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REVIEW OPEN ACCESS

The Effects of Photodynamic Therapy as a Treatment for Peri-implantitis Patients: A Literature Review

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Abstract

Introduction: Over the past decade, dental implant procedures have been studied to have high success rates. However, instances of complications have been observed among a large scope of patients, leading to diseases such as peri-implantitis (PI). Developing modern day treatments for PI, such as photodynamic therapy (PDT), is significant in discovering new maintenance strategies. This review explores the effects of PDT in the treatment of PI.

Methods: This review covers a broad range of studies published between 1995 to 2024. The studies highlight the results of PDT treatment as an adjuvant to mechanical/open flap debridement in the treatment of PI. The methodologies used during the analysis involved systematic literature review and meta-analysis. All literature reviewed is sourced from Google Scholar and online databases such as PubMed, ScienceDirect, and Scopus.

Results: Upon PDT treatment, as an adjunct to mechanical/open flap debridement, a significant decrease within BOP (bleeding on probing) and plaque index was distinguished. However, there was no significant difference between results in BOP and plaque index for the PDT groups in comparison to the control groups (debridement alone). For pocket probing depth (PPD), a significant difference is highlighted between the PDT and control groups at 3 and 6 months, as PPD was observed to be lower. Different adjuvant therapies compared to PDT posed different challenges ranging from lower effectiveness, allergen threats, and the development of bacterial resistance.

Discussion: There were not any prominent disadvantages observed in receiving PDT, however, factors such as time and number of sessions need to be weighed in to determine if small improvements are ultimately worth the commitment to the therapy. In terms of comparison to different adjuvant therapies, the choice of treatment varies based on the individual's allergies and the severity of the condition for PI.

Conclusion: Applying PDT as an adjuvant to traditional debridement treatments does not seem to contribute an extensive improvement for treating PI cases. If a patient is looking to find treatments that provide smaller improvements for PI, PDT may serve as a safe treatment. Further development in PDT needs to be conducted to achieve more optimal results in treating PI.

Keywords: photodynamic therapy; peri-implantitis; bleeding on probing; plaque index; probing depth; mechanical debridement; dental implant

Introduction

In the field of dentistry, dental implantation has become a common practice when addressing the problem of tooth loss in patients. As defined by the Canadian Dental Association, the process of dental implantation involves placing an artificial root into the jawbone to serve as an anchor that holds in place a bridge or a new tooth [1]. Although dental implantation is a highly successful procedure [2], there have been instances of complications throughout a large scope of patients. These complications vary in terms of their categorization into technical, biological, and aesthetic-based classifications [3]. With the prevalence of critical complication states such as peri-implantitis, the cost of maintaining dental implants was around 5x higher compared to the regular maintenance of teeth [4]. Many different treatments have been used to maintain peri-implantitis, including more newly developed treatments such as photodynamic therapy. This paper primarily focuses on examining the effectiveness of photodynamic therapy (PDT) as a treatment for peri-implantitis. Photodynamic therapy can be viewed as a non-invasive alternative treatment compared to traditional therapies for PI. With PDT in the field of dentistry first being introduced in the 90s [5], it is key for this treatment to be further researched since it is a new treatment in comparison to traditional therapies that are commonly used and heavily researched on.

Peri-implantitis and Photodynamic Therapy

Peri-implantitis (PI) is a condition that primarily affects the tissues surrounding dental implants [6,7]. More

specifically, it is classified by progressive bone loss, along with inflammation. It is important to recognize that PI is the result of the progression of dental implant complications, as it is classified as one of the later stages in the development of the complications. While peri-mucositis specifically refers to the soft tissue inflammation aspect of the complications alone, PI is an extension of it involving the aspect of bone loss [8]. With this, PI is considered to be a more severe stage into the progression of complications and has therefore been characterized as being irreversible [9,10]. Due to PI being irreversible, it is important for studies on treatments to be continued in order to find the best results for keeping the disease under control and preventing progression. This includes looking into more modern approaches in treatment, such as the use of PDT. The process of PDT starts with selecting a photosensitizer and light source for application. The photosensitizer can reach a level of excitation (triplet state) through activation by the selected light source, causing it to photochemically react with oxygen and create free radical species through the type I reaction, or create a singlet oxygen through the type II reaction [5,11]. Through these photochemical reactions, bacterial death can be achieved, as depicted by Figure 1.

With the severity of PI, developing treatments such as PDT need to be closely examined in order to determine the impact it may have on preventing further development of the disease. Analyzing the quantitative outcomes of PDT can indicate the extent of severity of the disease, and thus the effectiveness of the treatment. Some of the quantitative results that are gathered in this paper to measure progress made in the treatment of PI include BOP, plaque index, and PPD.

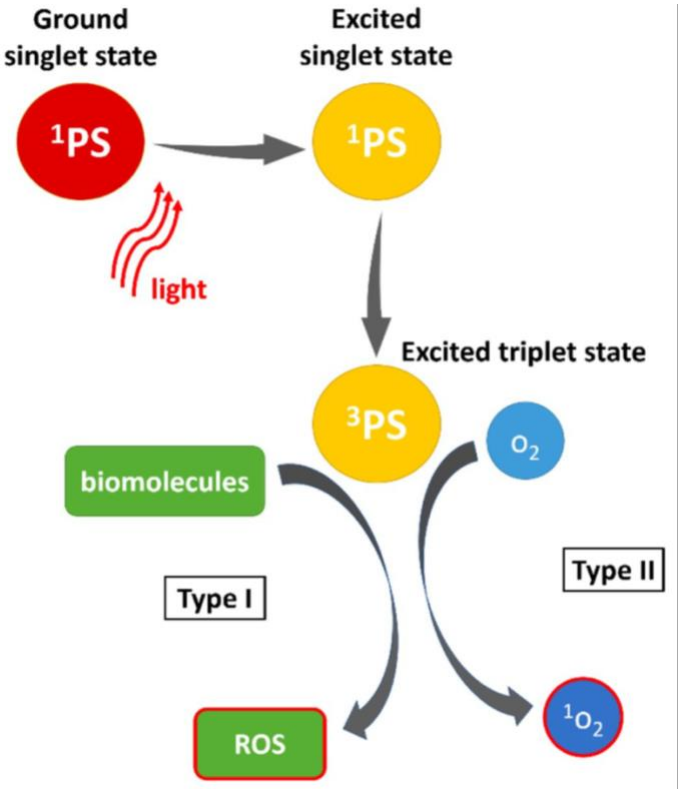

Figure 1: Schematic diagram of type I and type II reactions in photodynamic therapy. Figure sourced and permitted for use by the Anticancer Research Journal [28].

Methods

For the collection of literature in this review, Google Scholar was used as a primary search engine for the papers relating to the topic of focus. To gain access to papers that were not available to the public from Google Scholar, the University of Alberta library website provided access to various databases (e.g. PubMed, ScienceDirect, and Scopus) that held the full version of the articles absent from the initial search. Data collected was limited with the criteria of its publication date being between 1995 and 2024. In terms of the literature search, the filtered search option was used to condense the results of interest by using keywords. The keywords primarily used to find the relevant articles included “peri”, “peri-implantitis”, “photodynamic therapy”, “PDT”, “bleeding on probing”, “plaque index”, “probing depth”, and “mechanical debridement”.

For the criteria of the papers obtained, it was noted that each of the studies considered for the analysis of results had

to be trials that were of primary literature. However, this criterion was not set in place for the papers used to provide background information on general topics such as PI, PDT, and dental implants.

Study Selection

Primary findings from studies focused on photodynamic therapy were mainly composed of data on bleeding on probing, plaque index, and pocket probing depth. To examine the effects of photodynamic therapy, a baseline value was collected in each of the studies and compared to the values of the respective measurement at different times after treatment was applied. Analysis of each of these measurements allows for a better understanding of the effectiveness of photodynamic therapy as time progresses. The studies examined all tested the effects of PDT in adjuvant to a more common treatment such as mechanical debridement [12-20] and open flap debridement [21,22]. In terms of the light source used for these PDT treatments, studies that only utilized diode lasers were examined. Romeo et al. discussed the use of lasers in PDT as being a more effective and quicker source in the healing process of target areas in comparison to different sources of light [15]. By examining studies that only used lasers within the PDT treatments, data collected can be associated with one of the most effective PDT treatment methods that has a high likelihood of achieving optimal results.

Each of the participants in the studies gathered was associated with having PI. Ensuring this criterion is kept consistent across studies in this review is key for understanding the implications of PDT in the treatment of PI. This is due to the contrast between the baseline and post-treatment values serving as an indicator of improvement from severe PI conditions.

Results

Bleeding on Probing

Upon evaluation of many studies, one of the biggest differences observed after the application of PDT was the results in bleeding on probing. In this case, BOP refers to the soft mechanical application of pressure to sites around the implant to access bleeding [23]. The results collected for BOP help indicate inflammation, and hence, the possibility of the progression of disease conditions. Results from studies highlighted that treatments that received PDT as an adjuvant therapy had a statistically significant decrease in BOP within the group from a period of 3 to 6 months compared to baseline readings [12-15, 21, 22]. However, in comparison to the control group (mechanical debridement or open flap debridement alone), it was observed that there was not a statistically significant difference in the results for BOP after 3 to 6 months. Comparably, Cosgarea et al. described that after a 12-month period, there were significantly fewer bleeding sites observed in comparison to the control group [20]. The significance in these results may suggest that it takes time for the full effects of PDT to take place and showcase the impact it can have on BOP in comparison to simpler conditions (the control).

Plaque Index

Plaque can be observed as one of the most prominent indicators of the progression of peri-implantitis in patients [16]. The accumulation of plaque can contribute to gingival inflammation, which marks the earliest signs of the development of complications [17].

Romeo et al.'s research reported that in their study, plaque index was reduced by 70% within the PDT group in comparison to the collected baseline values, highlighting the phenomenon that within the treatment (PDT) group, plaque index can significantly be decreased as a result [13,15]. In terms of between-group comparison in the examined studies, there was no significant difference in plaque index between the PDT treatment group and the control group in observations at 3-6 months. However, a study by Wang et al. established that at the 3- and 6-month mark, there was significant difference between the groups in that the PDT group had a larger percentage of individuals with an overall lower score in plaque index [18]. The difference among the significance in this set of data can be a result of the sample size being larger than the other two studies that had smaller groups for their treatments. More specifically, for the two papers that stated that there was no statistical significance between the groups, plaque index was still slightly lower in the PDT treated groups [13,15]. This highlights the result of their being evidence that PDT can lead to a slight improvement in plaque index scores compared to treatments in its absence.

Pocket Probing Depth

Pocket probing depth is characterized by the measurement between the gingival margin and the tip of the probing instrument used [19]. A large value for the pocket probing depth can indicate the presence of tissue and bone loss, which in turn, can help determine the progression of dental implant complications. Studies highlighted that there was a significant decrease in the PPD for PDT treated groups during the 3- and 6-month observations [12, 18, 20]. In their study, Wang et al. emphasized that there were significantly higher PPD values observed in the treatment group in comparison to the control group during the 1-month observation, while PPD was observed to be significantly lower in comparison to the control group during the 3- and 6-month mark [18]. The change in the PDT group in comparison to the control group from the 1-month mark to the 3-month mark can highlight that the effects of PDT may take a while to develop for results to be seen (over a month). A possible explanation for the PPD measurements in the treatment group being higher than the control group during the 1-month mark could be that the use of lasers in combination with photosensitizers

as a part of PDT can lead to areas becoming immediately inflamed after treatments (which can take a period of up to 6 weeks to completely heal) [29]. Greater immediate inflammation from laser use can be linked to causing deeper pockets, thus explaining why PPD was greater during the measurement made earlier in the experiment where the treated area may have not been fully healed [30]. A related study by Cosgarea et al. emphasizes the association between BOP and PPD, in that an increase in BOP typically leads to an increase in PPD [20]. Furthermore, their study shows evidence of there only being lower PPD values observed at the 3-month mark for subjects that had higher BOP, as opposed to subjects with lower initial BOP having lower PPD values observed all the way up to the 12-month mark. This can emphasize the idea that achieving a lower BOP is key to consistently being able to lower PPD over long periods of time. In other words, understanding how to control BOP through PDT should be one of the primary goals to work towards achieving optimal results in other examinations such as PPD.

PDT Versus Different Adjuvant Treatments

The data analyzed thus far in this paper has focused on the results from treatments with PDT as an adjuvant to debridement procedures compared to debridement procedures in the absence of PDT. However, it is also important to analyze the different options for adjuvant treatments in order to assess the effectiveness of PDT in preventing the progression of peri-implantitis.

This section specifically focuses on chemical treatment with chlorhexidine and antibiotic use as an adjuvant to PDT due to these two methods being some of the most commonly used primary methods for preventing the development of periodontal diseases [31]. A study by Rakašević et al. explored the comparison between treatments that used PDT as an adjuvant versus a control group that used the chemical agent chlorhexidine (CHX) in the form of a bioadhesive gel [24]. Results showed that for the 3-month evaluation, there was a significant decrease observed for BOP in the PDT group compared to the CHX group. This result from the study conducted by Rakašević et al. highlights the overall effectiveness of PDT in comparison to CHX treatment. More so, the study emphasizes that there was a significantly lower number of microorganisms on the tissue from the PDT treatment in comparison to the CHX treatment, which can suggest that PDT has greater decontamination power compared to CHX. Similar research conducted by Anil et al. emphasized that their results pointed towards the PDT treated group having a significantly larger reduction in bacterial viability compared to the CHX treated group, which supports the idea of higher decontamination power being present in PDT treatments [33]. Comparably, a study by Schär et al. compared PDT therapy as an adjuvant to another adjuvant treatment, which in this case is specifically oral drug delivery of antibiotics [14]. The study emphasized that there was no significance for the in-between group results at the 3- and 6-month mark for observations. Although a clear significance for the differences in post-treatment measurements was not established between PDT and antibiotic therapy as an adjuvant, PDT treatment may provide a benefit over antibiotic treatments in that certain drug allergies and the potential of bacterial resistance may be avoided to a greater extent [24]. Another trial, reported by Bassetti et al., highlighted results from treatment groups that received either PDT as an adjuvant or local drug delivery [32]. Similar to the experiment by Schär et al., these results showed that over a period of time (12 months in this case), the PDT treated group and antibiotic (drug) treated group did not show statistically significant between-group differences in the decrease in BOP (although both groups had a significant within group decrease in BOP). However, the results from Schär et al. highlighted that after a period of 6 months, there was a significant difference between the control (antibiotic-treated) and treatment (PDT-treated) groups for the evaluations of plaque index, in that there was a greater decrease in the value for the treatment group [14]. This highlights that certain treatments take longer to show their results compared to others.

Discussion

When considering PDT as a treatment method for patients who suffer from peri-implantitis, it is important to start by viewing the cons in relation to receiving this therapy. Results highlighted that in most cases adjuvant PDT treatment was ultimately unable to provide a significant difference for BOP and plaque index in comparison to debridement methods alone [12-20, 21, 22]. However, when the values were viewed within each group, the measurements were slightly lower in the group where PDT was an adjuvant. Therefore, it can be gathered that traditional PDT treatments cannot serve the purpose of creating a large difference in the treatment of PI, however, if small differences want to be achieved to lower inflammation, it can serve as an appropriate treatment. With there being only small differences observed within PDT treatments, it is important to assess the possible risk associated with taking on this extra treatment as an adjuvant.

In the case of PPD, the results highlighted that as time progresses, a significant difference can be achieved with the PDT group having lower values in comparison to the control group [12, 18, 20]. In this aspect, this positive outcome can be achieved if proper time is invested into waiting for the results of the treatment to become effective.

As mentioned, it is important to evaluate the overall cons that can be associated with PDT and see if they outweigh the benefits, which in this case, is minimal. In terms of the side effects of PDT, there is a low probability of having any severe side effects since the elimination of bacteria is done at a local level [25]. Therefore, there is no major harm observed in a patient experimenting with PDT

to treat PI if there are no allergies associated with the photosensitizer used. More so, the process of PDT is highly controlled in the sense that specific wavelengths of light are used in relation to the specific photosensitizer.

When an individual wishes to assess the possible adjuvant therapies that can be used in combination with the typical treatments for PI such as mechanical and open flap debridement, PDT can serve as a good option when compared to a variety of treatments. As stated in the results of this review, when comparing PDT purely with a different therapy that can serve as an adjuvant, there are better results in BOP and plaque index [14, 24]. However, obtaining these results depends on the treatment length and type of therapy in comparison to PDT. When reviewing the possible treatment options for peri-implantitis, the choice in the path taken varies on several factors based on the individual receiving treatment. For instance, as mentioned, several patients can have allergies to the antibiotics prescribed by healthcare professionals [26]. More so, many individuals who have these allergies are typically unaware of them until they take antibiotics. Other than side effects due to allergies, the issue of bacterial resistance is another possible antibiotic treatment outcome that is not prominently seen with PDT [27]. When patients are deciding on the choice for adjuvant therapies, they should take note of PDT ultimately having a lower risk of side effects as opposed to the more common treatment of antibiotics. Although other treatments such as antibiotic use may seem like an easier and less time-consuming route to treating peri-implantitis, it is important to acknowledge the possibility of risk in taking the "shortcut". If a patient is willing to invest more time by taking the extra length of attending multiple PDT sessions, it may be slightly safer in terms of side effects.

Conclusions

Future Research

As of now, there are no major advancements made in making PDT highly effective for PI treatment. Although it can aid in reducing inflammation, it is crucial that more research should be put into experimenting with different light sources and photosensitizers to find the most effective combination in creating a more significant difference in outcomes between PDT alone and PDT as an adjuvant to more traditional treatments. Since time was considered to be a factor in obtaining optimal results from PDT treatment, future research can experiment with carrying out PDT for longer periods of time and a different number of sessions. Comparing PDT results based on the length and number of treatments can help with determining the most optimal length and time that patients need to commit to achieve the best results.

Due to peri-implantitis being a severe and irreversible stage in the development of dental implant complications [9,10], it is generally important to continue carrying out future research to create new treatments, or enhance existing treatments, to better maintain the patient in a healthy state and possibly find a solution in making peri-implantitis reversible.

PDT can serve as a minor treatment for peri-implantitis in the sense that significant reduction in BOP and plaque index can be achieved within its treatment group. However, if a patient is looking for a treatment that can have a more major effect compared to traditional therapies such as mechanical/open flap debridement, PDT would not be the most advantageous treatment to obtain major results in BOP and plaque index. Although it is a low-risk procedure, further development in PDT needs to be done to achieve more optimal results in treating peri-implantitis.

List of Abbreviations Used

CHX: chlorhexidine
BOP: bleeding on probing
PI: peri-implantitis
PDT: photodynamic therapy
PPD: pocket probing depth

Conflicts of Interest

The author declares that they have no conflict of interest.

Ethics Approval and/or Participant Consent

Due to this study being limited to the collection of previously conducted experiments as a literature review, having a review carried out by the institutional research ethics board (REB) was not necessary. The reasoning for this is that the experiments were not conducted directly by the author, and all collected data was taken from ethically performed experiments that have been approved for consent by participants.

Authors' Contributions

ET: Structuring and writing all sections of this literature review which includes, but is not limited to, searching for papers, analyzing research, interpreting results, and compiling information to create a structured interpretation of the research as a final manuscript.

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