



## EFFECT OF ARGON PLASMA CLEANING VS STEAM CLEANING ON IMPLANT ABUTMENTS IN PERIODONTALLY HEALTHY PATIENTS: A SYSTEMATIC REVIEW

### Periodontology

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### ABSTRACT

**Background:** The implant-abutment connection and surrounding hard and soft tissues plays an important role in establishing mechanical and biological stability. Contamination of implant abutments could potentially influence the peri-implant tissue inflammatory response. Plasma argon cleaning or steam cleaning is used to disinfect micro-pollution and bacterial contamination present on customized titanium abutments following laboratory steps. **Methods:** An electronic search was carried out on PubMed/MEDLINE, EBSCO Host and Google scholar till December 2021 in English language. It included randomized controlled trial assessing peri-implant tissues, success rate and implant survival. **Results:** Four randomized controlled trial were included in which 3 of the studies included were to assess radiographical marginal bone-level (MBL) changes around implants which were restored according to the platform switching and "one-abutment-one-time" concepts, using commercially available abutments, with and without plasma of argon cleaning treatment or by steam sterilization. Thus, for one study histological assessment was carried out to enhance and evaluate the effect of plasma of argon and to extend its effect in time over soft tissue and not to limit it at an early healing stage. **Conclusion:** Plasma of Argon produces surface disinfection and favorably alters surface characteristics. It promotes orientation of collagen fibers and its density and cell-adhesion. Also, to assess the soft and hard tissue level changes in patients with periodontal disease, plasma argon cleaning treatment with platform switching and one-abutment-one-time concept could be much more favorable.

### KEYWORDS

implant- abutment, platform switching, plasma of argon, steam cleaning

### INTRODUCTION

The integrity for maintaining peri-implant tissue health is a crucial soft tissue seal. Peri-implantitis is an inflammatory reaction that is seen around hard and soft tissue which occurs after the prosthetic component is connected and implant is exposed to the oral environment (Hermann et al. 1997).<sup>[1]</sup> Iatrogenic factors, such as incorrect seating of the abutment and/or the restoration, the presence of residual subgingival cement, will lead to loss of soft-tissue integrity and therefore would predispose to peri-implant disease. A key difference is the nature of the relationship of the connective tissue with the implant surface and in case of teeth, fiber attachment is perpendicular into the cementum. Thus, combined with reduced cellularity and vascularity in the peri-implant connective tissue makes implants more susceptible to disease progression and initiation. Presence of soft tissue around the implant acts as a barrier which prevents bacterial contamination which is necessary for the long-term success rate of implants (Abrahamsson et al. 1998).<sup>[2]</sup> Albrektsson et al in 1986 stated that physiological marginal bone loss is seen around implants once the prosthesis is placed in position. There is horizontal and vertical bone loss noticed during the first year of function.<sup>[3]</sup>

Interaction between implant abutments and cellular components influences the healing process during the prosthetic phase of implant treatment<sup>[4]</sup> which leads to microgaps as it would lead to infiltration of inflammatory cells.<sup>[5-7]</sup> Annibaldi et al. 2012 stated that there has been microgap shifting from vital bone levels which is 0.5mm of minimal bone loss that has been noticed in longitudinal analysis.<sup>[8]</sup> When an abutment of a smaller diameter is used it is positioned away from the crest bone levels moving the implant abutment junction away from the crestal bone.

Microtopography of abutments may alter aging of metal and contamination of abutment surface (Shen et al. 2016).<sup>[9]</sup> Contamination via bacteria, pollutions during lab procedures and may affect crestal bone levels leading to peri-implantitis of hard and soft tissue levels.<sup>[10-11]</sup>

<sup>[11]</sup> For this reason, cleaning and disinfection procedures represent a mandatory step during the prosthetic phases of implant rehabilitations. Autoclaves, ovens, chemicals such as ethylene oxide, and plasma treatment are different methods which can be used to clean and sterilize abutments to completely remove microcontamination.<sup>[12-15]</sup>

In an in-vitro study Tavares et al. 2009 stated that plasma cleaning has a triple impact on titanium i.e., corrosion protection, cleaning, and increases surface energy of the cleaned surfaces.<sup>[16]</sup> To activate the surfaces at the atomic and molecular level plasma treatment was demonstrated producing hydrophilic surfaces and enhancing their

wettability (Swart et al. 1992).<sup>[17]</sup> Appropriate plasma processes were demonstrated to enhance surface hydrophilicity which modifies the oxide layer which interacts with proteins and cells of surrounding tissue (Zhao et al 2005).<sup>[18]</sup> An interim 2-year report from the study suggested that removal of contaminants from titanium abutments by cleaning using plasma of argon treatment allowed for better peri-implant marginal bone level maintenance, when compared to steam cleaning of titanium abutments.<sup>[19]</sup> From a physico-chemical point of view, low-temperature plasma is usually adopted to remove organic residues from surface. Atmospheric gas is evacuated below 13 Pa (Pascal) it works within vacuum chambers. These low pressures allow for accelerated electrons, preserve the integrity of materials, remove chemical traces left from former treatments,<sup>[20]</sup> and effectively produce cleaner surface.<sup>[21]</sup> Plasma cleaning has been generically defined as a process that uses partially or entirely ionized gas with positively or negatively charged particles as of equal number approximately. Discharge of plasma gas is generated by supplying energy to natural gases to form small charge carriers, reactive species & UV radiations. For surfaces modification and organic cleaning low temperature plasmas are ionized and gases generated between 0.1 and 2 torr pressures. These low pressures of accelerated electrons and ions allow a relatively long free path. Also, in each of the randomized controlled trial the control group abutments after milled and polished, were cleaned by steam for 30s and in test group abutments after milled and polished underwent argon plasma treatment 75 W of power and -10 MPa of pressure for 12 min at room temperature in plasma reactor. Additionally, cleaning conventions in view of Plasma of Argon were demonstrated to permit further developed fibroblast bond, likewise proposing better soft tissue mending around titanium abutment.<sup>[22]</sup>

The present systematic review aims to evaluate the effect of Plasma Argon and Steam cleaning on marginal bone-level changes around implants in periodontally healthy subjects with dental implants.

**RATIONALE:** Plasma argon cleaning is an effective treatment for better peri-implant marginal bone level maintenance which helps to maintain surface modifications, making surfaces hydrophilic, and increasing the surface energy of the external oxide layer that interacts with proteins and cells of surrounding tissue, improving adhesion. Therefore, this systemic review was undertaken to evaluate the efficacy of Plasma argon cleaning on MBL changes around dental implants.

**FOCUSED QUESTION:** To review the included RCTs comparing effect of Plasma Argon and Steam cleaning on marginal bone-level changes around implants in periodontally healthy subjects with dental implants in the age group of 18 years and above?

**PRIMARY OBJECTIVE:** To evaluate the effect of Plasma Argon cleaning and steam cleaning on marginal bone-level changes around dental implants.

**SECONDARY OBJECTIVE:** To evaluate the effect of cleaning abutment titanium surfaces with plasma of argon on cell adhesion and collagen fiber orientation at an early healing time.

## MATERIAL AND METHODS:

### 2.1) STUDY REGISTRATION AND PROTOCOL:

This systematic review was conducted in accordance with the Preferred Reporting Items of Systematic Review (PRISMA) [23] and is registered under the number CRD42022310022 in PROSPERO database, created by the University of York, responsible for the registration and dissemination of systematic review.

**2.2) STUDY DESIGN:** This is a systematic review of Randomized controlled trials which aimed to evaluate the effect of Plasma Argon cleaning and steam cleaning on marginal bone-level changes around dental implants.

**2.3) ELIGIBILITY CRITERIA:** The PICO (patient, intervention, comparison and outcome) strategy was followed in this systematic review which are key for designing all stages of an interventional systematic review.

### PICO ANALYSIS:

- (P) Types of participants: Periodontally healthy patients with dental implants in the age group of 18 years and above.
- Type of intervention: Plasma of Argon cleaning vs steam cleaning
- (C) Comparison between intervention: Comparing the effect of plasma argon cleaning and steam cleaning/ sterilization on marginal bone-level changes around implants.
- (O) Type of outcome measures: Success rate of the implants and prosthesis, biologic and prosthetic complications, peri-implant marginal bone loss (MBL).
- (S) Type of studies: Only randomized controlled trials were considered in the review.

Additionally,

The following additional inclusion criteria were considered:

- Single tooth fixed implant-supported prosthesis in the maxillary and mandibular jaw.
- Age > 18 years
- No relevant medical history
- Non-smoker or smoking ≤ 10 cigarettes/day (all pipe or cigar smokers were excluded)
- Plaque Index and bleeding on probing ≤ 25%
- Possibility of follow-up for 5 years after prosthetic loading
- Presence of a wide ridge of bone allowing the insertion of a 4-mm platform implant according to the Brånemark protocol.

In this systematic review, the following points were considered as exclusion criteria:

- Sites with acute infections
- Pregnant or lactating patients
- Sites needing horizontal or vertical regenerative procedure

### 2.4) INFORMATION SOURCE AND LITERATURE SEARCH:

For the identification of randomization clinical trials to be considered for inclusion in this systematic review, PUBMED, MEDLINE, COCHRANE LIBRARY, GOOGLE SCHOLAR AND EBSCO HOST were employed as electronic databases, and a literature search was carried out with a personal computer on articles published up to and including December 2021.

Last electronic search was carried out on 31<sup>st</sup> December 2021. Following search electronically the terms alone and in combination were used in PubMed search builder:

(Plasma of argon) AND (implant abutment) AND (platform switching) AND (Steam Sterilization) AND (Randomized controlled trial)

“Plasma of argon alone” “implant abutment” “steam sterilization” “platform switching”

(Plasma of argon) OR (Implant abutment) OR (steam sterilization) OR (Randomized controlled trial) OR (platform switching)

Electronic search was carried out without any limits and language restriction to include all the possible clinical trials in the potentially relevant article search plane of the systematic review. Reference list of the reviews of the identified randomized trials were also checked for possible additional studies. This article search was then narrowed down manually by the reviewer according to the inclusion criteria of the present systematic review to include all the RCTs in English language only.

Additionally, hand search was also carried in all relevant journals up to and including December 2021.

### 2.5) STUDY SELECTION:

Study selection was conducted by independent reviewers in the following stages:

1. Initial screening of the potentially suitable titles and abstracts against the inclusion criteria to identify potentially relevant papers.
2. Before initial screening, all the items found through electronic and manual searches were grouped into a single list, excluding duplicates.
3. Independent screening of the titles and abstracts (when available) of all reports identified.
4. When studies met the inclusion criteria or when insufficient data from abstracts for evaluating inclusion criteria were gained, the full article was obtained.
5. For further screening Full text articles which met the inclusion criteria were considered eligible.

### 2.6) DATA MANAGEMENT AND COLLECTION PROCESS:

From the selected studies data collected was grouped into the following:

1. Study characteristics (author, year of publication, design, follow-up period)
2. Patient characteristics (no. of subjects, age, gender country)
3. Treatment (type, assessed, test and control group)
4. The collected data was then transferred into evidence-based tables to provide an overview of the included studies and data available.

### 2.7) DATA ITEMS:

Variables for which data was sought included:

1. Periodontal Disease – Periodontal Disease is characterized by microbially associated; host mediated inflammation that results in loss of periodontal attachment.
2. Marginal Bone Loss- A non-infective remodeling process of variable entity occurring within the first year after implant placement.

### 2.8) OUTCOME AND PRIORITIZATION:

Primary outcomes: success rate of the implants and prostheses, biologic and prosthetic complications, peri-implant marginal bone loss (MBL)

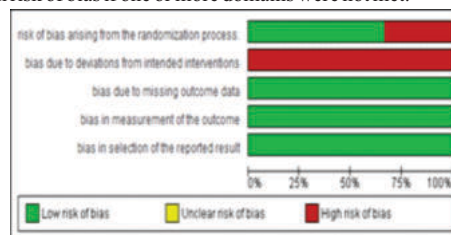
Secondary outcome - esthetic and periodontal parameters and patient satisfaction.

### 2.9) RISK OF BIAS OF INDIVIDUAL STUDIES:

Cochrane Risk of Bias tool was used for assessing the risk of bias.

Majorly, five domains risk of bias arising from the randomization process, bias due to deviations from intended interventions, bias due to missing outcome data, bias in measurement of the outcome, bias in selection of the reported result were evaluated and included in a graph. The Risk of bias of the included studies were categorized according to:

- (A) Low risk of bias if all domains were met.
- (B) Unclear risk of bias if one or more domains were partly met.
- (C) High risk of bias if one or more domains were not met.

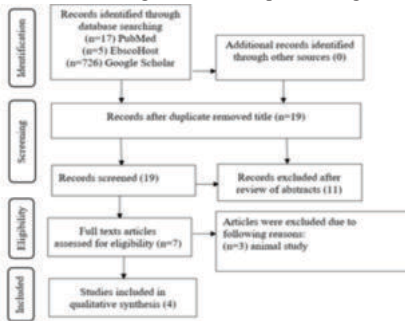


**Figure 1: The Risk of Bias of the included studies were categorized as follows:**

**RESULTS:**

**3.1) STUDY SELECTION:**

The search strategy provided a total of 748 Studies. After screening the title and abstracts, 19 studies were found to be duplicates of which 11 studies were excluded. The remaining 7 studies were potentially eligible and were read in full by the evaluators. At the end of the analyses, 4 articles published between 2015 to 2021 met the inclusion criteria and were included in the present systematic review. The flowchart of article screening and selection process is given



**Figure 2: Flow chart of literature search results and study selection:**

**3.2) STUDY CHARACTERISTICS:**

An overview of the included studies for the analysis is presented in the table format. The studies selected in this systematic review were published in the last 5 years which were all conducted in Spain. The studies included comparison between plasma of argon treatment vs steam sterilization in patients with exact same inclusion criteria was seen in all the studies, however only 1 study (Garcia et al) varied in the inclusion criteria and measurement parameters.

**Table 1: Characteristics of the studies included in the Systematic Review**

Before treatment, a full-mouth professional hygiene was scheduled. The sample sizes of the all the included studies varied from 10 to 15 patients except for one study (Canullo et al 2015) which mentioned the sample size as 5 patients in the test group and 7 patients in the control group.

AUTHOR	YEAR	COUNTRY	STUDY DESIGN	AGE	SAMPLE SIZE	INTERVENTION & COMPARISON	PRIMARY OUTCOME	MEASUREMENTS OF PARAMETERS	FOLLOW UP
Canullo et al	2015	Spain	RCT	> 18 years	Test group- 5 patients Control group- 7 patients	Test group- Argon plasma treatment Control group- Steam cleaning	MBL +success and survival rate of implants	Radiographs	2yrs
Canullo et al	2015	Spain	RCT	> 18 years	Test group- 15 patients Control group- 15 patients	Test group- Argon plasma treatment Control group- Steam cleaning	MBL +success and survival rate of implants	Radiographs	Baseline to 5 years
Garcia et al	2016	Spain	RCT	> 18 years	Test group- 15 patients Control group- 15 patients	Group 1- Argon plasma treatment Group 2- No treatment	% Of total area occupied by cells	histological	1 week, 2 weeks, 8 weeks
L Canullo et al	2017	Spain	RCT	> 18 years	Test group- 10 patients Control group- 10 patients	Test group- Argon plasma treatment Control group- Steam cleaning	MBL +success and survival rate of implants	Radiographs	Baseline to 6 years

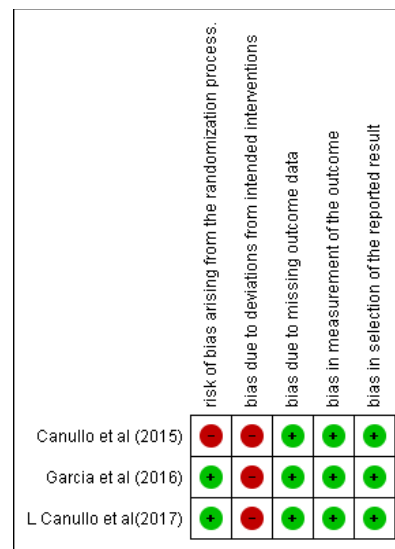
All the included studies were randomized controlled trial. The included studies evaluated primary outcome measures as success rate of implants and prosthesis, biologic and prosthetic complications, peri-implant marginal bone loss (MBL) was assessed using radiographic techniques. However, there was heterogeneity in the techniques used, one study (Garcia et al) was assessed histologically. The maximum follow-up ranged from 1 week to 6 years in the included trials. Details of the excluded studies are presented in table format.

**Table 2: Characteristics of excluded studies**

AUTHORS	YEAR	TITLE	STUDY DESIGN	REASON FOR EXCLUSION
Martins Neto EC et al [24]	2017	Use of argon plasma to enhance soft tissue integration of prosthetic components: a randomized, controlled animal study	RCT	Animal study
Tanaka et al [25]	2018	Effect of Plasma of Argon Treated Implants on Bone Density: A Randomized, Controlled, Histomorphometric Study in Dogs	RCT	Animal study
Canullo L et al [26]	2013	Plasma of argon accelerates murine fibroblast adhesion in early stages of titanium disk colonization	Experimental study	Animal study

**3.3) RISK OF BIAS WITHIN AND ACROSS STUDIES:**

Figure below shows the methodological quality of the individual studies. This assessment was conducted by using the recommended approach for assessing risk of bias in studies as per Revised Cochrane risk-of-bias tool for randomized trials (RoB 2) using the tool RevMan 5.4.1



**Figure 3: Risk of Bias Interpretation**

**3.4) RESULTS OF INDIVIDUAL STUDIES:**

The general information of selected studies is summarized in Table. The included 4 studies were published between 2015 to 2021. All the studies were carried out in Spain and involved 5 patients to 15 patients in test and control group within the age range of > 18 years according to the intervention and comparison group of each included study. The follow-up interval of the studies ranged from 1 week to 6 years of follow-up. All 4 studies were randomized controlled trial and were assessed based on the radiographic evaluation and only one study by Garcia et al was assessed histologically.

Out of the 4 studies 1 study reported the data at 1 week, 2 weeks and after 8 weeks, while other 1 study reported the data at 6 months and after 24 months and 2 study reported a follow up period of baseline to 5 years and 6 years follow-up. (Table 1)

One study out of four also evaluated percentage of area occupied by cells, the presence or absence of cells, aspect of adhered cells, and the presence of contaminants. Study by Garcia et al in the year 2016 was a parallel-group, triple-blinded, randomized controlled clinical trial which evaluated the early effect of titanium abutment cleaning and activation using plasma of argon treatment. Histological analysis of soft tissue evaluated orientation of collagen fibers and its density. Therefore, it resulted in the mean percentage of area occupied by cells were 15.14% (range 2.91–44.27) and 33.75% (range 2.37–68.4) for G1 & G2, respectively. Significant difference was close to (P = 0.089). The proportion of samples of adhered cell was homogeneous between presenting two groups (P = 0.142). And the orientation of the fibers

varied according to the coordinate area with oblique fibers predominant in G2 than in G1. Collagen fiber thickness was higher in the basal, medial, and coronal area of G2 compared to G1 with a statistical difference in the internal area ( $P < 0.05$ ).

In the study by Canullo et al 2015, was a prospective, randomized, match-paired, triple-blinded, controlled, clinical trial which evaluated radiographical marginal bone-level changes around implants inserted in anterior sites, restored according to the platform switching and "one-abutment-one-time" concepts, using commercially available abutments, with and without plasma treatment after customization. His study resulted that there were statistically significant differences among control and test groups were found at both time points. Absence of statistically significant difference between Intergroup comparison was relieved by an average interproximal bone loss of 0.16 mm (SD: 0.17) in control group and 0.07 mm (SD: 0.34) was revealed in test group at 6 months (T1) while after 24 months, groups showed a mean bone-level changes of 0.38 mm (SD: 0.44) and 0.11 mm (SD: 0.14), respectively.

Evaluating the study by Canullo et al 2015, was a randomized, match-paired, triple-blinded, controlled clinical trial which was designed to test cleaning effect of argon plasma versus steam cleaning, upon non-sterile implant customized abutments. His study resulted a statistically higher mean MBL was found in the control group compared to the test group at 6, 24, and 60 months after crown connection. During entire follow-up period, the study was statistically significant mean which was demonstrated in the intragroup comparison MBL in the control group, but not in the test group.

The study by L Canullo et al 2017 was randomized, match-paired, triple-blinded, controlled clinical trial which aimed to assess the 6-year radiographic changes around customized platform-switched abutments placed according to the one abutment-one time concept, with and without plasma of argon cleaning treatment. His study resulted from baseline to the 6-year follow-up, an intragroup comparison group showed an absence of statistically significant difference in the test group ( $P = .08$ ). On the other hand, significant differences were found in the control group ( $P = .01$ )

## DISCUSSION:

### 4.1) SUMMARY OF EVIDENCE:

The current systematic review was focused on the influence of cleaned and non-cleaned, plasma of argon treatment vs steam cleaning of titanium surfaces and their impact on soft tissues. Thus, for long-term implant success, the formation of a soft tissue barrier that prevents bacterial penetration through the transmucosal tunnel is essential.<sup>[27]</sup>

The aim was to assess radiographical marginal bone-level changes around implants restored according to the platform switching and "one-abutment-one-time" concepts, using abutments which are commercially available, with and without plasma of argon cleaning treatment. To improve the quality of this systematic review, we included only controlled clinical trials for the systematic review analysis.

In all the included studies, the primary outcomes were to evaluate the success rate of the implants and prostheses, biologic and prosthetic complications, peri-implant MBL.

To replace conventional methods of cleaning metallic or polymeric surfaces a very important area of research is developing with efficient high-vacuum technologies which will be able to clean and functionalize the surface. Oxide layers and pollution can indirectly and directly trigger the hard and soft tissue inflammatory response or may at least alter the interaction with the soft and hard tissue condition.<sup>[28]</sup>

Clinical trial showed differences in radiographical marginal bone-level changes around implants inserted in anterior sites, restored according to the platform-switching and "one-abutment one-time" concepts, using commercially available abutments, with and without plasma treatment. Focusing on the biological and bio-mechanic causes of peri-implant bone resorption, glow discharge techniques were demonstrated to be effective. It could be well evaluated that such faster molecular and cellular adhesion on plasma cleaned titanium abutment in the supra-crestal level might lead to a stronger fixation of the connective tissue collar and possibly preventing epithelial down growth. At the same time, it was demonstrated that plasma of argon

cleaning treatment can be positively adopted to improve connection screw preloading, longitudinally stabilizing the implant-abutment connection<sup>[29]</sup>

That interim study supported plasma of argon is an effective treatment for removal of contaminants from titanium abutments which in turn results in better peri-implant marginal bone when compared to steam disinfected method. 100% of implant and prosthesis survival rate after 5-year of prosthetic loading suggesting the stability of implant therapy regardless of disinfected method. However, argon plasma treatment group had a significant lower amount of MBL when compared to the steam disinfected group. In fact, it was demonstrated that abutment customization produces micro-pollutants.<sup>[30]</sup>

Collagen fiber density was observed to be higher in the plasma group in the basal, medial, and coronal area compared to the control group with a statistical difference in the internal area ( $P < 0.05$ ). Moreover, a statistical significance was present in most of all areas where there was predominance of oblique fibers in the plasma group. It is known that perpendicular and oblique orientation of fibers to the surface of implants will prevent the apical migration of junctional epithelium and will have a better

performance when subjected to the mechanical forces generated by mastication. Thus, could make think that plasma of argon treatment might be useful to produce a better soft tissue organization.<sup>[31]</sup> Activation of the abutment surface may also produce a better soft tissue organization (collagen fiber density and orientation) even at the early stage of soft tissue healing.

Differences between test and control groups may be further explained by enhancement of the energy surface on the titanium abutment. In fact, plasma cleaning was demonstrated to activate the surface through the stimulation of the electronic mantle, leading to a faster and stronger cell adhesion. A potential consequence might be a stronger soft tissue-abutment connection, which could increase the connective tissue sealing activity and thus decrease bone remodeling. On the other hand, the presence of remnants on the control group abutment could represent an obstacle for bone and soft tissue cell precursors during the first healing phase after abutment connection, therefore jeopardizing the connective tissue sealing ring around the crestal module.<sup>[32]</sup>

The risk of bias was high for one study by Garcia et al and low for other three studies in all the domains. Further long-term, multi-center clinical trials are essential to authenticate treatment strategies in evidence-based practice.<sup>[27]</sup> The activation of prosthetic titanium components with argon plasma treatment before their installation in the oral cavity could enhance soft tissue healing at an early stage and eliminate bacterial contamination.<sup>[31]</sup>

## LIMITATIONS:

Certain limitations to the present systematic review are:

1. There is heterogeneity among the study aims, methodology, protocols, limited number of patients and follow-up period.
2. Measurement of clinical parameters based upon the sites was not standardized.
3. Radiographic evaluation differed in each study which is subjective of re-evaluation.
4. Varied Study designs protocol were used in the studies which could lead to increase in risk of bias.
5. Larger sample size is required to provide statistically significant result.

## CONCLUSION:

Plasma of Argon produces surface disinfection and favorably alters surface characteristics. It promotes orientation of collagen and cell-adhesion. To assess the soft and hard tissue level changes in patients with periodontal disease, plasma argon cleaning treatment with platform switching and one-abutment-one-time concept could be favorable for maintenance of long-term peri-implant prosthetic crestal bone level.

## IMPLICATIONS FOR FUTURE RESEARCH:

In future histological aspects of this treatment must be investigated, to detect soft tissue to abutment adhesion present and how it can result in a longitudinally stability and to use a standardized radiographic method to assess marginal bone level. Also, further randomized controlled trials with larger sample size and longer follow-ups should

be held to confirm the present data.

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