A comparison of Er,Cr:YSGG laser to minimally invasive surgical technique in the treatment of intrabony defects: six-month results of a multicenter, randomized, controlled study

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This is the author manuscript accepted for publication and has undergone full peer review but has not been through the copyediting, typesetting, pagination and proofreading process, which may lead to differences between this version and the Version of Record. Please cite this article as doi: 10.1002/JPER.20-0028.

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Authors Contribution: All authors have made substantial contributions to the concept and design of the study. DC, RH, MM, TS, CR, and GT participated as investigators in addition to data collection and interpretation, drafting and revising of the manuscript. JG participated as biostatistician in addition to assistance in drafting the manuscript and tables. CG was involved in design of the study with respect to patient reported outcomes and data interpretation in addition to manuscript revision. All authors have given final approval of the version to be published.

Word Count: 4243

Running Title: Er,Cr:YSGG laser vs MIST in the treatment of intrabony defects

Number of Figures: 6

Key Findings: The Er,Cr:YSGG laser in the surgical treatment of intrabony defects was not inferior to MIST in terms of clinical outcomes but superior in terms of patient-reported bruising, swelling, and ice pack use.

Keywords: Periodontitis; Lasers; Oral Surgical Procedures; Periodontics

ABSTRACT

Background: The purpose of this publication is to report on the six-month clinical results and patient reported outcomes (PROs) comparing the surgical use of the Er,Cr:YSGG laser (ERL) and minimally invasive surgical technique (MIST) for the treatment of intrabony defects in subjects with generalized periodontitis stage III, grade B.

Methods: Fifty-three adult subjects (29 females and 24 males; 19 to 73 years) with 79 intrabony defects were randomized following scaling and root planing (SRP) to receive ERL monotherapy (n=27) or MIST (n=26). Recession (REC), probing depth (PD), clinical

attachment level (CAL), treatment time, and PROs were assessed and compared for each treatment group. Clinical measurements were recorded at baseline, 4-6 weeks following SRP, and six months following surgical therapy.

Results: The following primary and secondary outcome variables were non-inferior with the following margins: CAL with a non-inferiority margin of 0.6 millimeters (mm). ($p = 0.05$), PD with a non-inferiority margin of 0.5 mm. ($p = 0.05$), Recession with a non-inferiority margin of 0.4 mm ($p = 0.05$). Faster procedure times were found for ERL (16.39 ± 6.21 minutes) vs MIST (20.17 ± 5.62 minutes), $p = 0.0002$. In the first two to three days of post therapeutic diary outcomes, subjects reported less bruising, facial swelling, and use of Ice pack for the ERL group.

Conclusions: This is the first multicenter, randomized, blinded, and controlled study demonstrating the Er,Cr:YSGG laser is not inferior to MIST in terms of clinical outcomes but is superior in PROs for the surgical treatment of intrabony defects.

INTRODUCTION

There are a multitude of dental laser types that have been used to treat periodontitis, including CO_2, Diode, Nd:YAG, Er:YAG and Er,Cr:YSGG.[1-3] The diversity of wavelengths, mode of energy delivery, and variety of energy settings has proven challenging when comparing their effectiveness in the treatment of periodontitis. As a result, the American Academy of Periodontology's (AAP) Best Evidence Consensus (BEC) concluded that the body of evidence on the topic is inadequate to determine if lasers can be considered comparable to conventional periodontal therapy.[4]

The Er,Cr:YSGG laser (ERL) is an erbium, chromium: yttrium, scandium, gallium, garnet solid-state laser that provides a user-controlled distribution of infrared energy at 2,780

nanometers (nm) for a variety of intraoral applications. The Erbium laser utilizes ablation of water molecules and hydroxide ions to cut, shave, contour, roughen, etch and resect oral hard tissues. It also directs laser energy, with or without water for cooling and hydration, to perform oral soft tissue removal, incision, excision, ablation, and coagulation for periodontal applications.[5] The ERL has been shown to have some bactericidal effects.[6, 7] It has also demonstrated the ability to safely remove the smear layer from root surfaces without damage to the cementum, similar to hand instrumentation.[8] This wavelength is also capable of bone decortications and contouring without adverse effects.[9] Similar to conventional surgical approaches, these capabilities may be useful in managing the debridement of hard and soft tissues associated with periodontal defects.[6, 10-16]

The minimally invasive surgical technique (MIST) for periodontal surgery has been in development for over 30-years. Beginning with the "papilla preservation technique", [17] further improved by Cortellini, et al.[18] and combined with minimally invasive approaches,[19] MIST has evolved into a decision tree guideline for treating periodontitis based on periodontal pocket morphology and papilla width in the interdental space.[20] Currently, MIST is indicated for the treatment of intrabony defects that persist following scaling and root planing (SRP).[21]

PROs are an integral outcome measure in randomized controlled trials (RCT's).[22] PROs are a direct patient report of patient health and / or treatment through psychometrics without subjective interpretation.[23] The validity of these assessments is crucial to objectively understand the impact periodontal therapies have on patients apart from clinician industry claims. Specifically, our group was interested in objectively assessing patient responses to the particular treatment employed.

The BEC on the use of lasers for the treatment of periodontitis recommends conducting adequately sized RCT's comparing lasers to conventional periodontal therapy including minimally invasive treatments for defect elimination / resolution and attachment level gain.[4] In addition, the recommendations for future study designs include conducting larger studies involving multiple investigators to determine if the use of lasers is a predictable and reliable mode of periodontal therapy with sustained long-term results.[24] This study is based on these recommendations for study design in comparing laser therapy to contemporary periodontal surgery for the treatment of periodontitis.

The purpose of this publication is to report on the six-month clinical results and PROs comparing the surgical use of the ERL and MIST for the treatment of intrabony defects in subjects with generalized periodontitis stage III, grade B. Subsequent publications will evaluate radiographic changes and clinical outcomes at one year.

MATERIALS AND METHODS

Study population

The study initiated in May 2018 was designed as a randomized, prospective, multicenter, single-blinded (examiners) and controlled clinical trial of 15-months duration. The study protocol was reviewed and approved by Advarra institutional review board (IRB) protocol number: PRO00034874 and registered in ClinicalTrials.gov under ID NCT04169139. The study complied with the guidelines of the Helsinki Declaration of 1975, as revised in 2000. Written informed consent was obtained from each subject.

The study population was comprised of patients from the private practices of six periodontists at five locations in the continental United States. The inclusion criteria were 1) Adult subjects (ages 18-75 years); 2) generalized periodontitis stage III, grade B;[25] At least one, but up to two, non-adjacent qualifying study teeth exhibiting a probing depth (PD) ≥ 6 mm and radiographic evidence of an intrabony defect with vertical dimension ≥ 3 mm, pocket base ≥ 3 mm coronal to the tooth apex, and a defect angle ≥ 25°; 4) Six weeks after SRP, study teeth had to continue to exhibit PD ≥ 6 mm and subjects had to demonstrate adequate oral hygiene (full mouth plaque score < 25%); 5) Subjects were required to read, understand and sign an IRB approved Informed Consent Form (ICF); and 6) Subjects had to be able and willing to adhere to the study visit schedule and other protocol requirements.

The exclusion criteria were: 1) Inability to visually identify the cementoenamel junction (CEJ) or other landmark for probing measures; 2) Presence of an acute periodontal abscess at the time of treatment; 3) Mobility > 1 that persisted at the time of treatment; 4) Use of 3rd molars, defects distal to terminal 2nd molars and teeth treated endodontically; 5) Systemic diseases or other conditions that could compromise wound healing and/ or preclude periodontal surgery; 6) Traumatic occlusion of study teeth not addressed by occlusal adjustment or splint therapy prior to conclusion of SRP; 7) Subjects taking intramuscular or intravenous bisphosphonates; 8) Heavy use of nicotine products; 9) Female subjects who were pregnant or lactating, or who intended to become pregnant during the study; 10) Use of systemic antibiotics, systemic or topical nasal/ oral corticosteroids during the trial or within 30 days of SRP; 11) Anticipated use of agents with clinical evidence of secondary hyperplastic tissue reactions, including immunosuppressants, calcium antagonists, or phenytoin; 12) Subjects who received oral health treatments/ interventions within 90 days of the study initiation, which the investigator believed could interfere with the periodontal parameters to be assessed.

Power Analysis

The primary outcome variable was clinical attachment level (CAL), comparing change in CAL between the control (MIST) and test (ERL) therapies. The patient sample size required to adequately power the study was estimated to be 48, with a 10% dropout rate requiring 54 patients. The power estimate was based on non-inferiority. Given the wide range of standard deviations in historical studies,[10, 26, 27] a range of non-inferiority margins (0.4 to 0.8 mm) was used to determine what the margin would be at the 0.05 mm level. This was a novel approach, since power analyses are normally based on one, pre-determined non-inferiority margin.

Clinical data assessment

The following clinical parameters were assessed by single-blinded, calibrated examiners for each study center using a UNC-15 periodontal probe*: PD, CAL, recession (REC), bleeding on probing (BOP), modified gingival index (MGI), and tooth mobility (MOB). Full mouth assessments were taken at baseline and 4-6 weeks after SRP. Following therapy, at 90-day intervals up to and including six-months, clinical measures were recorded for study teeth and immediately adjacent teeth.

The primary outcome variable, change in clinical attachment level (ΔCAL), was calculated from pre-therapy baseline to 4-6 weeks post-SRP and to 6-months after test or control therapies. Secondary outcome variables included change in recession (ΔREC), probing pocket depth (ΔPD), and presence or absence of bleeding on probing (BOP).

Exploratory outcome variables included: time in minutes (min) to complete each procedure from the first MIST incision to the last suture placed or from the initiation of laser surgery to the completion of laser protocol (described below); inflammation; tooth mobility; and PROs for pain, bleeding, swelling, ice pack use, anxiety, and satisfaction. In addition, safety was assessed for treatment-emergent adverse events based on intra-oral examination and subject reported tolerability.

A calibration trial was conducted for the examiners of this multi-centered clinical trial. The goal was to obtain 90 percent agreement within one mm between examiners in PD and CAL for both intra and inter examiner agreement. The inter examiner calibration was conducted with “gold standard” examiner. All examiners met the 90 percent agreement criteria.

Treatment modalities

Upon enrollment, all subjects were treated with SRP at sites demonstrating PD $\geq$ 5 mm, including the selected study teeth. A PROs assessment was obtained prior to SRP

(baseline), at the time of SRP, and 4-6 weeks following SRP prior to surgical therapy. Four to six weeks following SRP the study teeth were evaluated for PD changes that would exclude them from therapy, e.g., PD < 6 mm. Study teeth were randomized to receive test (ERL) or control (MIST) therapy, with subjects randomized on a 1:1 basis. The randomization was segmented in blocks of four for each study center so that each study center would have an equal number of test and control subjects. The basis of the randomization process used a random value from a normal distribution. This value was used to randomize the subjects within each center's blocks of four. All examiners were blinded to the therapy subjects were assigned.

A standardized Er,Cr:YSGG laser[†] protocol[‡], including procedure steps and requisite device settings, was taught to and used by each investigator . The laser energy delivery was controlled by a computer interface via a touchscreen tablet that dictated the laser tip, fire rate, energy, and associated air and water mixes for each step. While it should be noted that the referenced protocol allowed for an optional gingivectomy step, this step was omitted since MIST does not include gingivectomy. The protocol used two different laser tips: 1) RFTP5: a radial firing tip with beam divergence of > 40° composed of quartz glass 14 mm in length and 0.5 mm in diameter with a spot size of 2.5 mm^2 @ 1 mm from tissue surface; and 2) MZ6: an end-firing tip with beam divergence of 8° composed of quartz glass 14 mm in length and 0.6 mm in diameter with a spot size of 0.4 mm^2 @ 1 mm from tissue surface. After administration of local anesthesia, laser therapy steps included (Fig. 1):

1. Removal of the outer pocket gingival epithelium from the free gingival margin down to a millimeter coronal to the mucogingival junction (MGJ) (Tip RFPT5; Power: 1.5 watts (W); Pulse energy: 50 millijoules (mJ); Pulse duration: 60 microseconds (μs); Frequency: 30 hertz (Hz); resulting in an energy density per pulse of 6 joules per

centimeter squared (J/cm²); Air/Water percentage output (%): 40% / 50%). Tip movement no faster than 2 mm per second.

2. De-epithelialization and reflection of pocket epithelium down to the bone level creating an intrasulcular incision and bisection of the interdental papilla under the contact point to design a miniflap, with the miniflap reflected as needed for access for further debridement / degranulation of the defect (Tip: RFPT5; Power: 1.5 W; Pulse energy: 50 mJ; Pulse duration: 60 µs; Frequency: 30 Hz; Air/Water output: 40% / 50%)
3. SRP without laser - conventional root surface treatment with ultrasonics and hand instruments to remove root surface accretions and/or calculus and to smooth cementum.
4. Root and defect debridement using the laser to remove the smear layer created by conventional SRP, along with any residual calculus, and prepare the root surface for reattachment, also removing any residual pocket lining and degranulate to insure full debridement of the defect to the bone surface (Tip: RFPT5; Power: 1.5 W; Pulse energy: 30 mJ; Pulse duration: 60 µs; Frequency: 30 Hz; Air/Water output: 40% / 50%)
5. Bone decortication by retracting the flap and holding the MZ6 laser tip parallel to root surface and gently extending to and into bone, repeating all the way around tooth's surface associated with the infrabony defect (Tip: MZ6; Power: 2.5 W; Pulse energy: 80 mJ; Pulse duration: 60 µs; Frequency: 30 Hz; resulting in an energy density per pulse of 56 J/cm²; Air/Water output: 70% / 80%)
6. Final sulcular debridement by removing residual debris and inducing blood coagulation (Tip: RFPT5; Power: 1.5 W; Pulse energy: 30 mJ; Pulse duration: 60 µs; Frequency: 30 Hz; Air/Water output: 10% / 10%).

After completion of the laser protocol, compression of the surgical site was accomplished using a wet 2x2 gauze for 3-5 minutes.

For subjects randomized to MIST, the procedure was accomplished according to the technique described by Cortellini and Tonetti[20] using magnification and illumination. Scaling and root planing and defect debridement was accomplished using mini curettes[§] and ultrasonics. Upon completion of defect debridement, sites were closed with a 6-0 PTFE modified internal mattress suture.

All subjects completed a PROs assessment immediately before and after the surgical procedure with respect to anxiety, pain, and satisfaction reported on a scale of 0-10. For the week following surgical therapy, a daily in-home diary was completed by each subject for pain, medications taken, bleeding, facial swelling/ bruising, ability to eat solid foods, and the perceived need to avoid the surgical site when chewing. In-office post-surgical PROs procedure and esthetics satisfaction questionnaires were completed at 1-week, 4-weeks, 12-weeks, and 6-months. To assure accurate collection of patient experiences, PRO assessment interviews were conducted and recorded by an individual not involved in the subjects' care.

Post-surgical care and periodontal maintenance

Immediately post-surgery, amoxicillin 500 mg was prescribed t.i.d. for 10 days, and subjects were instructed in the use of 0.12% chlorhexidine (Chx) soaked swabs[‖] b.i.d. for 1-week. If subjects were allergic to penicillin-based antibiotics, they were given azithromycin 500 mg as a single dose to start, then 250 mg q.d. for days 2-5, or clindamycin 300 mg t.i.d. for 10-days. For discomfort, subjects were given a 600 mg ibuprofen tablet and prescribed another

after 8 hours. Any subsequent medication use was recorded. If subjects were allergic to or could not tolerate ibuprofen, extra strength acetaminophen (1000 mg) was used, with subsequent use also recorded**.** Subjects were instructed to not brush the therapy areas for 1-week. Flossing was not allowed for 2-weeks. At one week and one-month post therapy, healing was assessed, oral hygiene instruction (OHI) was provided, and PROs questionnaires were administered. Periodontal maintenance, OHI, and PROs was completed every 90 days following therapy.

Statistical analysis

Randomization balance between the treatment groups was performed for the demographic variables of age, race and gender, and the baseline clinical variables of CAL, PD, and recession. Demographic continuous data was analyzed by t-test and categorical data by chi square analysis. For clinical variables the subject was the unit of analysis by establishing mean values for each subject and assessing the subject as a random effect in the analysis of variance models. A center effect was also modeled in the analysis to determine if the effects were consistent across all centers

The primary outcome was the change in CAL 4-6 weeks after SRP compared with six months after therapy. The intent to treat (ITT) subjects were all subjects qualified for ERL and MIST therapies, with the primary analysis based on non-inferiority within the ITT subjects. CAL, Rec, and PD measures were computed as means for each subject. Means included both the lingual (L) and buccal (B) measures for study teeth defects (mesial-buccal or mesial-lingual for a mesial (M) defect and distal-buccal or distal-lingual for a distal (D) defect). Sensitivity analysis were carried out to determine if the following effects influenced the estimation of the primary and secondary variables: clinical center, per protocol or ITT

samples and any imbalances in baseline demographic or initial clinical values. This was done by analysis of variance with the subject as a random effect. Stepwise regression was used to determine which variable or if different initial variables influenced outcomes. The PROs and procedure analyses were based on superiority.

RESULTS

Fifty-three adult subjects (29 females and 24 males; 19 to 73 years) with 79 intrabony defects were randomized and received MIST or ERL therapies. No adverse events were reported. Fifty-four subjects were originally enrolled in the study and completed SRP with one dropout prior to completion of the study. The data from the dropout was used in the evaluation of the randomization process to investigate the balance of groups in both demographic and the evaluation of SRP only. For investigating changes over the six-month period of time, fifty-three subjects were used – no imputations were done. This was based on having a less than 2% drop out rate making the per protocol and intent to treat samples essentially the same. No adverse events or complications were reported.

Descriptive statistics of both the demographic (Table 1) and initial clinical variables (table 2) demonstrate that the randomization process provided similar populations for both therapies with no significant differences between groups. While the root planing reductions in probing depths were evenly distributed between groups, they were minor.

Primary and secondary outcomes indicate that the ERL therapy was non-inferior to the MIST therapy (Table 2): CAL with a non-inferiority margin of 0.6 mm ($p < 0.05$), PD with a non-inferiority margin of 0.5 mm ($p < 0.05$), recession with a non-inferiority margin of 0.4 mm ($p < 0.05$). These margins are within the power analysis margins (0.4 to 0.8 mm.) Changes in

clinical values were: ΔCAL MIST 1.22 ± 1.32 mm, ERL 1.26 ± 1.20 mm; ΔRec MIST -0.35 ± 0.66 mm, ERL -0.41 ± .65 mm; ΔPD MIST 1.63 ± 1.22 mm, ERL 1.71 ± 1.18 mm;). Mobility, BOP, and inflammation were also similar. (Fig. 2)

An analysis of single- vs mutli-rooted teeth revealed that the MIST and ERL groups included 16 and 21 multi-rooted teeth respectively. The MIST group included 11 maxillary molars and 5 maxillary first premolars. The ERL group included 15 maxillary molars and 6 maxillary first premolars. A one-way ANOVA of interproximal defect probing depths in sites that could include furcation defects was compared to interproximal defect probing depths in sites that could not have furcation defects. There were no clinical or statistically significant differences between the two different types of defects at baseline or at post-operative assessments out to six months.

Shorter procedure times were found for ERL vs MIST (Table 3 - 16.39 ± 6.21 minutes vs 20.17 ± 5.62 minutes). Five of the six centers reported less procedure time for ERL than MIST.

In the first three days, the post therapy daily diary reported important differences in post therapeutic adverse outcomes for the two therapies (Table 4). On the first post therapy day, 62% of the MIST subjects needed to use an ice pack versus 17% of the ERL subjects. On the same day 81 % of the MIST subjects reported swelling versus 46 % of the ERL. This difference persisted to the third day when 42% of the MIST subjects still reported a high level of swelling and only 4% of the ERL subjects reported swelling. There was also a much lower level of bruising in the MIST group of 14% of the subjects with only 4% of the ERL subjects reporting bruising.

DISCUSSION

The study reported herein indicates that use of an Er,Cr:YSGG laser for the surgical treatment of intrabony defects is not inferior to MIST. There were no statistically significant differences between the two treatment groups with respect to Rec, PD reduction, or CAL gain (Table 2). The only other study comparing this wavelength to a surgical approach was performed by Gupta, et al.,[11] and did not reveal a statistically significant difference in CAL gain between open flap debridement (OFD) and Er,Cr:YSGG monotherapy. In comparison to our investigation, which included a single laser treatment, the Gupta, et al. study used the laser on three separate treatment sessions over the course of six days. They did find a significant difference, with the laser group demonstrating less PD reduction and REC compared with OFD.

The clinical results of this study with respect to previously published studies[20, 28-31] of MIST are not readily comparable as the majority used enamel matrix derivative (EMD) and did not include a MIST-only control. The one study[32] comparing MIST alone to MIST-EMD achieved a higher average baseline PD/ CAL reduction and deeper intrabony defects with both groups than reported in this study, which includes intrabony defects with angle $\leq$ 25º. It has been demonstrated that deeper PD/ CAL intrabony defects with narrower intrabony defect angles have greater gains in PD reduction and CAL.[33] This study's defect morphology combined with the minimally invasive surgical approach may also explain the comparable CAL gains with less relative PD reduction and less REC compared to other studies[34, 35] reporting on the use of OFD.

Previously published studies on SRP compared to the PD reduction and CAL gains of this study are difficult to contrast as there are limited studies[35-37] analyzing conventional nonsurgical therapy when specifically treating intrabony defects. These studies indicate a PD reduction ranging from 2.1–3.4 mm and CAL gain ranging from 1.4-1.6 mm on subjects without a history of prior periodontal therapy. In comparison, 36 of the 54 subjects with 57 of the 80 defects from our study had a history of prior periodontal therapy consisting of SRP or surgical therapy with ongoing maintenance care. Therefore, these sites would be less likely to respond extensively to nonsurgical treatment. Nevertheless, the consensus was that it was prudent to perform SRP as initial therapy to demonstrate the outcomes that could be achieved in this subject population. In addition, there is evidence that SRP prior to surgical therapy is more effective than surgical care without prior SRP.[38] Furthermore, subjects were not fully eligible for enrollment unless they demonstrated a defect with a PD $\geq$ 6 mm 4-6 weeks following SRP. This is in contrast to some therapies which are performed in the absence of prior SRP. Our group is concerned that application of surgical therapy without prior SRP may skew data to imply that the applied therapy is more effective by not considering the benefit of SRP alone.

To our knowledge, this is the first study comparing any laser wavelength to a minimally invasive surgical technique. Of the 475 studies evaluated by the AAP BEC for a systematic review[3] on lasers in the treatment of periodontitis, only 28 were found to meet the inclusion criteria for the meta-analysis. Of those 28 studies, 4 pertained to the use of lasers in a surgical approach and none included the Er,Cr:YSGG wavelength. A review of the eight previously published human clinical studies using the Er,Cr:YSGG laser in the treatment of chronic periodontal disease[10, 11, 13, 14, 39-42] revealed only one used a surgical control.[11] Most of these studies compared the use of the laser to SRP[13, 14, 39-42] while one did not have a control.[10] The majority of studies used the Er,Cr:YSGG laser as an adjunct to SRP while two

studies used only the laser as the test therapy.[11, 39] The method of the laser's use varied greatly across these studies with some limiting the time of laser application to 60 seconds per tooth[11, 40] and others repeating laser applications over the course of several days[11, 42] to several weeks.[13, 14] The manner in which the laser energy was directed to the hard and soft tissues was also heterogeneous across these studies with some only treating the root surface[40] or not adequately describing how the laser was used.[42]

The PROs analyzed in this study demonstrated a statistically significant difference between Laser and MIST groups, with the laser group reporting less bleeding, swelling, bruising, and use of ice following the procedure. Both groups reported a low level of post-operative pain without a statistically significant difference between Laser and MIST. While one study[39] using the Er,Cr:YSGG laser as a monotherapy attempted to quantify pain on a visual analog scale (VAS), it was not compared to a surgical control. There are other studies implying that the use of the Er,Cr:YSGG laser as an adjunct to SRP is less painful or "painless" because local anesthesia was not used or only topical anesthetic was used when pain was reported.[10, 43] These studies agree that laser treatment is tolerable, but they do not provide PROs through the post-operative phase. Studies using papilla preservation flaps[31] or MIST[20, 30] in the treatment of intrabony defects have evaluated post-operative patient pain as well as perception of hardship and similarly reported low levels of pain or hardship.

This study illustrates that multiple investigators with varying degrees of experience (0-15 years) in the use of lasers to affect clinical measures of intrabony defects can achieve repeatable outcomes that compare to minimally invasive surgical techniques. While a surgeon's experience level has been previously correlated with less effective debridement in open and closed approaches of deep periodontal pockets,[44] our study did not find a

statistically significant difference amongst the investigators with respect to clinical measures (CAL, PD, REC) or PROs.

Future studies should be conducted on the use of this wavelength in comparison to and in combination with conventional regenerative therapies employing bone grafts and/or biologics to confirm the findings of this study and further define the role of laser therapy in the treatment of intrabony defects. In addition, studies should be conducted on the use of laser monotherapy in sites with horizontal bone loss requiring surgical intervention compared to conventional pocket elimination surgical approaches. Other outcome measures that should be considered include the effect of the Er,Cr:YSGG laser on subgingival bacterial loads and gingival crevicular fluid levels of cytokines, metalloproteinases, and acute-phase proteins.[45] It should be emphasized that this analysis did not include radiographic assessments which will be done in a separate report. This analysis should only be interpreted based on clinical measures and PROs.

SUMMARY AND CONCLUSIONS

In summary, this is the first multicenter, randomized, blinded, and controlled study demonstrating the Er,Cr:YSGG laser in the surgical treatment of intrabony defects is not inferior to MIST in terms of clinical measures. Patient reported outcomes were found to demonstrate less post-operative side effects in subjects receiving laser therapy compared to those receiving conventional surgical treatment. Long-term results, including standardized radiograph results, will be reported in the future.

FOOTNOTES

* PCPUNC15, Hu-Friedy Mfg. Co., LLC, Chicago, IL.

† Waterlase Express™, Biolase Technology, Inc., San Clemente, CA

‡ Biolase Repair®, Biolase Technology, Inc., San Clemente, CA

§ Micro Mini Gracey Curettes, Hu-Friedy Mfg. Co., LLC, Chicago, IL.

‖ Toothette® oral swabs untreated, Sage Products, LLC; Cary, IL.

ACKNOWLEDGEMENTS

The authors would like to thank Todd Scantlebury of The Avenues for his expertise and guidance in the development and implementation of the study. They would also like to thank the clinical research coordinators & examiners from each investigation site, as well as Kathy Donkin and Rebecca Williams of The McGuire Institute for their time and assistance in managing this study. The study was supported, in part, by funding from Biolase Technology, Inc., San Clemente, CA. The authors report no conflicts of interest related to this study.

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FIGURE LEGENDS

Figure 1: A) Removal of the outer pocket gingival epithelium from the free gingival margin down to a millimeter coronal to the MGJ. B) De-epithelialization and reflection of pocket epithelium down to the bone level C) SRP without laser. D) Root and defect debridement using the laser. E) Bone decortication. F) Final sulcular debridement by removing residual debris and inducing blood coagulation.

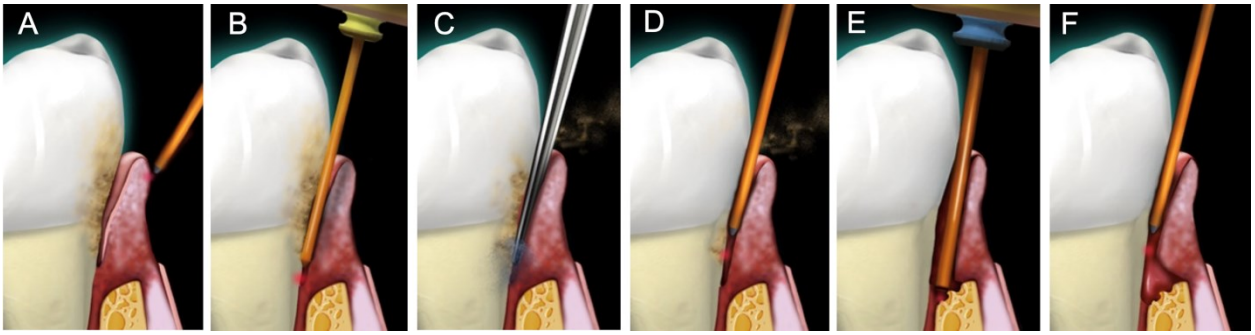

Figure 2: A) Pretreatment probing depth of 8 mm. B) Probing depth of 3 mm six months following treatment with ERL. C) Baseline periapical radiograph. D) Pretreatment probing depth of 7 mm. E) Probing depth of 4 mm six months following treatment with MIST. F) Baseline periapical radiograph.

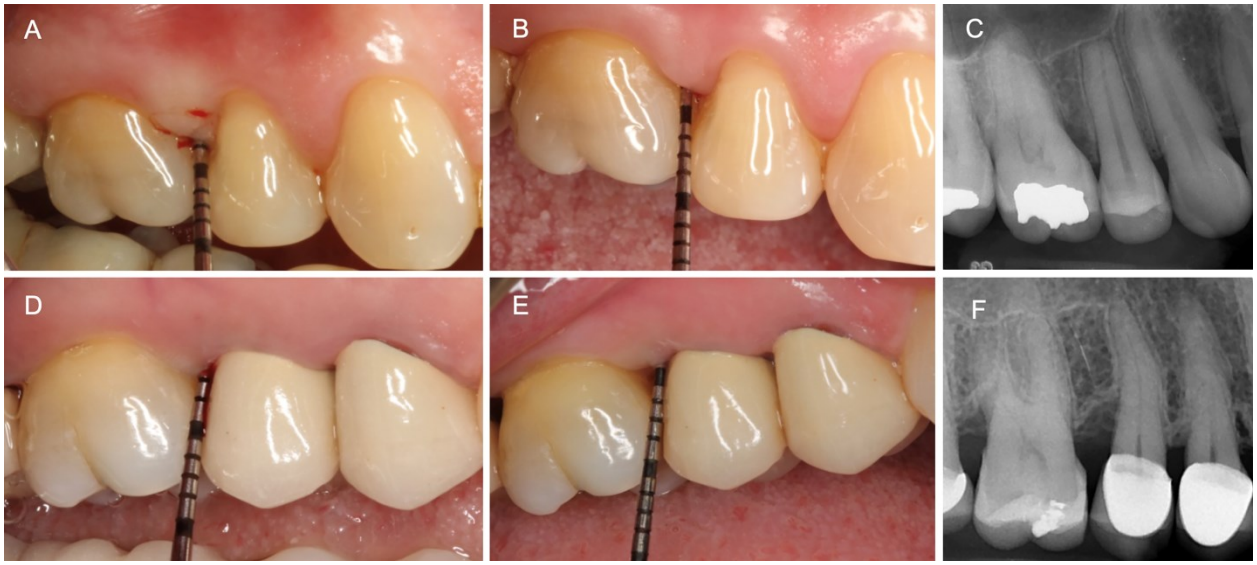

Table 1

Demographic Information by Treatment Group

	Age			BMI (kg/m2)		
TREAT	**N**	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**
MIST	26	58.08	12.40	26	27.15	3.86
ERL	28	54.93	12.35	28	29.10	6.02

	Gender		Ethnicity		Race				Tobacco Use	
TREAT	**M**	**F**	**H**	**NH**	**A**	**B**	**W**	**O**	**N**	**Y**
MIST	13	13	5	21	1	2	23	0	16	10
ERL	11	17	3	25	4	5	18	1	16	12

Key: N- Number of Subjects; BMI-Body Mass Index M-Male, F-Female; H-Hispanic;

NH- Non-Hispanic A- Asian; B-Black; W-White; O-Other; Y- Yes; N- No; MIST- Minimally Invasive Surgical Technique; ERL- Er,Cr:YSGG laser

Table 2

Baseline – pre-scaling

	REC			PD			CAL		
Group	**N**	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**
MIST	26	0.50	1.34	26	7.36	1.13	26	7.79	1.57
ERL	28	0.31	1.03	28	7.25	1.33	28	7.51	1.60

Six weeks – post-scaling

	REC			PD			CAL		
Group	**N**	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**
MIST	26	0.72	1.20	26	7.10	1.05	26	7.76	1.54
ERL	28	0.60	1.15	28	6.79	1.08	28	7.25	1.46

Change due to scaling and root planing

	Change in REC			Change in PD			Change in CAL		
Group	**N**	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**
MIST	26	-0.22	0.45	26	0.26	0.58	26	0.04	0.49
ERL	28	-0.29	0.60	28	0.46	0.70	28	0.25	0.61

Main effect of MIST and ERL on REC, PD, and CAL at six months

	Post therapy REC			Post therapy PD			Post therapy CAL		
TREAT	**N**	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**
MIST	26	1.07	1.18	26	5.47	1.53	26	6.54	2.01
ERL	27	1.03	1.47	27	4.98	1.40	27	5.91	2.10

	Change in REC			Change in PD			Change in CAL		
TREAT	**N**	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**	**N**	**Mean**	**Std Dev**
MIST	26	-0.35	0.66	26	1.63	1.22	26	1.22	1.32
ERL	27	-0.41	0.65	27	1.71	1.18	27	1.26	1.20

Gingival inflammation at defect sites

	Baseline			Six weeks post-SRP		Three Months post-surgery		Six months post-surgery	
TREAT	**N**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**	**Mean**	**Std Dev**
MIST	26	1.46	0.75	1.28	0.64	0.88	0.88	0.70	0.60
ERL	27	1.58	0.84	1.09	0.79	0.67	0.70	0.75	0.60

Key: N- Number of Subjects; REC- recession; PD- probing depth; CAL- clinical attachment level;

MIST- Minimally Invasive Surgical Technique; ERL- Er,Cr:YSGG laser; SRP- scaling and root planing

Table 3

Procedure Time Per Defect in Minutes by Clinical Center

		Treatment times per defect adjust-number of procedures		
Clinical center	**Group**	**N**	**Mean**	**Std Dev**
01	MIST	5	19.60	4.56
	ERL	4	14.00	3.63
02	MIST	6	17.92	5.90
	ERL	7	16.43	6.45
03	MIST	4	24.38	5.85
	ERL	5	14.70	4.58
04	MIST	2	22.75	2.47
	ERL	2	10.50	1.41
05	MIST	7	17.07	4.19
	ERL	7	22.14	6.79
06	MIST	2	28.25	1.77
	ERL	3	12.83	2.47
All Centers	**MIST**	**26**	**20.17**	**5.62**
	ERL	**28**	**16.39**	**6.21**

The evaluation of procedure time by analysis of variance, found a significant ($p < 0.0002$) group effect (MIST 20.17 $\pm$ 5.61, ERL 16.39 $\pm$ 6.20 minutes and only one center had a ERL procedure time greater than

a MIST time). Key: N- Number of Subjects; MIST- Minimally Invasive Surgical Technique; ERL- Er,Cr:YSGG laser

Table 4

Post Therapy Daily Diary Reported Percentage of Swelling, Bruising, and Icepack use by Treatment Group

		Facial Swelling			Bruising			Icepack
Measure		0-10			0-10			Y/N
Time	**Group**	**% > 0**	**Mean**	**Std Dev**	**% > 0**	**Mean**	**Std Dev**	**% - Y**
Day 1	MIST	**81%**	**2.35**	**2.53**	**15%**	**0.19**	0.49	**62%**
	ERL	**46%**	**0.78**	**1.01**	**0%**	**0.00**	0.00	**17%**
Day 2	MIST	**62%**	**1.77**	**2.64**	**19%**	**0.19**	0.40	30%
	ERL	**15%**	**0.3**	**0.72**	**0%**	**0.00**	0.00	22%
Day 3	MIST	**42%**	**1.04**	**1.66**	12%	0.12	0.33	13%
	ERL	**4%**	**0.15**	**0.77**	4%	0.04	0.19	4%
Day 4	MIST	19%	0.46	1.1	8%	0.19	0.69	12%
	ERL	4%	0.07	0.38	4%	0.04	0.19	4%
Day 5	MIST	15%	0.31	0.79	12%	0.19	0.63	4%
	ERL	4%	0.04	0.19	0%	0.00	0.00	4%
Day 6	MIST	15%	0.23	0.59	4%	0.04	0.20	4%
	ERL	4%	0.04	0.19	0%	0.00	0.00	0%
Day 7	MIST	4%	0.04	0.2	0%	0.00	0.00	4%
	ERL	0%	0	0	0%	0.00	0.00	4%

(Individual statistical differences indicated in red (p=0.05) repeated measures analysis of variances individual time points tested with Tukey's test at p=0.05) Key: Y/N- Yes/No; MIST- Minimally Invasive Surgical Technique; ERL- Er,Cr:YSGG laser