The Impact of Implant Design, Defect Size, and Type of Superstructure on the Accessibility of Nonsurgical and Surgical Approaches for the Treatment of Peri-implantitis

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Purpose: *The success of nonsurgical or surgical treatments of peri-implantitis is unpredictable, often without a clear reason. The aim of this study was to investigate the efficacy of nonsurgical and surgical cleaning, focusing on the impact of implant design, defect size, type of superstructure, and experience of the operator.* ***Materials and Methods:*** *Conical and straight implants were coated with a biofilm-like material and placed in shallow/deep defects in an artificial jaw model. Treatment was done by three operators and included either healing abutments or crowns as superstructures. Analysis was done using stereomicroscopy and ImageJ software.* ***Results:*** *Nonsurgical treatment of peri-implantitis defects was inefficient in removing all biofilm areas, regardless of the depth of the defect. The type of implant, experience of the operator, or type of superstructure did not have a significant impact. Surgical treatment was more efficient than a nonsurgical approach with regard to biofilm residues. However, the surgical approach failed to clean the apical portion of the exposed part of the implants.* ***Conclusion:*** *Nonsurgical and surgical treatment were found to be ineffective in cleaning the exposed portion of implants with peri-implantitis. Treatment of peri-implantitis should therefore also include other approaches, such as chemical or biological modalities.* Int J Oral Maxillofac Implants 2016 (7 pages). doi: 10.11607/jomi.4781

Keywords: *cleaning, nonsurgical treatment, peri-implantitis, surgical treatment*

The peri-implant area is more susceptible than the periodontium to bacteria,[1] indicating that early plaque removal is essential in patients with dental implants.[2] If perimucositis occurs, maintenance treatment ought to quickly and efficiently resolve it.[3,4] However, peri-implantitis poses a different challenge given the fact that there is no clear treatment protocol with a predictable favorable outcome. A Cochrane systematic review states that peri-implantitis will reoccur in up to 100% of treated cases after 1 year.[5]

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Peri-implantitis has been shown to occur in 10% to 47% of patients with dental implants.[6–8] Therefore, peri-implantitis treatment is an integral part of the standard treatment and maintenance of implants.[9] The primary etiologic factor for peri-implantitis inflammatory conditions is the establishment of biofilm on the implant surfaces.[10] Accordingly, the aim of any cause-related therapy is the effective mechanical removal of the biofilm.[11]

Various protocols for the treatment of peri-implantitis have been tested over the last decades. These protocols use a wide range of mechanical instruments,[12,13] including manual plastic, carbon, or metal curettes; prophylaxis instruments such as brush or rubber cup; sonic and ultrasonic tips; and air polishing.[3,14–16] Some studies have shown that the use of sonic and ultrasonic scalers with metal tips may be useful for implant therapy.[17–20] Limited access to the biofilm deposits with these different tools is one of the main obstacles in the treatment of peri-implantitis due to implant morphology (rounded shape, conical body, macro- and microthreads, and a small shoulder). These obstacles are more significant in nonsurgical techniques because of the mucosa presence, which makes the operator "blind" to the infected areas. As a consequence, this treatment modality does not provide a predictable and successful outcome, especially in advanced cases.[3,21] Many "clinical adaptations" have

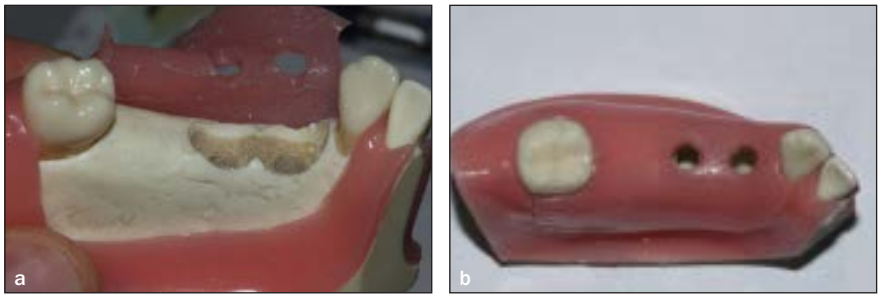

Fig 1 Mandibular model with edentulous area at the premolar and first molar. *(a)* Two rounded angular defects were made at the premolar sites using a conical bur and *(b)* covered with a mucosa-like silicone envelop with 4-mm-diameter holes located above each defect.

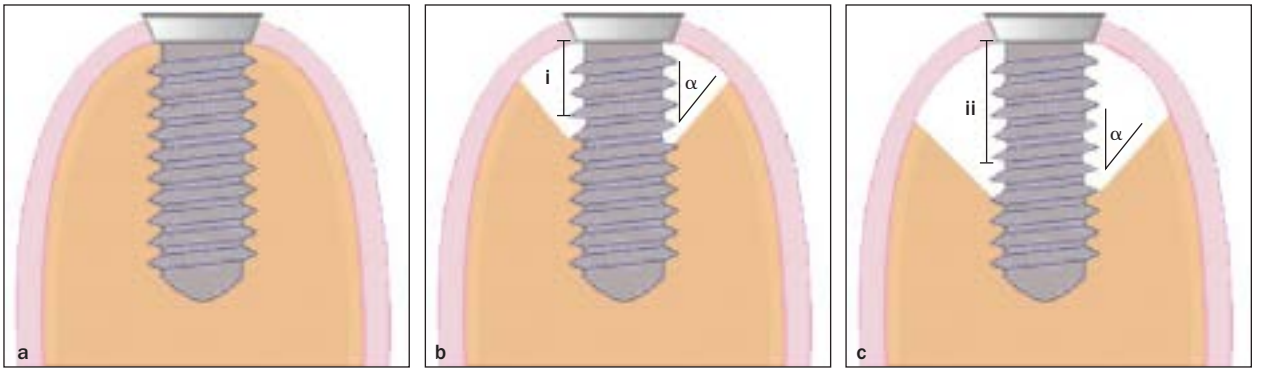

Fig 2 Cross-sectional illustrations of the model of *(a)* healthy implant with healthy mucosa, *(b)* implant with a shallow defect, and *(c)* implant with a deep defect. α = apical angle of the defects (50 degrees); i = shallow defect depth (3 mm); ii = deep defect depth (5 mm).

been suggested to allow better access to the implant surfaces, such as replacing the crowns with healing abutments before treatment.

The purpose of this study was to investigate various factors that may affect the ability to access the implant surface during nonsurgical, as well as surgical, treatment of peri-implantitis. The tested factors were implant design, superstructure, bony defect depth, and experience of the operator.

MATERIALS AND METHODS

Jaw Model and Critical Defects Design

A mandibular model with an edentulous area at the premolar and molar regions (Nissin Dental Products) was used as a platform for the study (n = 6). The silicone mucosa-like cover was elevated, and two critical defects were created using a wide conical-shaped bur at the position of two adjacent premolars (Fig 1a). Round holes, 4 mm wide, were made in the silicone mucosa-like cover on the defects, imitating the soft tissue mucosa on peri-implantitis defects (Fig 1b). Half of the experiment included defects with a 3-mm depth and 50-degree angle (shallow defects, Fig 2b), while the other half included defects with a 5-mm depth and 50-degree angle (deep defects, Fig 2c).

Implant and Superstructure Design and Biofilm-like Model

Conical and straight implants (sandblasted and acid-etched surfaces) with an internal hexagon connection and a diameter of 3.75 mm and length of 13 mm (provided by MIS Implants) were used. The two implant designs also differed in terms of microthreads (not present in the conical-shaped implants). The implants were covered with a biofilm-like material—a white correction fluid (Figs 3a and 3b). The material was applied evenly in a thin layer from the shoulder of the implants and corresponding to the depth of the defects (3 mm in the shallow-defect group and 5 mm in the deep-defect group). Two implants were placed in the prepared defects (conical implant in the mesial defect and straight implant in the distal defect) without disturbing the biofilm-like material (Fig 3c).

Two superstructure designs were used: *(1)* healing abutments with a straight profile and length of 4 mm (Fig 3d) and *(2)* straight superstructures with provisional crowns (Fig 3e). The superstructure emergence profile was continuous with the implant shoulder (not a platform-switching design).

Nonsurgical and Surgical (Control) Treatment

The nonsurgical treatment was done on the mandibular model with the implants inserted and the mucosa-like cover in place. The treatment was done using an ultrasonic tip (No. 1 tip, Satelec-Acteon) with water irrigation for 120 seconds/implant by two periodontists (DP and TC) and

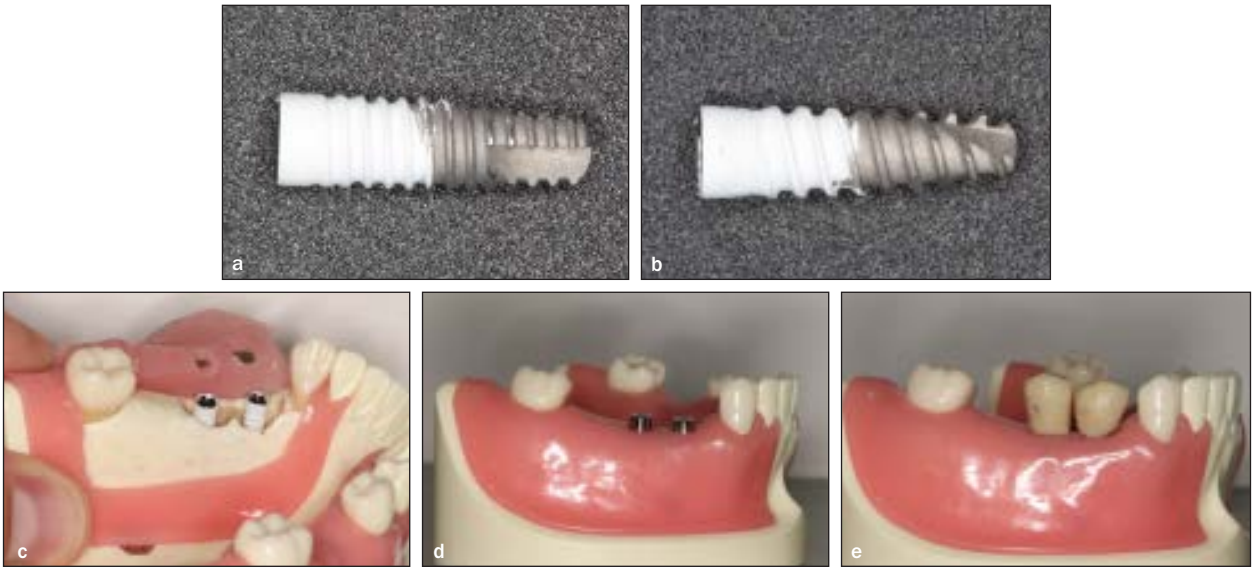

Fig 3 Biofilm-like and superstructure models. *(a)* Straight and *(b)* conical implants were coated with a biofilm-like material. *(c)* The implants were inserted into previously prepared bone defects and covered by a mucosa-like envelop. The superstructures were then connected to the implants with *(d)* healing abutments or *(e)* crowns.

one postgraduate student in periodontology (EM). The buccal aspect of each placed implant was then marked in the internal hexagon aspect of the implant using a high-speed bur.

Control groups included the same treatment parameters but without the mucosa-like cover (ie, simulating flap elevation during surgical treatment). All experiments were repeated twice.

Measurement of Biofilm Residues

The buccal, mesial, lingual, and distal aspects of the implants were viewed under stereomicroscope (Stemi SV11, Zeiss) with ×10 magnification. Quantification of the areas with remnants of biofilm-like material was done using ImageJ software.

Data Analysis

The data were analyzed using a statistical software package (SigmaStat, Jandel Scientific). One-way repeated measure analysis of variance (RM ANOVA) was applied to test the significance of the differences between the treated groups. If the results were significant, intergroup differences were tested for significance using the Student *t* test and Bonferroni correction for multiple testing.

RESULTS

Narrative Analysis

All of the various settings for nonsurgical cleaning failed to properly clean the implant surfaces. The most noticeable areas that were left unclean were the inter-thread valleys. This was most evident in the microthreads by comparing the cervical area of straight and conical implants (due to the fact that only straight implants have microthreads) (Fig 4). While the smooth cervical area of the conical implants was clean, the cervical area of the straight implant microthreads showed clear residues of biofilm-like material within all inter-thread valleys (Fig 4).

All aspects of the implants (buccal, mesial, lingual, and distal) showed similar amounts of biofilm-like material residues. However, the buccal aspect appeared to be less clean compared with the other aspects of the implants (Fig 4).

Comparison by defects (shallow vs deep defects) revealed that the cervical aspect of the implants in the deep defects was cleaner than that of the implants in the shallow defects. However, the apical aspect of the implants in both defects remained unclean in a similar manner. Also, the increased inter-thread width of the straight implant design did not change the ability to reach and clean these areas (Fig 4a). The superstructure used (healing abutment vs crown) did not influence the ability to clean the implants. Furthermore, the results did not differ when different operators performed the treatment.

The above results are confounding in comparison with the results of open-flap treatment. The open-flap cleaning was more successful in the smooth surfaces as well as the inter-thread areas (Fig 4b). However, in the deep defects there were remnants of biofilm-like material in the apical portion of the implants, regardless of implant design or superstructure (Fig 4b).

In all implant surfaces, microdamage scars caused by the ultrasonic tip could be easily observed. The most prominent areas with these scars were the smooth cervical areas and the peaks of threads.

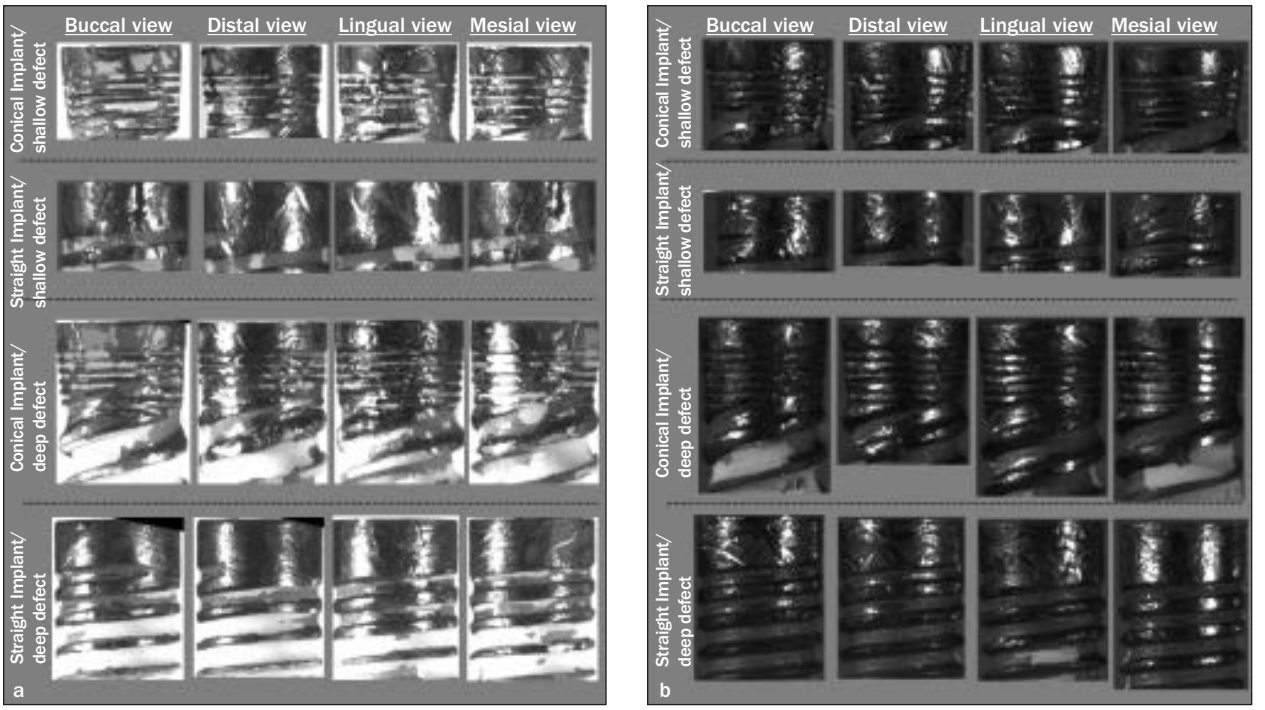

Fig 4 Stereomicroscope view of implants following *(a)* nonsurgical treatment and *(b)* surgical treatment. The implants were retrieved after treatment and viewed under stereomicroscope (×10 magnification). The biofilm-like residues are clearly visible as white remnants.

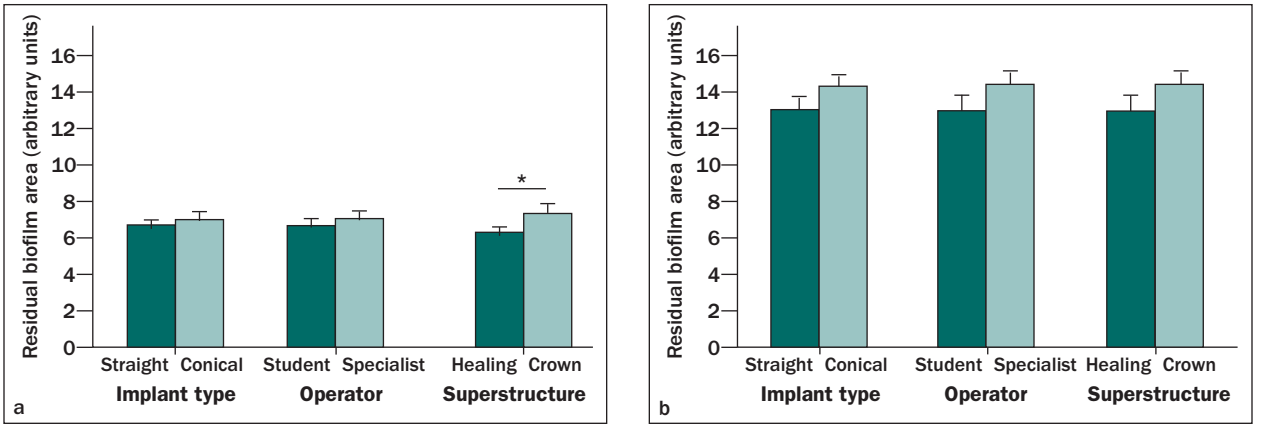

Fig 5 Quantitative analysis of biofilm-like residues of *(a)* shallow defects and *(b)* deep defects following nonsurgical treatment by implant type, operator, and superstructure. Data presented in arbitrary unitsand represents three experimental repetitions. *Statistically significant difference between groups ($P < .05$).

Quantitative Analysis

Comparative analysis was done based on the type of defects (shallow and deep). Nonsurgical treatment of implants with shallow defects resulted in a similar amount of residual biofilm-like material regardless of implant design or operator (Fig 5a). There was a statistically significant difference between the superstructure groups, favoring healing abutment (Fig 5a). However, the magnitude of this difference was small and may be clinically insignificant.

In the deep-defect groups, the amount of biofilm-like material was greater than that observed in the shallow-defect groups (Fig 5b vs 5a). Taking into consideration that the implants in deep defects had a greater area with biofilm-like material, such comparison is not relevant. There was no difference in the residual biofilm-like material between all groups (implant type/operator/superstructure; Fig 5b).

Breakdown of the results according to aspects of the implants (buccal/distal/lingual/mesial) showed similar results as above. Residual biofilm-like material in

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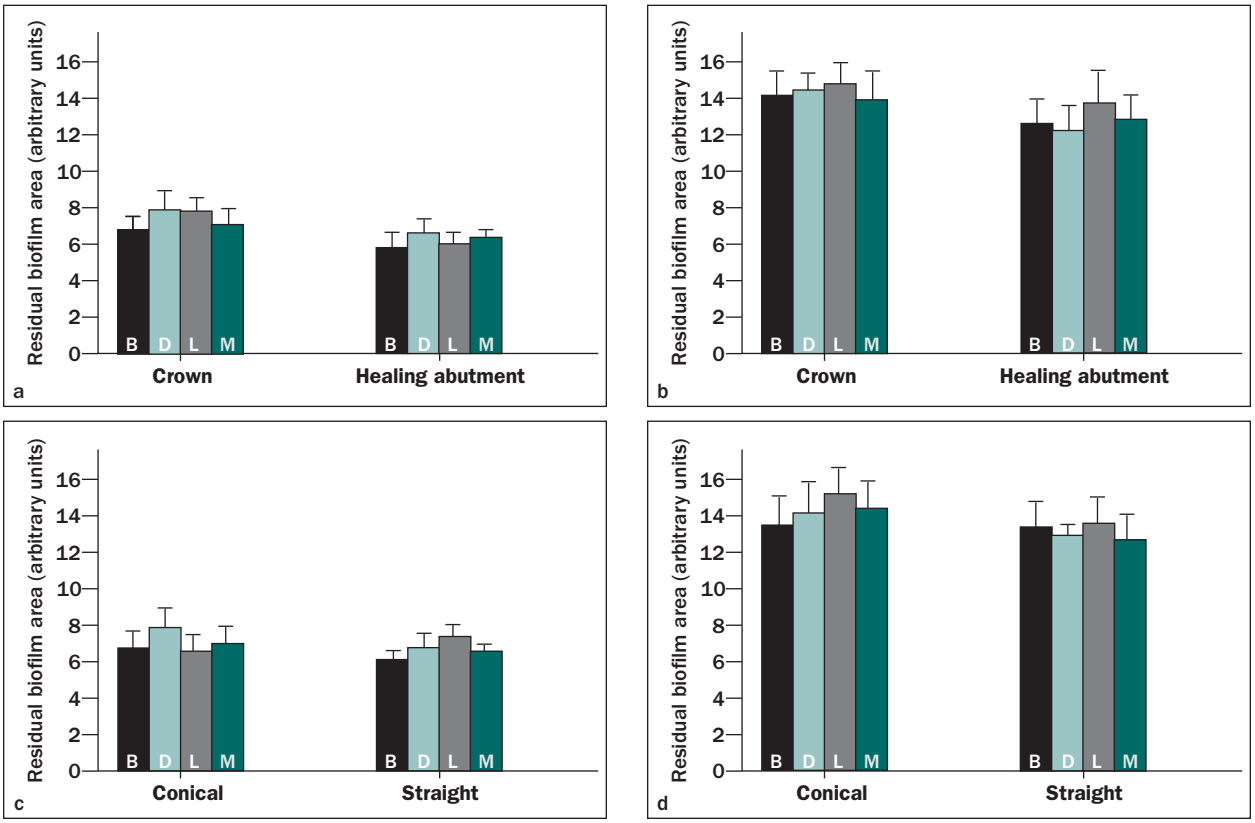

Fig 6 Quantitative analysis of biofilm-like residues by implant aspect (B = buccal; D = distal; L = lingual; M = mesial) of *(a)* shallow defects and superstructure; *(b)* deep defects and superstructure; *(c)* shallow defects and implant design; and *(d)* deep defects and implant design. Data presented in arbitrary units and represents three experimental repetitions.

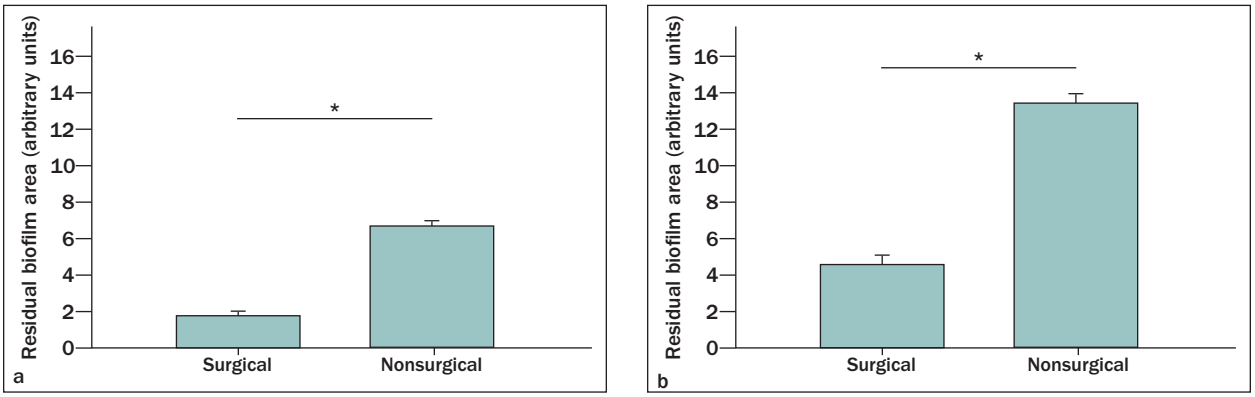

Fig 7 Quantitative analysis of biofilm-like residues of *(a)* shallow defects and *(b)* deep defects following surgical and nonsurgical treatment. Data presented in arbitrary units and represents three experimental repetitions. *Statistically significant differences between groups ($P < .05$).

shallow defects did not differ significantly with respect to superstructure (Fig 6a) or implant design (Fig 6c). Deep defects also showed similar results without a clear difference with respect to superstructure (Fig 6b) or implant design (Fig 6d).

Comparison of the results following nonsurgical vs surgical treatment showed a clear pattern. The amount of residual biofilm-like material in the shallow defects and in the deep defects was statistically significantly lower following flap access (Figs 7a and 7b, respectfully). In the shallow defects, the amount of residual biofilm-like material was lower in the conical-type implants (Fig 8a), while in the deep defects the straight implants showed lower amounts of residual biofilm-like material (Fig 8b).

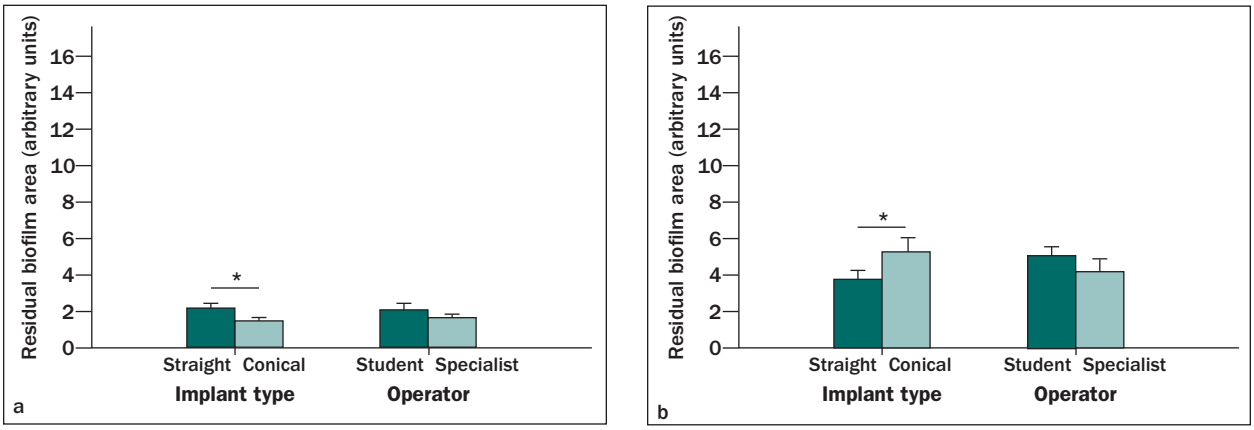

Fig 8 Quantitative analysis of biofilm-like residues of *(a)* shallow defects and *(b)* deep defects by implant type and operator. Data presented in arbitrary units and represents three experimental repetitions. *Statistically significant differences between groups ($P < .05$).

DISCUSSION

This study demonstrated that nonsurgical and surgical approaches using ultrasonic tips for the treatment of peri-implantitis sites were ineffective in their ability to clear biofilm deposits from implant surfaces. Furthermore, the impact of implant design, defect size, operator dexterity, and type of superstructure had little influence on the ability to clean the implants.

In an effort to increase the success rate of peri-implantitis treatment, various suggestions have been made by clinicians, such as replacing the crown of the implants with healing structures before treatment.[22] That approach facilitates better accessibility for instrumentation during treatment and allows proper cleaning of the implant-abutment junction. The current study attempted to single out a most "convenient" setting that would maximize the efficiency of the treatment outcome. Variables that were looked at in the current study included implant design (conical vs straight), superstructure (crown vs healing abutment), clinician dexterity (periodontist vs postgraduate student) and defect depth (shallow vs deep).

Nonsurgical treatment was found to be ineffective in cleaning the implant surfaces at any tested setting. Healing abutments showed mild superiority in shallow defects compared with crowns. However, this difference seems clinically insignificant. Stratification according to implant aspect (mesial, distal, buccal, or lingual) also showed that all aspects had similar levels of biofilm residues. In the current study only an ultrasonic device was used. However, there is evidence of similar effectiveness with the use of other instrumentation. For example, Renvert et al compared the efficacy of nonsurgical treatment with either titanium hand-instruments or an ultrasonic device in humans and did not find a difference between the two methods.[23] Also, Persson et al did not find microbiological superiority of nonsurgical treatment with curettes vs an ultrasonic device.[24] In a dog model, Schwarz et al reported a limited effect of nonsurgical mechanical debridement on the treatment of peri-implant diseases, irrespective of the type of adjunct treatment used.[25] The authors argued that different amounts of residual plaque biofilm areas on implant surfaces might have influenced peri-implant wound healing. Thierbach and Eger found similar results in humans in their comparison of the efficacy of nonsurgical treatment in peri-implantitis sites; their results showed that sites with pus before treatment did not respond to the treatment.[26] These results align with the results of the present study, which indicates that a nonsurgical approach leaves contaminated implant surfaces, leading to a nonideal environment for proper healing. Recently, Muthukuru et al systematically reviewed nonsurgical approaches for the treatment of peri-implantitis; they concluded that basic mechanical treatment is insufficient and that there is evidence that adjunctive methods (such as local delivery of antibiotics, submucosal glycine powder air polishing, or Er:YAG laser treatment) may increase the efficacy of the treatment.[27]

A clear difference was found between nonsurgical and surgical approaches. The surgical approach was superior with regard to the ability to access the implant surfaces for proper cleaning. Nevertheless, the surgical treatment was incomplete and biofilm residues could be found at the apical areas of the defects. Sahrmann et al looked at the cleaning potential of different implant debridement methods in an in vitro model mimicking a surgical approach.[28] In their study, it was found that better cleaning of the implant was feasible in wide defects. Similar to the nonsurgical treatment, none of the tested methods (Gracey curette, ultrasonic device, or air-powder abrasive device) was able to properly clean the implant surfaces. These results align with those of the current study, showing the vague efficacy of mechanical cleaning of implants in osseous defects. Furthermore, the fact that no difference was found between the operators (specialist vs postgraduate student) also substantiates the findings

of Sahrmann et al, which showed limited effect of the operator experience.[28]

Overall, the data from the current study demonstrates the limitation of mechanical debridement of peri-implantitis sites. An effort, therefore, should be made to discover novel approaches for treatment or adjunctive materials that will lead to positive and predictable results of treatment of peri-implantitis.

The current study limitation should be stressed. An in vitro design does not allow inclusion of all variables present in real clinical cases (such as limited visibility of the treated site, bleeding and inflammation, microorganism adhesion to implant surfaces, etc). Furthermore, the current study was done using a standard ultrasonic tip, which is not designed for clearing inter-thread valleys.

CONCLUSIONS

This study highlights the problematic circumstances that occur in the course of cleaning infected peri-implant sites. Although a positive correlation could be observed between defect size and magnitude of uncleaned implant surface, none of the tested variables (including implant design, type of superstructure, and operator dexterity) resulted in higher cleaning ability in a nonsurgical treatment setting. Although a surgical approach increased the accessibility and efficiency of the treatment, the implant surfaces still had residual deposits. Additional cleaning measures (eg, chemical, photodynamic, and biologic agents) should be tested and possibly included in the treatment plan of peri-implant infections.

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