

# Detoxification of Implant Surfaces Affected by Peri-Implant Disease: An Overview of Non-surgical Methods

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**Abstract:** *Objective:* The aim of this review is to summarize the findings of studies that have evaluated non-surgical approaches for detoxification of implant body surfaces *in vitro* and *in vivo*, and to evaluate clinical trials on the use of these methodologies for treating peri-implant disease.

*Materials and methods:* A literature search was conducted using MEDLINE (Pubmed) from 1966 to 2013. *In vitro* and *in vivo* studies as well as clinical trials on non-surgical therapy were evaluated. The outcome variables were the ability of the therapeutic method to eliminate the biofilm and endotoxins from the implant surface, the changes in clinical parameters including probing depth, clinical attachment levels, bleeding on probing; radiographic bone fill and histological re-ossseointegration.

*Results:* From 134 articles found 35 were analyzed. The findings, advantages and disadvantages of using lasers as well as mechanical and chemical methods are discussed. Most of the *in vivo* and human studies used combination therapies which makes determining the efficacy of one specific method difficult. Most human studies are case series with short term longitudinal analysis without survival or failure reports.

*Conclusion:* Complete elimination of the biofilms is difficult to achieve using these approaches. All therapies induce changes of the chemical and physical properties of the implant surface. Re-ossseointegration may be difficult to achieve if not impossible without surgical access to ensure thorough debridement of the defect and detoxification of the implant surface. Combination protocols for non-surgical treatment of peri-implantitis in humans have shown some positive clinical results but long-term evaluation to evaluate the validity and reliability of the techniques is needed.

**Keywords:** Detoxification, lasers, local drug delivery, non-surgical periodontal therapy, peri-implantitis.

## INTRODUCTION

The vast majority of dental implants are successful over the long term. However, failure does occur. The two most common reasons for implant failure are mechanical (macro or micro motion) and infection. Peri-implant disease is initiated by bacteria and is differentiated into two subtypes, peri-implant mucositis and peri-implantitis [1, 2]. By definition continued bone loss is seen in peri-implantitis but not in peri-implant mucositis. It is currently assumed that some cases of peri-implant mucositis will lead to peri-implantitis.

A recently published meta-analysis reported that peri-implant, mucositis affects 63.4% of patients and 30.7% of implants while peri-implantitis affects 18.8% of patients and 9.6% of implants [2]. Peri-implantitis is frequently associated with implant failure. In order to reduce the number of implant failures the profession must develop appropriate methods for treating these disease states.

Peri-implant diseases have been associated with bacterial plaque [3]. Once these biofilms form on the implant surface removal of the bacteria and their byproducts such as lipopolysaccharides has proven problematic. In a previous paper by Valderrama and Wilson published in 2013, surgical methods for detoxification of implant surfaces were covered in detail [4]. The aim of this literature review is to summarize the available evidence about the non-surgical approaches to detoxify the contaminated implant surface.

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## MATERIALS AND METHODOLOGY

A literature search was performed using MEDLINE (Pubmed) from January 1, 1966 to September 1, 2013. The search strategy is the same that was used for our recently published article about the surgical approach for detoxification of implants [4]. Briefly, the search included the following terms: non-surgical peri-implantitis treatment; implant surface decontamination and non-surgical treatment of mucositis. Articles in English were included and the search resulted in 134 articles. Titles and abstracts were screened and the full text of 69 publications reporting on the evaluation of mechanical, chemical and lasers used for the non-surgical treatment of contaminated implant surfaces were selected.

The following type of reports were included: *in vitro* and *in vivo* studies, case series, cohorts, systematic reviews and meta analysis. The bibliographies of systematic reviews and meta analysis were hand searched. Clinical studies reporting on the surgical treatment of peri-implantitis were excluded. The outcome variables were the ability of the therapeutic method to eliminate the biofilm and endotoxins from the implant surface, the changes in clinical parameters like probing depth (PD), clinical attachment levels (CAL), bleeding on probing (BOP), radiographic bone fill and histological reosseointegration as reported in *in vivo* studies.

## RESULTS

Commonly used methods for non-surgical implant surface detoxification.

## MECHANICAL METHODS

### Implantoplasty

Implantoplasty is a technique to flatten/smooth the contaminated implant surface using rotary instruments [5]. This approach was proposed by Lang *et al.* [6] and reported by Suh *et al.* [7], and seeks to reduce the roughness of the implant surface which facilitates the colonization of biofilms [8-10] because it has been demonstrated that smoother surfaces retain less bacteria [11]. Rimondini *et al.* (2000) tested fifteen polishing procedures *in vitro*. They included carbide burs and diamond burs and demonstrated that all procedures resulted in smoother surfaces than at baseline under the scanning electron microscope. However, they reported that the best sequence was first using 30 microns and 15 microns mean-particle-size diamond burs followed by carbide 12 plus 16 bladed burs. They also reported that diamond burs produced granular debris and that carbide bladed burs produced needle or flake shaped debris [12]. Under proper cooling conditions, implantoplasty does not generate excess temperature increases that can damage soft tissue or bone surrounding the treated implant [13]. *In vitro* studies have shown that the use of diamond polishing devices can remove the coating of the implant surface entirely thus exposing the body of the fixture [14]. The exposure of the bulk of the implant could put the implant at risk for corrosion and therefore this technique should be limited to cases in which there are no other alternatives [15]. The remnants of the coating of the implant are expected to remain as metal debris in the surrounding tissues [14] inducing a foreign body reaction that could re-

sult in more inflammation and bone loss around the implant as has been found in human histological analysis performed by our group (study in progress unpublished data). Another disadvantage of this technique is the increased post-operative soft tissue recession and exposure of the implant surface which affects esthetics [16].

### Air Powder Abrasives (AP)

The use of an abrasive powder, like sodium bicarbonate, sodium hydrocarbonate [14], or the amino acid glycine [13], propelled by a stream of compressed air and water is called air powder abrasive [17]. This technique uses pressures of 65 to 100 pounds per square inch (psi) [18] and has been demonstrated with *in vitro* and *in vivo* studies to be effective in cleaning the previously contaminated implant surfaces [19]. Tastepe *et al.* (2012) concluded that this technique allows the removal of 84% to 98% of bacterial endotoxin from the implant surface and the removal of the bacteria biofilm up to 100% [17]. The use of AP for the treatment of peri-implant mucositis with sodium carbonate air-powder in combination with resin cures resulted in a significant improvement in all clinical parameters. Tumor necrosis factor-alpha (TNF-alpha) levels were significantly reduced achieving the same level as the healthy group at 3 months after therapies [20]. AP using amino acid glycine powder (AGP) has been compared to mechanical debridement using carbon cures and antiseptic therapy with chlorhexidine digluconate. Both groups exhibited comparable PD reductions and CAL at 6 months, however, AGP showed significantly higher BOP reductions [21].

Some studies have shown that AP does not alter the physical structure of some implant surfaces, [22, 23] but others have shown that it could largely obliterate the milling marks and cause some surface pitting and irregular crater-like defects [24]. These changes are time dependent, in all specimens, a 5-second exposure did not induce deep changes in the surfaces but a 15-second exposure modified all the specimen surfaces [23]. Moreover, it has been shown that particles of the powder can stay attached to the implant surface after cleaning [23, 25, 26].

It can be concluded that air powder abrasive can contribute to the detoxification of the implant surface and can produce a surface that is smoother than the original [5]. Negative adverse effects like subcutaneous emphysema and epithelial desquamation have been reported with the use of air abrasive around teeth [18] and around implants [27]. This potential complication may be prevented if the tip of the instrument is used at a 45° angle to the implant [14].

### Ultrasonic Scalers With a Metal Tip

When applied to rough surfaces, an ultrasonic scaler with a metal tip has been shown *in vitro* to produce a smoother surface with reduced irregularities and to remove bacteria more efficiently than ultrasonic scalers covered with a plastic tip [28]. Ultrasonic tips have been shown to decrease plaque scores from 73% to 53% ( $p < 0.01$ ) and bleeding scores ( $p < 0.01$ ), however, no differences in probing depths were identified [29]. There is a concern about temperature increase when this instrument is used subgingivally during a non-surgical approach. It has been demonstrated that sonic

and ultrasonic scalers did not show increase in temperatures of the implants and that there is a satisfactory functioning of the cooling system [30]. Metal tips have been shown to smooth the roughened surface which could facilitate the removal of bacteria using personal oral hygiene [28]. Machined surfaces may be altered, however, the scratches of the surfaces do not significantly affect the amount of biofilm that adheres. In fact one *in vivo* study showed that reduction of the surface roughness, below a certain threshold R(a) (0.2 microns), has no major impact on the supra- and subgingival microbial composition [31]. Ultrasonic scalers with metal tips may change the topographic characteristics of the implant surface or abutment, however, the changes may be inconspicuous or may enhance future plaque removal and facilitate maintenance.

### Metallic Curettes

These instruments cause alteration of the smooth surface [32] including pronounced irregularities and high substance removal [22], however, the damage observed is less at the SEM level when curettes made of titanium are used [5]. An *in vitro* study using a surface profilometer showed that metal curettes made of stainless steel alloys reduce the roughness of rough surfaced implants and decrease the attachment of *Streptococcus sanguinis* which is an important early colonizer in the oral cavity [26]. Another study showed that 30 minutes after treatment with stainless steel alloy curettes, *Aggregatibacter actinomycetemcomitans* (serotype a) (former *Actinomyces actinomycetemcomitans*), *Lactobacillus acidophilus*, *Streptococcus anginosus*, and *Veillonella parvula* were found at lower counts ( $p < 0.001$ ). However, no microbiological differences between baseline and 6-month samples were found for any species [33]. Scaling alone with stainless steel alloy curettes has been shown to have no effect on mucosal hyperplasia, nor bleeding on probing scores. Some slight effect has been reported on plaque scores at 4 weeks but they tend to return to baseline values at 12 weeks; however, probing depths, clinical attachment levels, and probing bone levels have shown to remain unchanged after the use of this therapy alone [34].

One advantage of stainless steel alloy curettes is that after 20 seconds of use they can remove superficial material from the rough surface of on average 0.83  $\mu\text{m}$ . This compared to 0.19  $\mu\text{m}$  removed by titanium curettes and ultrasonic tips covered with plastic inserts [22]. This could be advantageous when considering that Wilson demonstrated in 2009 that in 81% of cases of peri-implantitis there was excess of cement attached to the implant surface [35]. Removal of this material is important but in most cases complete removal is difficult to achieve. Moreover, some cements are chemically toxic to the peri-implant tissues [36]. Therefore, the need of removing strongly attached materials (including cement) from the surfaces can be more important than the risk of increasing the roughness of the surface [22, 35] since it has been shown that biofilm accumulation on rough implant surfaces is not significantly increased in subgingival areas (0.8% +/- 1.0%) compared to supragingival areas (17.3% +/- 23.1%) [37]. Also, the use of metallic curettes for cement removal may be advantageous compared to the use of

ultrasonic devices, because the use of ultrasonics may leave small particles of cement in the peri-implant tissues. Unpublished results by our group have shown that these small particles of cement are routinely surrounded by inflammatory cells and may contribute to peri-implant disease.

### Non-Metallic Curettes

These instruments can be made of plastic, carbon, resin-reinforced and resin-un-reinforced. An *in vivo* study in which peri-implant mucositis was induced in monkeys, showed that acrylic curettes and polishing with rubber cups and paste resulted in improvement of clinical parameters and minimal inflammation histologically [38]. However, with induced peri-implantitis in dogs where there was 40% bone loss present the non-surgical treatment with plastic curettes showed limited improvement and resulted in just 1% reosseointegration histologically [39]. In humans, the same approach also has proven to be beneficial for the treatment of peri-implant mucositis, plaque reduction and BOP reduction [40] but not for the treatment of peri-implantitis [41]. In a study in which carbon fiber curettes were used for subgingival debridement, plaque, BOP, PD, and bone levels remained unchanged 3 and 6 months after treatment [41]. The main advantage of non-metallic curettes is that they do not cause significant alteration of the surface when used to treat smooth surfaced implants [5]. However, when used several times the cumulative effect could result in a rougher surface [42]. A possible undesirable secondary effect is that when using non-metallic curettes to clean rough surfaces some of the curette material is deposited on the implant surface [5, 30, 43]. The effect of this debris is unknown, however, some plastic particles have been observed in human biopsies from patients with peri-implantitis (study in progress, unpublished data) An additional concern is that curettes made from these materials have difficulty in removing hard accretions, such as cement, from the implant surface.

*In vitro* studies have shown incomplete removal of biofilm with non-metallic curettes [14]. This could be associated with the size of these curettes which could prevent exact placement and application and may result in inefficient plaque removal [5]. However when combination of mechanical therapy with carbon fiber curettes and local antibiotics are used has shown to improve clinical parameters like PD and BOP [44].

### Rubber Cups

Rubber cups have shown to generate significant smoothing of the titanium surface and significantly decrease roughness by removing surface debris and rounding off the sharp machined grooves present on the untreated abutment surface [32]. In another *in vitro* study it was shown that the rubber cup, the plastic curette, and AP left the implant surfaces unchanged [22]. Polishing the implant surfaces with pumice and a rubber cup combined with irrigation with chlorhexidine and systemic antibiotics results in reduction of anaerobic bacteria and bleeding scores in patients with peri-implantitis [45].

## CHEMICAL METHODS

### Citric Acid (CA)

*In vitro*, CA pH1 has been shown to significantly decrease the amount of *Escherichia coli* LPS after burnishing with a cotton pellet for 1 minute on titanium alloy grit blasted and on hydroxyapatite (HA) coated strips [46]. CA also has shown to reduce *Porphyromonas gingivalis* endotoxin when applied for one minute or 2 minutes *in vitro*. The one minute treatment lead to a reduction of the endotoxin by up to 85.8% for machined surface, 27% for titanium plasma sprayed and 86.8% for hydroxyapatite coated titanium implants. The reduction after 2 minutes of CA application was 90%, 36.4% and 92.1% respectively [47]. However, CA was unable to inactivate bacterial biofilms formed on smooth titanium discs intraorally in humans after submerging the discs in a 40% CA solution for 1 minute [48]. This could be the result of the characteristics of biofilms that are protected by glycocalix or the fact that no mechanical disruption happened in the immersion study.

CA can alter the composition of the implant surface increasing the amount of ions of carbon, oxygen and nitrogen which could inhibit re-osseointegration [25]. CA has been shown to suppress fibroblast attachment *in vitro* [49], CA application therefore must be limited to the implant surface avoiding the spread of it to the bone and marrow spaces making clinical application of this material difficult. Also low pH acidic substances like CA have been related to implant surface corrosion, potentially reducing the chance for re-osseointegration [50].

### Chlorhexidine (CHX)

Due to the bactericidal effect of CHX, it has been used frequently to try to decrease the bacteria in cases of peri-implantitis. Subgingival irrigation with CHX 0.12% combined with mechanical debridement has shown to reduce bacteria and improve probing depths up to 3 months after therapy in humans [40]. *In vitro*, application of CHX (0.2%) for 60 seconds has shown to be effective against *Streptococcus sanguinis* and *Candida albicans* [51]. Rubbing the implant surface for 1 minute with a cotton pellet soaked with 0.12% CHX reduces the amount of *Porphyromonas gingivalis* endotoxin on machined surfaces up to 92.9%, on titanium plasma sprayed surfaces to 62.9% and on HA coated surface to 62.8% [47]. Topical application of 0.2% CHX gel after mechanical cleaning combined with a 1 mg total dose of minocycline microspheres into the peri-implant defect has been shown to successfully reduce the microbiota in 48% of the cases, however, authors reported that 32% of the subjects did not respond to this therapy resulting in either implant loss or increased bacterial load to baseline levels [52]. 1% CHX gel as an adjunctive subgingival antimicrobial treatment results in limited reduction of bleeding scores at 12 months [53].

The cell toxicity of CHX is influenced by concentration and exposure time. No osteoblast phenotypic alteration has been observed after exposure to 0.2% CHX for 1 minute and CHX 1% for 30 seconds [54]. The clinical application of

CHX as evidenced in this review requires longer periods of time than 30 seconds or 1 minute. CHX has been shown to induce apoptosis and cell necrosis due to disturbance of mitochondrial function, intracellular  $Ca^{2+}$  increase and oxidative stress [55]. CHX also has shown to inhibit cell proliferation and collagen synthesis [56]. These negative effects could explain the reduction in bacterial counts but no significant improvement in tissue healing.

### Hydrogen Peroxide (HP)

Rubbing with a cotton pellet soaked with 3% HP for 1 minute *in vitro* has been shown to significantly decrease the amount of *Escherichia coli* LPS (LPS count 108 min/mm<sup>2</sup>) on titanium alloy grit blasted and HA coated strips compared to untreated controls (LPS count 197 min/mm<sup>2</sup>). However, HP was the least effective when compared to citric acid, plastic sonic scaler tips and air powder abrasive [46]. In another *in vitro* study designed to evaluate the ability of HP to eliminate *Candida albicans*, *Streptococcus sanguinis*, or *Staphylococcus epidermidis* from titanium specimens, HP alone was effective against *Candida albicans* [51]. 3% HP was capable of inactivating attached bacterial cells from human biofilms after immersion in HP for 1 minute [48]. 10% HP has also shown to inactivate a human biofilm created in the lab and to eliminate 99.9% of the bacteria attached to the implant surface [57]. Swabbing the implant surface with 10% HP for 1 minute has also been shown in animals to decontaminate the implant surface and to allow re-osseointegration to previously contaminated surface in dogs [58].

### Lasers

Many different types of lasers have been investigated including but not limited to diode, carbon dioxide (CO<sub>2</sub>), neodymium doped yttrium aluminum garnet (Nd:YAG), erbium, yttrium aluminum, garnet (Er:YAG), and gallium aluminum arsenide (GaAlAs). *In vitro* studies have demonstrated the ability of lasers to lower total bacterial counts on contaminated titanium surfaces. In an *in vitro* study, Nd:YAG and GaAlAs lasers were demonstrated to sterilize implant surfaces of *Porphyromonas gingivalis* and *Escherichia faecalis* with no surface topography changes when viewed under SEM [59]. However, laser energy at the wrong setting can alter and/or melt the surface of dental implants, potentially interfering with re-osseointegration. Many *in vitro* studies have been completed analyzing the effect on the implant surface after irradiation at varying power settings, modes, and application times. In one *in vitro* study sand blasted and acid-etched, plasma sprayed, hydroxyapatite-coated, and smooth surface titanium discs were treated with Nd:YAG, Holmium:YAG (Ho:YAG), Er:YAG, CO<sub>2</sub>, and GaAlAs lasers at a variety of power settings and viewed under SEM and energy dispersive spectroscopy. The authors found that the pulsed Er:YAG, Ho:YAG and Nd:YAG lasers induced implant surface changes in an energy-dependent manner. Within the study parameters, the CO<sub>2</sub> induced surface changes in the hydroxyapatite, sand blasted and acid etched, and plasma sprayed discs. GaAlAs irradiation did not damage any of the disc surfaces. Based on their findings, the authors recommended that Nd:YAG and Ho:YAG lasers can be damaging to the implant surfaces and should not be used.

Also, the Er:YAG and CO<sub>2</sub> lasers may be useful but the power output should be limited to avoid surface alterations and finally that the GaAlAs laser was safe with respect to surface alterations [60]. In another *in vitro* study, the surface alterations on machined and sand-blasted, large grit, acid-etched (SLA) titanium discs after laser irradiation with a CO<sub>2</sub>, diode, and Er:YAG laser were analyzed by SEM and light confocal microscopy. No surface alterations on either type of disc were observed after irradiation with a CO<sub>2</sub> or diode laser for any of the chosen study parameters. In contrast, the Er:YAG laser caused surface alterations in both SLA and polished discs. The SLA surfaces showed changes after 10 seconds of treatment at 300mJ/10Hz. The polished surfaces showed surface alterations after 10 seconds of irradiation at 500 mJ/10Hz. The authors concluded that if an Er:YAG laser was to be used, power settings should be limited to below 300-500mJ/10Hz [61]. Another *in vitro* study analyzed the effects of different power and cooling methods when an Er:YAG laser was used on anodically etched, medium rough (RP MKIII TiUnite 3.75mm x 13mm, Nobel Biocare) titanium implant surfaces. The authors found that a power setting of 100 mJ with a wavelength of 10 Hz was optimal and was able to evenly strip a layer of titanium oxide from the implant surface without causing thermal damage to the newly exposed layer of titanium oxide. At this power setting with water spray, the maximum the implant surface was heated was 3 Celsius degrees, whereas without water spray the temperature increased by 30-33 Celsius degrees. Also, when the authors performed the same protocol with a CO<sub>2</sub> laser with air cooling, the implant surfaces were heated by 50 Celsius degrees [62]. An *in vivo* study by Schwarz *et al.* (2005) in humans analyzed treatment of peri-implant defects in twenty patients with 40 contaminated implants. 20 implants were decontaminated non-surgically with an Er:YAG laser (wavelength 10 Hz, power 100 mJ), and 20 implants were treated with mechanical debridement with plastic curets and a 0.2% CHX rinse subgingivally. Both groups had significant beneficial changes in BOP, PD, and CAL at 3 and 6 month recall exams, however these gains were not maintained at the 12-month recall exam, except for sustained significantly lower reductions in BOP in the laser group compared to the control group [63]. In another *in vivo* study in humans, the use of an Er:YAG laser in conjunction to S/RP was compared to Er:YAG treatment alone in a split mouth protocol in 20 patients. Clinical and microbiologic parameters were assessed at baseline and at 3, 6, and 12 months post-treatment. The Er:YAG laser was set at 160 mJ at a repetition rate of 10 Hz. The authors reported statistically significant reductions in plaque scores, gingival index, and BOP at each recall appointment with each treatment modality. Mean probing depths decreased from 5.2 mm to 3.2 mm after 12 months in the laser treatment group alone and from 5.0 mm to 3.3 mm in the laser + S/RP group. Gains in CAL for both the laser treated and laser treated + S/RP sites were 1.6 mm. Both treatments resulted in a significant increase of cocci and non-motile rods and a decrease in motile rods and spirochetes. No significant differences between sites were observed at any time point [64]. In another human study, Renvert *et al.* assessed treatment of peri-implantitis lesions in 21 patients using an Er:YAG laser or AP with a subgingival application tip in a non-surgical approach. At the end of the 6-month study period, no significant differences in

clinical outcomes was observed between either treatment modality with respect to changes in PD, BOP, and CAL [65]. While some laser applications have shown promising results, at present specific conclusions cannot be drawn concerning type of laser, power settings and appropriate clinical scenarios for their use.

### Photodynamic Therapy (PDT)

PDT involves coating a substance (implant surface, bacterial cells, etc) with a particular photosensitizing agent with a known wavelength of activation. Once activated by light of the excitation wavelength in the presence of oxygen, the photosensitizer transitions from a low-energy ground state to a high-energy singlet state, causing a production in free radicals that are toxic to target cells [66]. It has also been demonstrated *in vitro* that lethal photosensitization of bacteria can be achieved without damage to the implant surface [67]. It has also been shown *in vitro* that photosensitization and light activation is more effective in killing bacteria from titanium surfaces than laser ablation alone [67]. In an *in vivo* study by Schär *et al.*, forty patients with one affected implant were treated by photodynamic therapy with a diode laser (wavelength 660 nm, power 100 mW) was compared to minocycline microsphere delivery (n=20 each group) after initial debridement with titanium curettes and AP with glycine powder. Phenothiazine chloride was applied as a photoactivator and activated with a 10 second laser application and this was repeated after 1 week. The minocycline treated implants had 1mg applied subgingivally. At sites with residual BOP, the interventions were repeated at the 3 and 6-month recall exam. At 3 months, both interventions resulted in reduction of BOP (2.21 sites in PDT and 1.77 sites in the minocycline group). At 6 months, 15% of control implants had total resolution of inflammation where 30% of test implants had no BOP. All implants had statistically significant gains in CAL, reduction in PD and plaque at the 3 and 6-month recall exams, with no statistical difference between the two treatment modalities. The authors concluded that PDT is as effective as local delivery of minocycline in treating peri-implantitis after initial therapy + glycine AP had been completed and these gains were maintained up to 6 months [68]. In conclusion, the use of photosensitizing dyes in conjunction with laser excitation may be beneficial in lowering bacterial counts from affected implants, however the short term evaluation periods in these studies do not allow to evaluate the arrest of the peri-implant lesion's progression long-term.

### DISCUSSION

The goal of treating peri-implant diseases (peri-implant mucositis and peri-implantitis) is to stop the inflammatory process and if possible reverse the bone loss seen as a result of disease. If one starts with the assumption that these disease states are initiated and exacerbated by bacteria then removal of these microbiota and their byproducts becomes essential. This review has looked at currently used approaches to achieve this goal with non-surgical methods. We found that to date no one method or combination of methods applied non-surgically has routinely resulted in the elimination of these disease states. Our conclusion agree with the results of a network meta-analysis [69] and systematic re-

views [70, 71]. Most of the human studies published are case series with short term follow-up periods making it difficult to determine the stability of the resolution of the inflammation and decrease of pathogenic bacteria over time. Most of the human studies included in this review base their conclusion on clinical measurements like probing depths or clinical attachment levels, but do not report success or survival rates. Therefore it is difficult to determine what approach will improve implant survival. This is a common inconvenient found when analyzing the data about therapies for peri-implant diseases [72, 73].

Care should be exercised in the use of acidic chemicals to detoxify implant surfaces, due to surface alterations in the titanium oxide layer that appears to be necessary for reattachment. The same can be said for certain approaches using lasers. However, within this last group some laser types at specific settings have showed early promise in detoxification. Combination of physical and chemical and laser therapy may provide more predictable results. In general, it should be noted that the profession is early in its understanding of these diseases and their treatment.

From this review it can be argued that further investigation of optimal ways to treat implants affected by peri-implantitis and peri-implant mucositis as well as the prevention of these problems is warranted.

## CONCLUSION

Complete elimination of the biofilms needed for reattaching bone to previously contaminated implant surfaces is difficult to achieve. All therapies induce changes of the implant surface chemical and physical properties. Combination protocols for non-surgical treatment of peri-implantitis in humans have shown some positive results but long-term evaluation to establish the validity and reliability of the techniques has yet to be concluded.

## CONFLICT OF INTEREST

The authors confirm that this article content has no conflict of interest.

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