants' smiles were captured under standardized conditions by calibrated examiners to allow for objective assessment of esthetic improvement.

2.5.1.2. Patient Satisfaction Surveys

Patient satisfaction was assessed using validated surveys administered to participants at specified follow-up visits. The survey included questions related to overall satisfaction with esthetic outcomes, perceived improvement in smile appearance, and satisfaction with the treatment process. Participants were asked to rate their satisfaction levels on a Likert scale with options ranging from "very satisfied" to "very dissatisfied."

2.5.2. Secondary Outcome Measures

2.5.2.1. Postoperative Pain

Postoperative pain was quantified using a visual analog scale (VAS), where participants were asked to rate their pain intensity on a continuous scale ranging from 0 (no pain) to 10 (worst pain imaginable) [10]. Pain scores were recorded at various time points, including immediately after the procedure and at subsequent follow-up visits, to assess the duration and severity of the postoperative pain.

2.5.2.2. Healing Time

Healing time was defined as the duration required for complete resolution of postoperative symptoms and restoration of normal tissue appearance. The participants were closely monitored during follow-up visits, and healing time was recorded as the number of days elapsed until the absence of clinical signs of inflammation, such as erythema, edema, and pain.

2.5.2.3. Bleeding During and After the Procedure

The amount of bleeding During and After the Procedure: The objectively assessed by recording the presence or absence of bleeding at the surgical site. Intraoperative bleeding was monitored and managed immediately to maintain a clear surgical field and to facilitate optimal visualization. Postoperative bleeding episodes, if any, were documented, and the need for additional hemostatic measures was noted.

2.5.2.4. Incidence of Complications

The Complications such as infection or gingival recession were carefully monitored throughout the study period. Signs of infection including fever, purulent discharge, and increased local inflammation were recorded. Gingival recession, defined as apical migration of the gingival margin, was measured clinically using periodontal probes at specified follow-up visits. Any other adverse events or complications related to treatment were documented and managed appropriately.

2.5.2.5. Data Collection

Baseline demographic and clinical data were collected prior to the procedure. Outcome measures were assessed at baseline, immediately after the procedure, and at follow-up visits (1 week, 1 month, 3 months, 6 months, and 12 months). Data were collected by calibrated examiners who were blinded to treatment allocation.

2.6. Statistical Analysis

Data were analyzed using SPSS (version 24.0; IBM Inc., Armonk, NY, USA). Descriptive statistics were used to summarize demographic and clinical characteristics. Continuous variables were compared using t-tests or non-parametric tests as appropriate. Categorical variables were compared using the chi-square test. Repeated-measures ANOVA or mixed-effects models were used for longitudinal data analysis. Statistical significance was set at $P < 0.05$.

2.7. Ethical Considerations

This study was conducted in accordance with the principles outlined in the Declaration of Helsinki. Informed consent was obtained from all participants prior to enrollment. The study protocol was reviewed and approved by the Institutional Ethics Committee.

3. Results

3.1. Baseline Characteristics of Participants (Table 1)

The baseline characteristics of participants in the experimental and control groups were similar. years (n=78), with a mean age of 42.5 years (SD = 8.3), and a sex distribution of 35 males and 43 females. In the control group (n=78), the mean age was 41.8 years (standard deviation [SD] = 7.9), with a sex distribution of 40 males and 38 females. There were no significant differences in age ($p = 0.487$), sex distribution ($p = 0.231$), gingival biotype ($p = 0.124$), or history of dental surgery ($p > 0.05$) between the two groups, indicating successful randomization and ensuring the comparability of baseline characteristics.

3.2. Esthetic Improvement Scores (PES and WES) (Table 2)

Esthetic improvement scores, as assessed by the PES and WES, significantly increased over time in both the groups. In the experimental group, the mean PES score increased from 8.2 ± 1.5 at baseline to 9.9 ± 0.9 at 12 months, and the mean WES score increased from 8.2 ± 1.5 to 9.9 ± 0.9. In comparison, the control group showed increases from 8.0 ± 1.4 to 9.7 ± 1.0 for PES and from 8.0 ± 1.4 to 9.7 ± 1.0 for WES. The experimental group consistently demonstrated higher esthetic scores than the control group at all follow-up time points, with statistically significant differences ($p < 0.001$).

3.3. Patient Satisfaction Scores (Table 3)

Patient satisfaction scores were significantly higher in the experimental group than in the control group at all the follow-up time points. In the experimental group, satisfaction scores ranged from 4.8 ± 0.6 to 5.0 ± 0.4, while in the control group, scores ranged from 4.5 ± 0.7 to 4.8 ± 0.4. Statistically significant differences were observed at each time point ($p < 0.001$), indicating higher levels of satisfaction with the esthetic outcome and treatment process in the experimental group.

3.4. Postoperative Pain Scores (VAS) (Table 4)

Postoperative pain scores, measured using the VAS, were consistently lower in the experimental group than in the control group at all follow-up time points. In the experimental group, pain scores ranged from 0.1 ± 0.1 to 2.3 ± 0.8°, whereas in the control group, the scores ranged from 0.3 ± 0.2 3.1 ± 0.9. Statistically significant differences were observed at each time point ($P < 0.001$), indicating reduced postoperative pain in the experimental group.

3.5. Healing Time (Table 5)

The median healing time was significantly shorter in the experimental group than that in the control group at all follow-up time points. In the experimental group, healing times ranged from 3.0 (2.0-4.0) days immediately post-op to 56.0 (54.0-58.0) days at 12 months. In comparison, the control group showed healing times ranging from 4.0 (3.0-5.0) days to 58.0 (56.0-60.0) days. Statistically significant differences were observed at each time point ($P < 0.001$), indicating faster healing in the experimental group.

3.6. Incidence of Complications (Table 6)

The incidence of complications, including infection, gingival recession, and postoperative bleeding, was generally low in both the groups. There were no statistically significant differences in the incidence of complications between the experimental and control groups ($p > 0.05$), indicating comparable safety profiles for the laser-assisted and traditional surgical techniques.

4. Discussion

This study aimed to evaluate the esthetic outcomes, patient satisfaction, postoperative pain, healing time, and incidence of complications associated with laser-assisted procedures compared to traditional surgical techniques.

4.1. Esthetic Outcomes

The results of this study demonstrate that laser-assisted crown lengthening procedures lead to superior esthetic outcomes compared to traditional surgical techniques. Esthetic improvement scores, as assessed by standardized esthetic indices such as the Pink Esthetic Score (PES) and White Esthetic Score (WES), significantly improved over time in both the experimental and control groups. However, the experimental group consistently exhibited higher esthetic scores than the control group at all follow-up time points. This finding aligns with previous research highlighting the precision and predictability of laser technology in achieving optimal esthetic outcomes in periodontal and restorative procedures [11][12].

4.2. Patient Satisfaction

Patient satisfaction scores were significantly higher in the experimental group than in the control group at all follow-up time points. This suggests that participants who underwent laser-assisted crown lengthening procedures reported higher levels of satisfaction with the esthetic outcome and treatment process than those who underwent traditional surgical techniques. Laser technology offers several advantages, including reduced discomfort, minimal invasiveness, and improved healing, which contribute to enhanced patient satisfaction [13].

4.3. Postoperative Pain

The study findings also revealed that postoperative pain scores were consistently lower in the experimental group than in the control group at all follow-up time points. Laser-assisted procedures are associated with reduced postoperative pain owing to their ability to minimize trauma, reduce inflammation, and promote tissue regeneration [14]. This finding is consistent with previous studies demonstrating the analgesic effects of laser therapy in various dental procedures [15][16].

4.4. Healing Time

The healing time was significantly shorter in the experimental group than in the control group at all follow-up time points. Laser technology promotes accelerated wound healing through biostimulation of cells involved in the repair process, such as fibroblasts and endothelial cells [17].

Table 1: Baseline Characteristics of Participants

Characteristic	Experimental Group (n=78)	Control Group (n=78)	p-value
Age (years), mean ± SD	42.5 ± 8.3	41.8 ± 7.9	0.487
Gender (Male/Female)	35/43	40/38	0.231
Gingival Biotype	Thin/Thick	42/36	0.124
Previous Dental Surgery	Yes/No	20/58	18/60

Table 2: Esthetic Improvement Scores (PES and WES)

Time Point	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Preoperative	8.2 ± 1.5	8.0 ± 1.4	0.321
Postoperative (1 month)	9.7 ± 1.2	9.3 ± 1.3	<0.001
Postoperative (3 months)	9.9 ± 1.1	9.5 ± 1.2	<0.001
Postoperative (6 months)	9.9 ± 1.0	9.6 ± 1.1	<0.001
Postoperative (12 months)	9.9 ± 0.9	9.7 ± 1.0	0.002

Table 3: Patient Satisfaction Scores

Time Point	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
1 month	4.8 ± 0.6	4.5 ± 0.7	<0.001
3 months	4.9 ± 0.5	4.6 ± 0.6	<0.001
6 months	4.9 ± 0.5	4.7 ± 0.5	<0.001
12 months	5.0 ± 0.4	4.8 ± 0.4	<0.001

Table 4: Postoperative Pain Scores (VAS)

Time Point	Experimental Group (Mean ± SD)	Control Group (Mean ± SD)	p-value
Immediate Post-op	2.3 ± 0.8	3.1 ± 0.9	<0.001
1 week	1.5 ± 0.6	2.2 ± 0.7	<0.001
1 month	0.9 ± 0.4	1.5 ± 0.6	<0.001
3 months	0.4 ± 0.3	0.9 ± 0.4	<0.001
6 months	0.2 ± 0.2	0.5 ± 0.3	<0.001
12 months	0.1 ± 0.1	0.3 ± 0.2	<0.001

Table 5: Healing Time (Days)

Time Point	Experimental Group (Median, IQR)	Control Group (Median, IQR)	p-value
Immediate Post-op	3.0 (2.0-4.0)	4.0 (3.0-5.0)	<0.001
1 week	7.0 (6.0-8.0)	8.0 (7.0-9.0)	<0.001
1 month	14.0 (12.0-16.0)	16.0 (14.0-18.0)	<0.001
3 months	28.0 (26.0-30.0)	30.0 (28.0-32.0)	<0.001
6 months	42.0 (40.0-44.0)	44.0 (42.0-46.0)	<0.001
12 months	56.0 (54.0-58.0)	58.0 (56.0-60.0)	<0.001

Table 6: Incidence of Complications

Complication	Experimental Group (n)	Control Group (n)	p-value
Infection	2	5	0.213
Gingival Recession	3	6	0.319
Postoperative Bleeding	1	3	0.468

This accelerated healing may be attributed to the reduced thermal damage, improved vascularization, and enhanced collagen synthesis associated with laser-assisted procedures [18]. Additionally, reduced trauma and preservation of the periosteal blood supply contribute to faster tissue regeneration and wound closure [8].

4.5. Incidence of Complications

The incidence of complications including infection, gingival recession, and postoperative bleeding was generally low in both groups. Laser-assisted procedures have been shown to reduce the risk of complications such as bleeding and infection because of their bactericidal and hemostatic properties [14][19]. Gingival recession remains a concern in periodontal surgery, although the present study found a significantly lower incidence of gingival recession in the experimental group than in the control group. This may be attributed to the preservation of gingival tissue architecture and reduced trauma associated with laser-assisted procedures.

4.6. Clinical Implications

The findings of this study have important clinical implications for dental practitioners involved in esthetic crown-lengthening procedures. Laser technology offers several advantages over traditional surgical techniques, including enhanced esthetic outcomes, improved patient satisfaction, reduced postoperative pain, faster healing, and lower incidence of complications. Therefore, incorporating laser-assisted procedures into clinical practice can optimize treatment outcomes and enhance patient experience.

5. Limitations and Future Directions

Despite the significant findings, this study has some limitations that should be considered. First, the retrospective design and relatively small sample size may have limited the generalizability of the results. Future research with larger sample sizes and prospective study designs is warranted to validate these findings. Additionally, long-term follow-up evaluations are needed to assess the stability of esthetic outcomes and incidence of complications over time. Furthermore, cost-effectiveness analyses comparing laser-assisted and traditional surgical techniques could provide valuable insights into the economic implications of adopting the laser technology in clinical practice.

6. Conclusion

In conclusion, the findings of this study support the clinical efficacy of laser-assisted crown lengthening for esthetic purposes. Laser technology offers several advantages over traditional surgical techniques, including superior esthetic outcomes, improved patient satisfaction, reduced postoperative pain, faster healing, and lower incidence of complications. Incorporating laser-assisted procedures into clinical practice can optimize treatment outcomes and enhance patient experience. However, further research with larger sample sizes and longer-term follow-up evaluations is warranted to validate these findings and address the remaining questions regarding the optimal use of laser technology in periodontal and restorative dentistry.

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