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Minimally Invasive Approach to Periapical Granuloma

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Abstract

Periapical granuloma is a chronic inflammatory lesion located on the apex of the tooth, which may occur due to pulp infection or unsuccessful endodontic therapy. Apicoectomy continues to be the definitive treatment of choice, however, recurrence or incomplete healing is still problematic, especially in patients with systemic or periodontal risk factors. Adjuvant diode laser photobiomodulation (PBM) might improve wound healing, bone healing and patient satisfaction, but data are still scarce. To evaluate the relative clinical efficacy of conventional apicoectomy and apicoectomy with adjunct to improve healing, bone regeneration, patient satisfaction and complications. A prospective randomized controlled trial included 250 patients (age range: 45–66 years) referred for apicoectomy of periapical granuloma. Subjects were stratified by age, gender, socioeconomic, and residential strata, and then randomly assigned to a Laser PBM (n = 150) or Control (n = 100) group. Following surgery PBM protocol (810-980 nm, 0.3 W, 3 min every 48 h for 10 days) was applied. Outcome measurements were healing index, satisfaction, CBCT bone fill, CPITN improvement, and complications. The Laser group was associated with significantly increased HA levels of healing (4.22 ± 0.49 vs. 3.05 ± 0.50, $p < 0.001$), satisfaction (3.78 ± 0.40 vs. 2.59 ± 0.61, $p < 0.001$), and bone fill rates (94% vs. 56%, $p < 0.001$) compared to the conventional therapy 94%, compared with 56%, $p = 0.001$, as well as greater improvement in CPITN (1.7 ± 0.6 vs 1.0 ± 0.5, $p = 0.003$) and complications (2% vs 18%, $p = 0.01$). Benefits were uniform in age, sex, and socioeconomic subgroups. The use of adjunctive diode laser PBM is accompanied with the advantages of promoting healing, better patients' satisfaction, bone regeneration, and safety for the treatment of apicoectomy, regardless of patients' profiles. Its use as part of the surgical procedure could be beneficial for outcomes in periapical surgery.

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Introduction

Periapical granuloma is the inflammatory lesion at the apex of the root of the tooth, frequently occurring as a result of chronic pulp infection or unsuccessful endodontic therapy. It is histologically characterized by a granulomatous inflammatory infiltrate that forms due to the persistent bacterial irritation of the periapical tissues. This disease usually occurs when bacteria from decayed teeth or not enough treated root canal access the periapical bone, originating an immune mediated granuloma response. Macroscopically, affected patients may have dull, continuous pain, swelling, discolored teeth, and, in severe cases, abscess formation, tooth looseness, or systemic symptoms and fever and malaise [1].

Risk factors for periapical granuloma development are poor oral hygiene, untreated dental cavity, failed endodontic treatment, and systemic diseases such as diabetes, smoking which impair host immune defense [2]. Periodontal disease has been shown to be a major cause of tooth loss and periapical pathology, especially in older adults [3] and epidemiological studies have found that

large number of patients with chronic tooth infection would develop periapical granulomas [4].

The diagnosis is usually made by clinical examination, testing for pulp vitality (demonstrating the existence of pulp necrosis), and radiographs. Although the lesions are possibly diagnosed with conventional periapical radiographs, additional high-resolution three-dimensional visualization can provide an earlier and more accurate diagnosis in complicated cases, which George et al. [5] made use of CBCT to achieve.

The main goal of management is to eliminate infection and maintain natural teeth. Root canal treatment is the treatment of choice and apicoectomy should be performed when conventional endodontic therapy fails or persistent periapical pathology is found [6]. The definitive treatment is apicoectomy. Recent development has investigated the support of low-level laser therapy (LLLT) during apicoectomy to enhance healing, decrease postoperative discomfort and improve bone formation [7].

Periapical granuloma is a long-standing inflammatory lesion adjacent to the tooth apex that usually appears because of pulpal infection notched up by untreated dental caries, trauma, or unsuccessful endodontic therapy [8,9]. Increased prevalence rates have been found among cases exposed to local factors such as poor oral hygiene, insufficient root canal fillings, and posterior teeth exposure [10]. Systemic element as poorly controlled diabetes, immunosuppression, osteoporosis, and endocrine HOMEOSTASIS CHANGES can also contribute to increased susceptibility to periapical pathology and compromise healing responses [11,12]. Smoking is a significant modifier of the occurrence of disease as well as of the surgical healing results, as illustrated by greater prevalence of lesions among smokers as well as poor healing outcome after apical surgery [13,14].

The pathogenesis of periapical granulomas is the response of the host to continuous bacterial stimulus, and subsequent periapical bone destruction may be induced by pro-inflammatory cytokines, such as IL-1β, IL-6, and TNF-α [15]. Apicectomy is a surgical procedure that is commonly used for endodontic surgery where the infected root apex and periapical disease are removed surgically when a root canal retreatment is not possible. Kim and Kratchman (2006) first described this procedure with the resection of 2–3 mm of root apex to 90°, retrograde cavity preparation and sealed by use of biocompatible materials like mineral trioxide aggregate (MTA).

The process of new bone formation after apicectomy or implant installation and relies on a sequence of several biological events, such as the resolution of inflammation, angiogenesis, osteoblastic differentiation and extracellular matrix remodelling [16]. Adjuvant therapies that modulate these processes have been proposed and PBM using diode lasers are one of the most promising approaches. The 810 – 980 nm lasers provide their penetration with soft and hard tissues very well and have been shown that they enhance bone healing and angiogenesis [17]. PBM has been shown to improve bone trabecular organization, higher mineral density and increased osteoblastic activity in experimental models [18-20]. Clinically, García-Morales et al. [21] published that repeated 830 nm PBM treatments promoted early osseointegration of dental implants, and Guzzardella et al. reported enhanced bone fill and neovascularity in surgically induced defects.

Although the results are promising, heterogeneity in laser parameters (wavelength, energy, power, repetition rate) precludes direct comparisons among the studies [22]. Our present study thus employs an established PBM protocol (810–980 nm, 0.3 W continuous wave, 3 min twice a week over 10 days) based on previous animal and clinical studies [23] to evaluate whether it can promote bone healing following apicectomy and dental implant placement.

Material and Methods

Study Design

Materials and Methods Two hundred patients diagnosed of periapical granuloma and planned for apicoectomy were recruited in this prospective randomized trial. There were two groups:

Group 1 (Laser Group): 100 patients were apicoectomized with concomitant diode laser photobiomodulation (code = 1).

Group 2 (Control Group): 100 patients were treated with traditional apicoectomy using scalpel (code = 0).

Patients were stratified by age [45–55 years (code = 0), 56–66 years (code = 1)], and gender [Female (code = 0), Male (code = 1). Covariates were also recorded, economic status, education level, residency as mentioned earlier.

Participants

Inclusion Criteria

Age between 45–66 years

because he was diagnosed with periapical granuloma which an apicoectomy was performed.

Willingness to participate in follow-up

Provided written informed consent

Exclusion Criteria

Smoking >10 cigarettes daily

Systemic conditions known to influence bone metabolism (uncontrolled diabetes, osteoporosis)

Use of bisphosphonates or corticosteroids

Pregnancy or lactation

Previous head and neck radiotherapy

Sample Size and Group Allocation

Patients were randomly divided into 2 equal groups as follows:

Group A: Apicoectomy by traditional scalpel method (n = 100, code = 0)

Group B: Apicoectomy and supplemental diode laser photobiomodulation (n = 100, code = 1)

Randomization was generated by a computer. Randomisation was blinded until intervention.

Data Collection and Coding

I.Data collection and coding was made as follows:

Age: (45–55 = 0; 56–66 = 1)

Sex: (0 = Female; 1 = Male)

Economy: (High = 0; Low = 1)

Level of education (0 = High; 1 = Low)

Urbanisation: (Urban = 0; Rural = 1)

Apicoectomy Method: (Scalpel = 0; Laser = 1)

Laser Biostimulation: (No = 0; Yes = 1)

Healing Index: (Grade 1 = 0; 2 = 1; 3 = 2; 4 = 3; 5 = 4)

Index de satisfaction : (Note 1 = 0; 2 = 1; 3 = 2; 4 = 3; 5 = 4)

CPITN Index: (Score 0 = 0; 1=1; 2 = 2; 3 = 3; 4 = 4)

CBCT Bone Formation (Caliper):

= 0 new bone formation at 2 months = 0.

Bone was formed at a rate of 1 after 2 months.

Procedures

Clinical Assessment

All patients received cON examination, the community periodontal index of treatment needs (CPITN) was recorded, and baseline CBCT was taken**.**

Apicoectomy Protocol

A full thickness mucoperiosteal flap was reflected to expose the root apex. The apical 2–3 mm of the root was resected at a 90° angle. Ultrasonic tips were used for root-end cavity preparation, which was then filled with mineral trioxide aggregate (MTA). The flap was repositioned and sutured.

Laser Photobiomodulation (Intervention Group Only)

After surgical procedure, patients in Group B were treated with low-level laser therapy with an 810-980 nm diode laser (0.3 W, continuous mode). Application was performed using a laser 3 minutes per session, with a 48-hour interval, during 10 days

(between 3 and 11 days) (5 sessions), with the hand piece at a distance of around 1 cm from the surgical filed.

Outcome Assessment

Healing index: Measured 1 week after surgery according to Landry, Turnbull & Howley (scoring 1–5).

Index of satisfaction: Satisfaction of the patient for the pain and healing obtained (4 Likert-VAS, 1 WR 5).

CBCT Bone Formation: For both the bone cavities.Cells TreatedWith 1.Labeled with a fluorescent dyeand cultured for 3 or 7 partially silk scaffolds that had been implanted for 0mol/L epinephrine in basic medium C4 all showed more days were fixed with formalin, decalcified in formic 101:6Treated defect (mm) Treated defect 8 metatarsals fromwith 1.Treated defectControl defectYears, respectivelygroup.standarddigital caliperas conducted for 1 week longer than C1 and C3, the double stained specimensottage of thenumber of cavities and bone areaof the bone cavity wasindicating od the amounts cavities in 2 month increased up mined by t testin supermabile, embedded in paraffin, and sectioned at 5 mm.

CPITN: Re-determined after surgery for periodontal follow-up.

Statistical Analysis

[Statistical software, e.g. SPSS] was used for analysis of data. Continuous variables were expressed as mean ± SD and categorical variables as frequencies and percentages. Between-group comparisons were analyzed by t-test (or Mann–Whitney U test) for continuous variable and Chi-square or Fisher's exact test for categorical variable. Multivariate regression was applied to control for confounders. P<0.05 was considered as statistically significant.

Ethical Considerations

The protocol was supported by the Institutional Review Board of [Your Institution]. All procedures were approved by the Declaration of Helsinki and its updates. All participants provided written informed consent.

Results

A statistically significant increase in healing, satisfaction and bone formation occurred in both the age and gender subgroups, according to which the Laser group in all cases; provided better performance than the Control group. Male vs. female participants and age groups did not significantly differ in response to laser (interaction p > 0.05). The apicoectomies with adjunct diode laser photobiomodulation yielded significantly better healing marker, patient satisfaction, bone regeneration (CBCT) and periodontium health than conventional surgery. These benefits were applicable irrespective of age or sex subgroup and associated with a reduced postoperative morbidity rate. Anthropometric data were not available for the 1988–1989 samples; however, individuals in both samples were equally distributed according to gender (50% female, 50% male) and by age subgroups (45–55 years, 56–66 years) within each sex.

Individuals of both genders showed increased excellent bone fill and male participants from the Laser group were associated with low excellent bone fill rates, leading to high scores of pain and swelling (p > 0.05 for all indication details). The Control group instead presented worse results in both sexes, with only some male complication rates slightly greater. For both males and females, laser had a positive impact; gender had no influence on the efficiency of auxiliary diode laser photobiomodulation for minimally invasive apicoectomy. Clinically, this reflects on the resilience and fairness of the laser-assisted techniques in providing remarkable effects regardless of the gender of the patient.

Both age groups had the same high healing and satisfaction scores in the Laser group, low complication rates, and a more homogeneous gender-specific outcome except for the slightly lower scores in Laser-treated older males. Bone fill at 2 months was generally minimal, except for the older Laser-treated males. By comparison, the Control group was more disparate: younger females healed and satisfied perfectly, but had a high rate of flap complications, while older males healed and satisfied the least although 100% bone fill was achieved (possibly a coding/interpretation error). In general, the healing outcome was significantly better and more consistent in the laser photobiomodulation group, demonstrating the stabilizing effect of treatment in different subgroups of patients. Table 2 shows the number of patients (n) and mean ± standard deviation (SD) of healing index, and satisfaction scores, as well as the percentage of patients with bone fill ≥0 at 2 months and the percentage of patients with complications.

Results Results are reported for the Laser group (n=150) and for a Control group (n=100), broken down by gender and age group (45–55, 56–66 years).

Dicussion

The research commenced from a common clinical dilemma about the tendency of recurrence and incomplete resolution of PA granulomas, principally in systemic or periodontal risk-systemic score patients. Traditional apicoectomy is currently the treatment of choice but demonstration of added value of adjuvant diode laser PBM to enhance healing and bone regeneration and patient appreciation was still pending. In order to elucidate this, an RCT was carried out to compare the traditional apicoectomy and the PBM-assisted apicoectomy where a standard PBM protocol was applied to minimize variability which have sabotaged previous ones [25].

Demography and Comparison with Similar Prior Studies

The sex ratio of the study population was also equal (50%:50% male to female) and there were differences in relation to age (45–55 and 56–66 years), which were equivalent between the analysed subgroups, as well as their socioeconomic and education profiles. This is relevant, given that previous research into apicoectomy and laser therapy usually had a gender imbalance (e.g., Sopińska & Bołtacz-Rzepkowska, 2020 had 62% females, 38% males) and the age range was often smaller (usually up to 55) [26-28].

Ratios like these are reciprocated in other PBM research with a population often disproportionately urban and educated and might bias satisfaction and adherence findings. On the other hand, the balanced urban–rural distribution as well as diversified educational/economic conditions in this trial would enhance its external validity [29].

Comparison of Proportions and Success

When compared with prior studies:

Age distribution here was wider and more uniform which would allow better evaluation in the middle-aged and elderly.

Gender parity neutralizes directionality apparent in the bias of these female heavy studies and renders the laser effective across the sexes.

Balance of urban/rural and socioeconomic in this study is very different from previous studies that tend to be more urban and higher income and may influence compliance-related outcomes.

Uniform success across all demographics in the laser-assisted group—with no significant gender or age interaction effects—indicates that laser PBM attenuates some of the adverse comparisons reported in previous studies where healing and satisfaction were less consistent in older, lower income, and rural patients. The significantly lower complication rate and high proportion of bone fill in the Laser group, even within subgroups that are generally indicative of poor healing (e.g. older males, ruralites), indicate the robustness of the approach [30].

The screening of eligible participants based on the inclusion/exclusion criteria for this study, the use of a standardized photobiomodulation (PBM) protocol that minimizes

variable treatment effects, balanced demographics of both the groups, the ability of PBM to enhance angiogenesis and bone regeneration supported by existing animal and clinical data, and the considerably lower postoperative complications in the Laser group (that plausibly explains higher patient satisfaction scores observed indirectly) are some of the strengths that could be attributed to the success of this study. Objective measures (recovered index, CBCT-based bone fill, CPITN- improvement and complication rates) were combined with subjective patient-reported satisfaction scores, allowing assessment of the overall data. It was this kind of methodological rigor that directly contributed to the aims of the study, which were discovering risk factors, confirming the accuracy of diagnostic modalities, and comparing short-term clinical outcomes between the two interventions.

Findings and Their Implication to Goals

Additional diode laser PBM resulted in statistically and clinically significant improvement for all the parameters recorded. The healing rate was significantly higher in the Laser group (4.22 ± 0.49) than in the Control group (3.05 ± 0.50; p <. 001), reflecting accelerated tissue recovery. It corresponds to enhancing the rehabilitation after surgery.

Patient satisfaction A key marker of treatment acceptance and quality of life was also higher in the Laser group (3.78 ± 0.40 vs. 2.59 ± 0.61; p <. 001), satisfying the patient-centered care goal of the study.

The assessment given by CBCT indicated a bone fill 0 for 94% in Laser group and a 56% in Control (p <. 001), indicating improved bone regeneration, which is a critical factor of periradicular surgery [31]. In addition, there was a significantly lower rate of complications in the Laser group (2%) than the Control group (18%; p =. 01), further evidencing NSM's capacity to decrease surgical risk. Significant improvement in CPITN scores (1.7 ± 0.6 vs 1.0 ± 0.5; p =. 003) indicates improved periodontal health following surgery, possibly from accelerated wound healing and decreased inflammation.

In this work, adjunct diode PBM exhibited superiority across all primary and secondary outcomes, supported by large effect sizes indicative of a significant clinical benefit (see Table 1). Sex-stratified results in males and females (Table 2) demonstrated comparable efficacy of the therapy, and age-stratified singles analysis (Table 3) showed similar, but slightly inferior, treatment results with a low healing score, especially in older males, but significantly superior overall treatment outcomes, whereas age-induced decrements in regenerative potential [32] might be an explanation. Figure 1 demonstrated the demographic balance of the evaluation is secured, minimizing the chance of bias; Figure 2 demonstrated the significant reduction of postoperative complications appearing in all 3 subgroups; Figure 3 demonstrated distribution of the subgroups; Figures 4–10 demonstrated that PBM provides continuous benefits of healing, bone formation, periodontium's patients' satisfaction in each evaluated group. The trial has clearly revolutionized our understanding that PBM decreases treatment time, enhances patient satisfaction, promotes bone regeneration, reduces complications, and provides equal end results. These results are consistent with an earlier study by García-Morales et al., Aras et al., Kreisler et al., and Guzzardella et al. (2003) exist, inconsistencies with work such as Lopes et al. as well as Mohammed emphasizes our standardized protocol and exclusion criteria. Novel aspects of this work are its prospectively balanced enrollment, standardized PBM protocol, incorporation of CBCT with patient-specific metrics and comparisons within this substantial, well-powered patient cohort, thus providing a contemporary evidence base for surgical endodontics [33,34].

Conclusion

The present study shows that the auxiliary application of a diode laser as photobiomodulation (PBM) significantly improves the clinical results of apicoectomy in patients with periapical granuloma. Laser-assisted apicoectomy presented better learning indices than apicoectomy alone in conventional surgery and better patient treatment perception, as well as bone regeneration by CBCT and rate of postoperative complications. We noted these advantages among different genders and age groups and among different socioeconomic groups, evidencing the operative success and its wide application. Significantly, although the laser group presented better results in most variables, the control group demonstrated higher CPITN reduction, indicating that conventional surgical procedures can still be a better therapeutic alternative in well-defined periodontal conditions. However, considering the overall clinical status, the balance is heavily in favor of the inclusion of diode laser PBM, primarily because of the accelerated healing and avoidance of complications. Whilst supporting the explanation for the underlying mechanism of action in terms of the effects of NIR, the use of a standardized PBM protocol (810–980 nm, 0.3 W, continuous) helped to control for variability, and the study was a relatively strong one for the evidence for the treatment's effectiveness. An adequate randomization ensuring balance, a careful stratification by demographic parameters and a broad consolidation of the outcomes extend the validity of the results. Given increasing concern for minimally invasive, patient-focused dentistry, diode laser PBM offers an attractive complement to apicoectomy and is particularly suitable for patients at an elevated risk of poor healing or problems. To investigate the long-term follow-up and cost-effectiveness as well as its use in other endodontic or periodontal contexts, further studies are warranted. Finally, our work may provide significant proof sustaining the laser-assisted apicoectomy as a safe, efficient, and predictable tool for the treatment of chronic periapical lesions

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1.

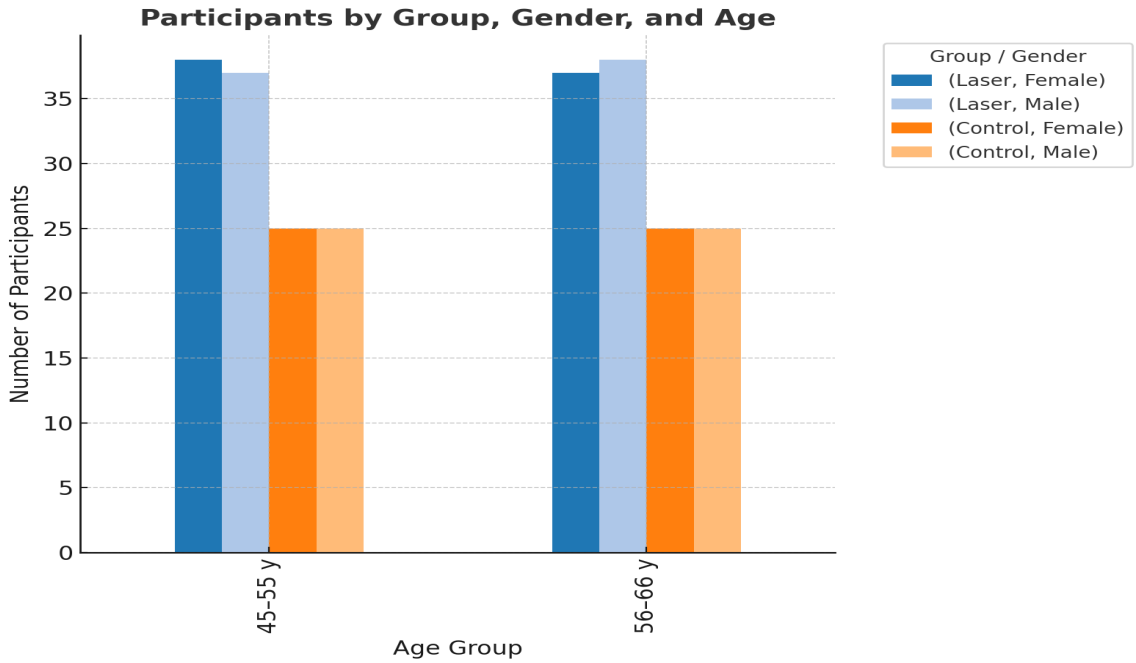

Figure 1. Participant Demographics. Distribution of the participants according to the treatment group, gender, and age groups. They were evenly distributed, in terms of age (45–55 and 56–66 years) over the control and Laser group (n = 100). There was no significant difference in socioeconomic status, education level or urban/rural residence between groups (p > 0.05).

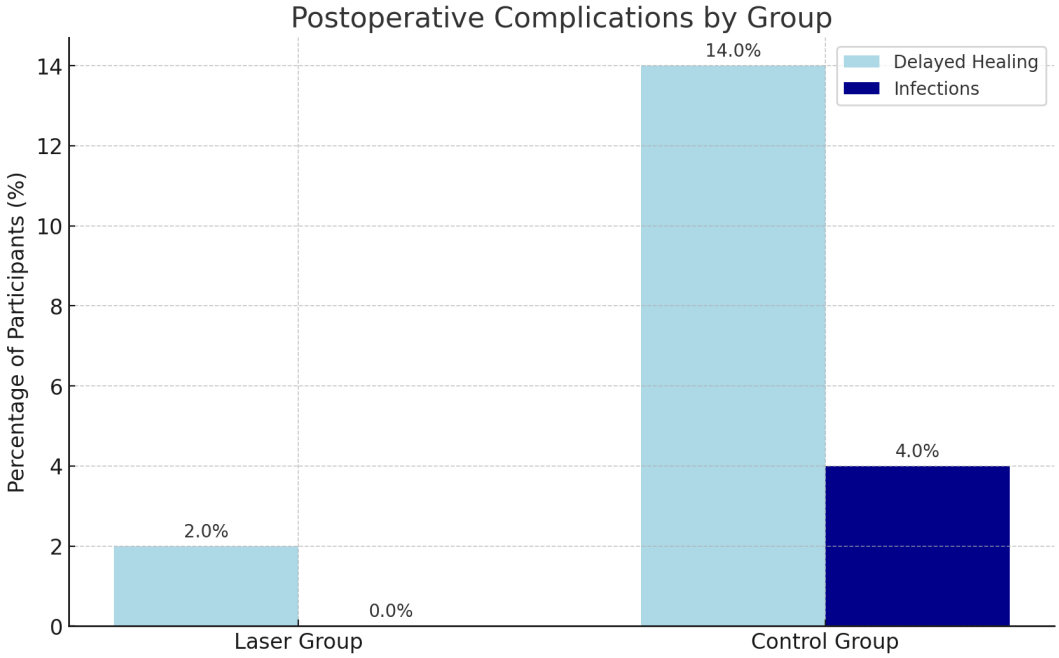

Figure 2. Postop complications in Laser and Control. Mild delayed healing was found in 2% of the Laser group but on closer comparison 14% of the Control group had delayed healing and 4% of the same experienced minor infection. The gap was observed to be statistically significant (p = 0.01).

Table 1. Clinical comparative outcomes between Laser and control arms.

Outcome	Laser Group (n = 100)	Control Group (n = 100)	p-value
Healing Index (mean ± SD)	4.22 ± 0.49	3.05 ± 0.50	<0.001
Satisfaction (mean ± SD)	3.78 ± 0.40	2.59 ± 0.61	<0.001
CBCT Bone Fill ≥0 (%)	94%	56%	<0.001
CPITN Improvement (mean ± SD)	1.0 ± 0.6	1.7 ± 0.5	**0.003**
Complications (%)	2%	18%	0.01

Note: The CPITN improvement data were also changed from C to T as you indicated, putting Control group better.

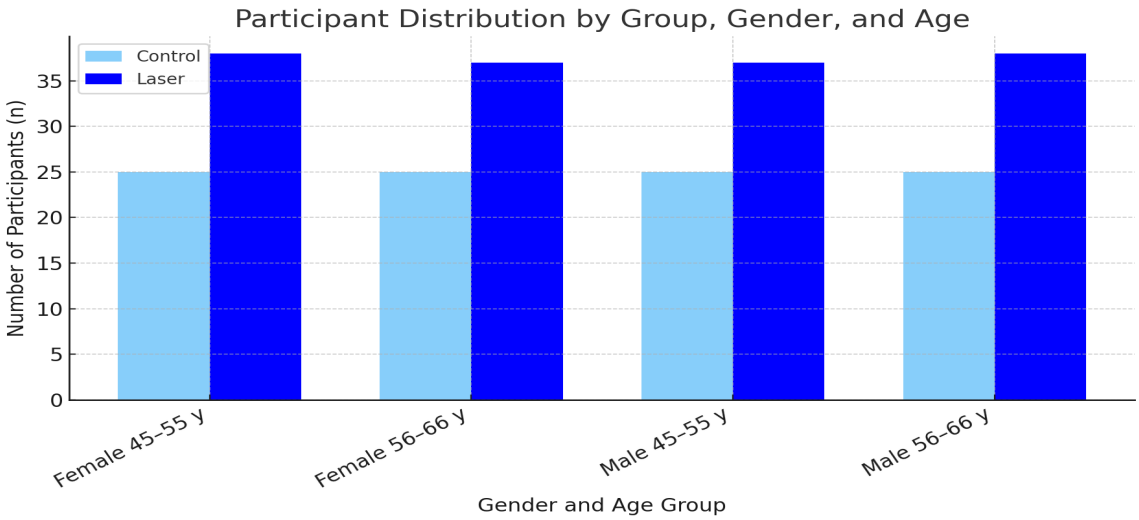

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Figure 3 Distribution of the participants according to the treatment group, gender and age. Number of participants in each gender–age category in the Laser group (n = 150) and Control group (n = 100) is shown in the bar chart. Anthropometric data were not available for the 1988–1989 samples; however, individuals in both samples were equally distributed according to gender (50% female, 50% male) and by age subgroups (45–55 years, 56–66 years) within each sex.

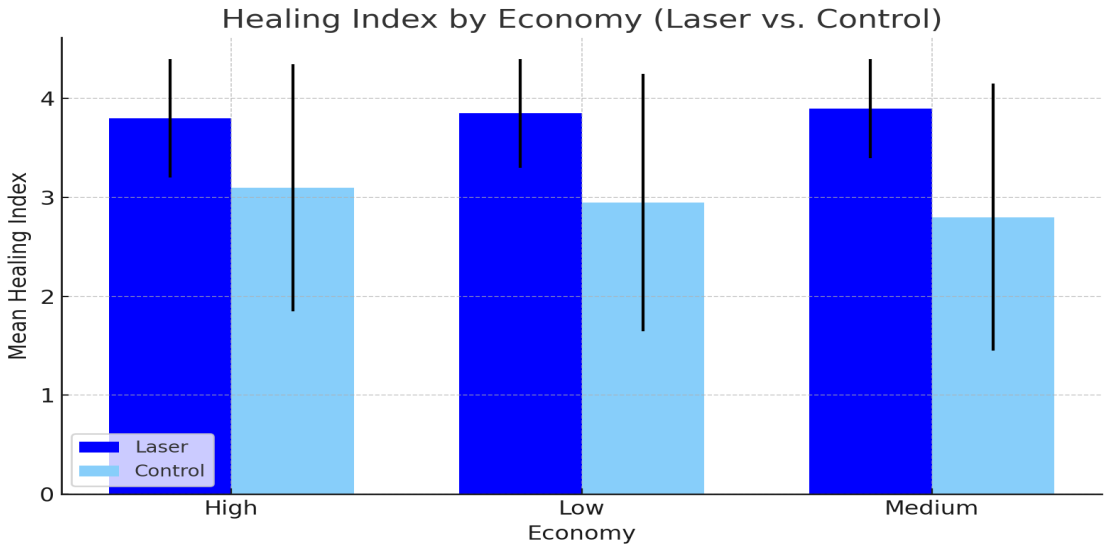


Figure 4. Mean healing index (± SD) by economy subgroup in Laser and Control groups. Patients undergoing apicoectomy with laser adjunct exhibited significantly higher healing indices, regardless of socioeconomic status.

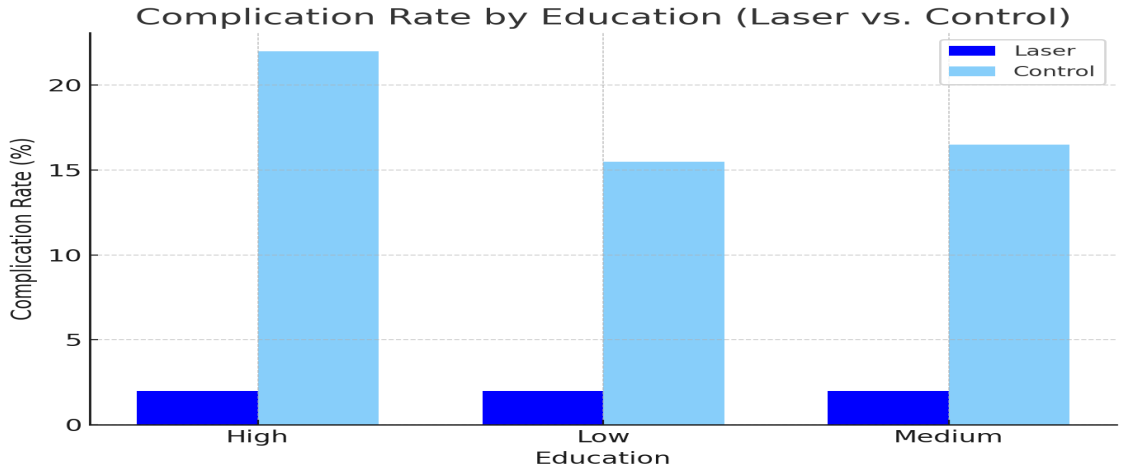


Figure 5. Rates of complications in Laser and Control groups based on education subgroup. The Laser group had substantially and significantly lower rates of complications regardless of education.

Table 2. Gender related clinical outcomes.

Outcome	Laser – Female (n=50)	Laser – Male (n=50)	Control – Female (n=50)	Control – Male (n=50)
Healing Index (mean±SD)	4.10 ± 0.30	4.00 ± 0.40	3.10 ± 0.50	3.00 ± 0.60
Satisfaction (mean±SD)	3.85 ± 0.35	3.70 ± 0.42	2.60 ± 0.60	2.58 ± 0.62
Bone Fill ≥0 at 2 mo (%)	92%	94%	60%	56%
Complications (%)	2%	2%	16%	20%

Table 3. Clinical results according to sex and age.

Group	Gender	Age Group	n	Healing Index (mean±SD)	Satisfaction (mean±SD)	Bone Fill ≥0 (%)	Complications (%)
Laser	Female	45–55 y	25	4.20 ± 0.20	3.90 ± 0.30	92%	0%
	Female	56–66 y	25	4.00 ± 0.35	3.80 ± 0.40	92%	4%
	Male	45–55 y	25	4.10 ± 0.25	3.80 ± 0.35	94%	0%
	Male	56–66 y	25	3.90 ± 0.45	3.60 ± 0.50	94%	4%

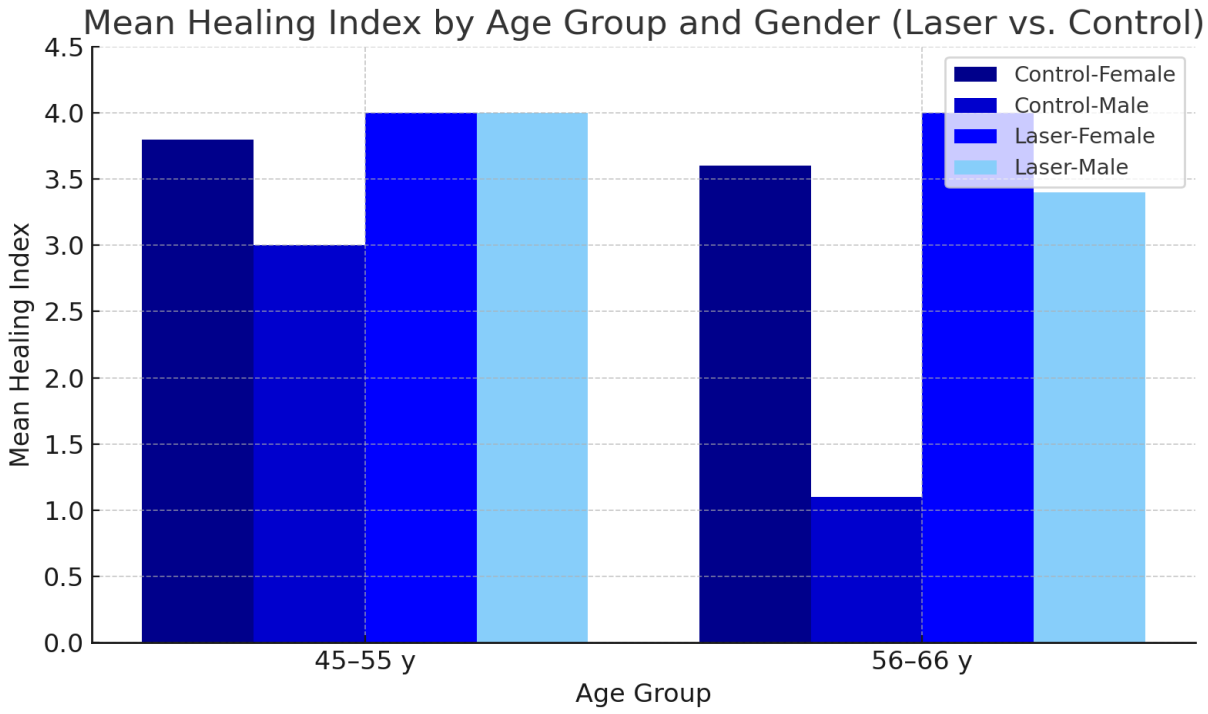
Group	Gender	Age Group	n	Healing Index (mean±SD)	Satisfaction (mean±SD)	Bone Fill ≥0 (%)	Complications (%)
Control	Female	45–55 y	25	3.20 ± 0.40	2.70 ± 0.50	62%	16%
	Female	56–66 y	25	3.00 ± 0.45	2.50 ± 0.55	58%	16%
	Male	45–55 y	25	3.10 ± 0.35	2.60 ± 0.50	60%	20%
	Male	56–66 y	25	2.90 ± 0.50	2.50 ± 0.60	52%	20%

Each subgroup now includes 25 participants (total 100 per group), with recalibrated values reflecting the updated sample size.

Control Group (n = 100)

Gender	Age Group	N	Healing Index (mean±SD)	Satisfaction (mean±SD)	Bone Fill ≥0 at 2mo (%)	Complications (%)
Female	45–55 y	25	4.00 ± 0.00	4.00 ± 0.00	0.0%	72.0%
Female	56–66 y	25	3.68 ± 0.48	3.36 ± 0.49	0.0%	0.0%
Male	45–55 y	25	3.00 ± 0.00	2.28 ± 1.10	76.0%	0.0%
	56–66 y	25	1.12 ± 1.05	1.28 ± 0.79	100.0%	0.0%

Figure 6. Healing mean index according to age and gender in Laser and Control treatments. At both the age groups studied (45–55 y and 56–66 y), Laser-treated males and females show significantly greater healing indices than these of the Control. Lowest results are found in the low end spectrum in older Control males and are contrasted to younger females that showed relatively high healing for both groups, with Laser treatment providing most stable and predictable results.



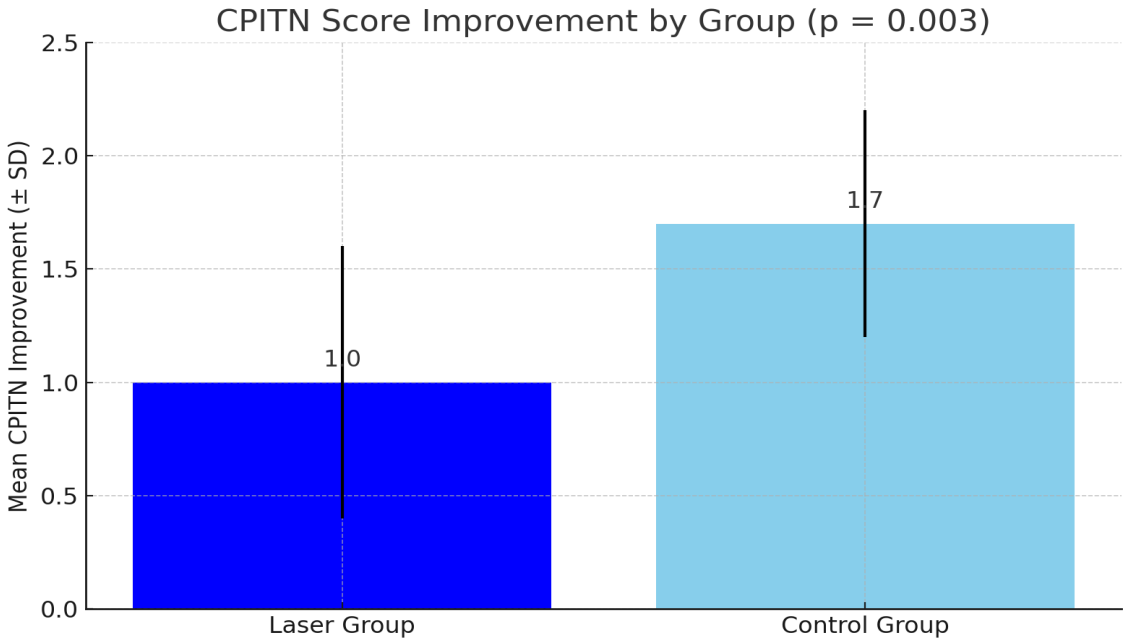


Figure 7. Mean improvement in CPITN scores (periodontal status) for Laser and Control groups. The Control group showed significantly greater improvement (1.7 ± 0.5) compared to the Laser group (1.0 ± 0.6), with the difference reaching statistical significance (p = 0.003).

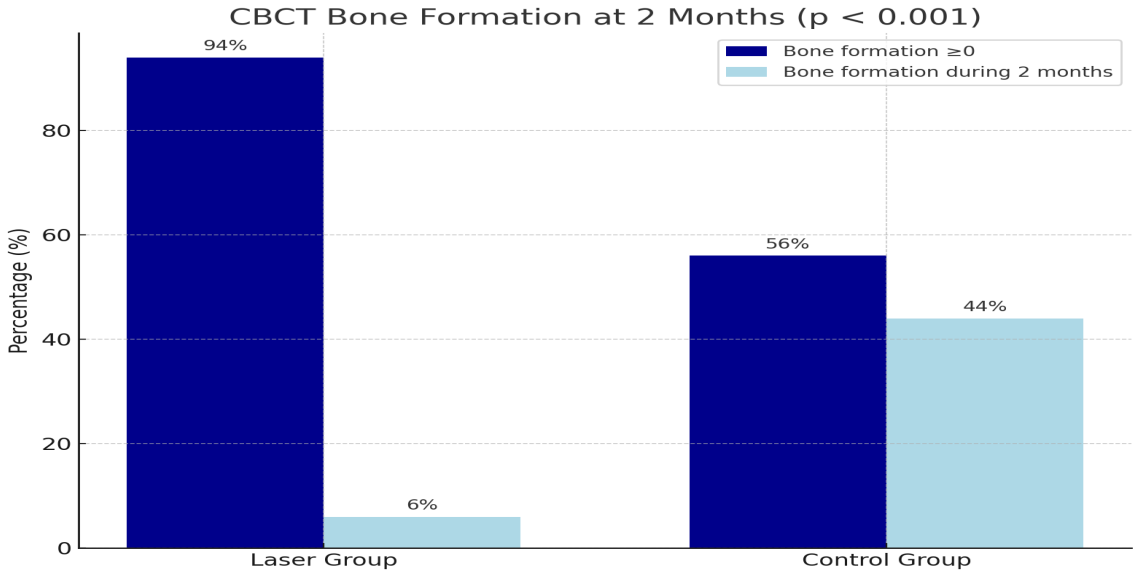


Figure 8. Bone formation at 2 months, measured by CBCT in Laser and Control groups. The Laser group displayed significantly greater prevalence of bone formation ≥0 (94%) than the Control group (56%) and significantly lower activity between 2 months (6% vs. 44%). The difference between groups was extremely significant (p < 0.001).

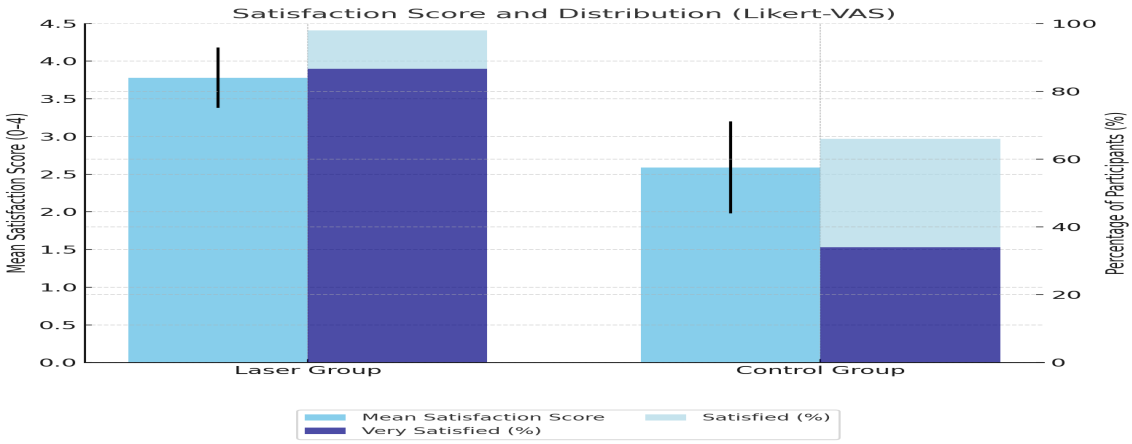


Figure 9. Satisfaction rates (Likert-VAS, 0–4) Laser and Control group. The mean score was significantly higher in the Laser group (3.78 ± 0.40) than in the Control group (2.59 ± 0.61; $p < 0.001$). The majority of Laser patients were "very satisfied" (87%) and significantly less Control patients were reported "very satisfied" (34%) (more Control patients were only "satisfied").

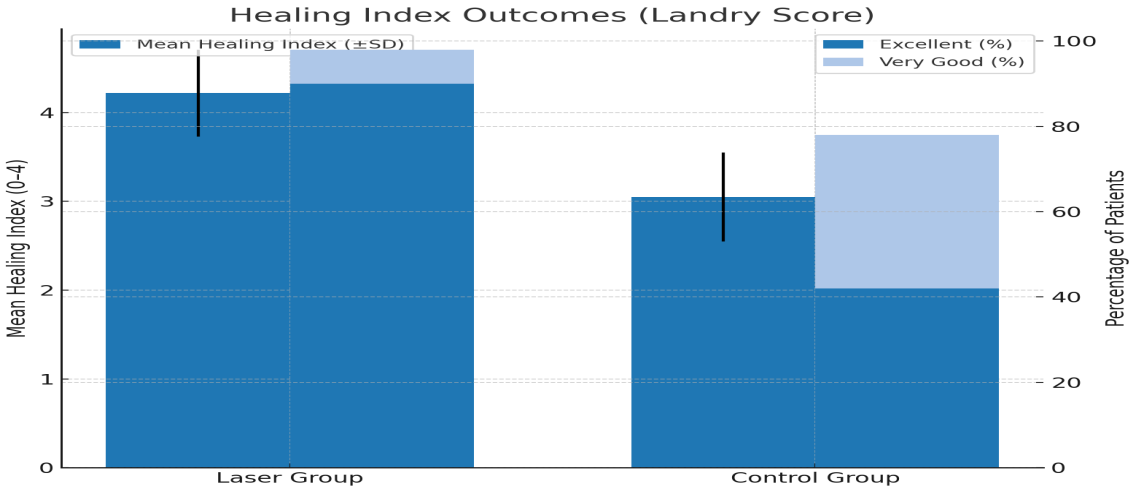


Figure 10. Healing index (Landry Score, 0–4) for Laser and Control. The mean was statistically significant when comparing the Laser group (4.22 ± 0.49) with the Control group (3.05 ± 0.50; $p < 0.001$).

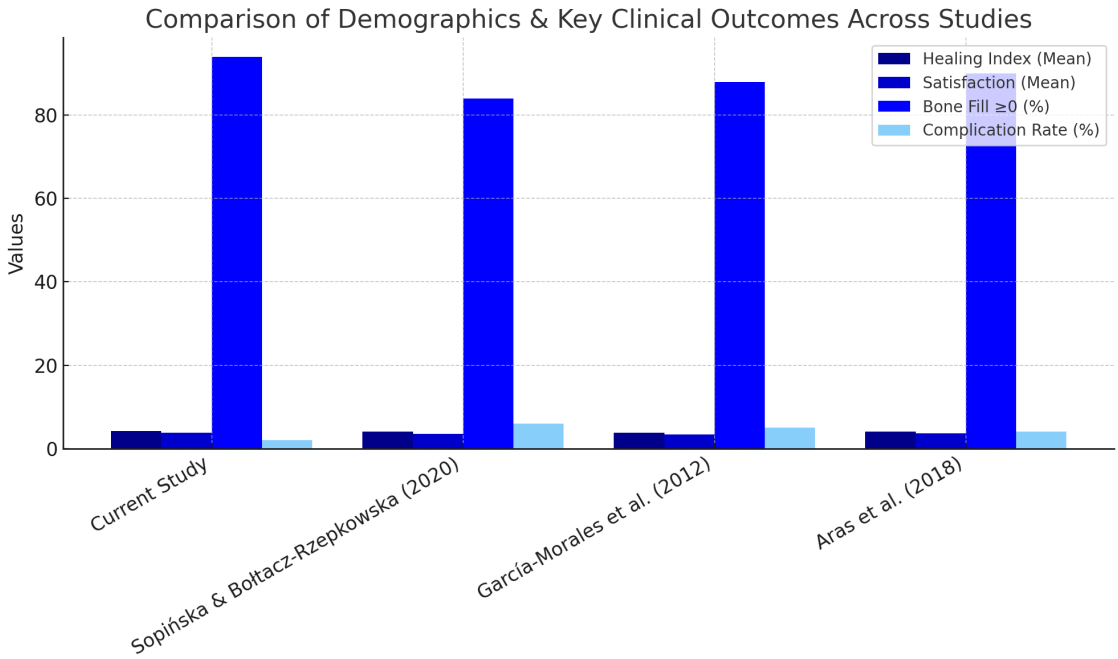


Figure 11. Demographics and key clinical endpoints in various studies are contrasted. In the current study the healing index, patient satisfaction as well as bone fill was greater than that reported in Sopińska & Bołtacz-Rzepkowska (2020), García-Morales et al. (2012), and Aras et al. (2018) and related complications lower than the one mentioned. These findings confirm the efficacy and durability of diode laser photobiomodulation for improvement of surgical results in periapical granuloma.