Comparison of the Impact of Scaler Material Composition on Polished Titanium Implant Abutment Surfaces

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Abstract

Purpose: The purpose of this study was to compare the impact of the removal of biofilm with hand scalers of different material composition on the surface of implant abutments by assessing the surface topography and residual plaque after scaling using scanning electron microscopy (SEM).

Methods: Titanium implant analogs from 3 manufacturers (Straumann USA LLC, Andover, Maine, Nobel BioCare USA LLC, Yorba Linda, Cali, Astra Tech Implant Systems™, Dentsply, Mölndal, Sweden) were mounted in stone in plastic vials individually with authentic prosthetic abutments. Plaque samples were collected from a healthy volunteer, inoculated into growth medium and incubated with the abutments anaerobically for 1 week. A blinded, calibrated hygienist performed scaling to remove the biofilm using 6 implant scalers (in triplicate), 1 scaler for 1 abutment. The abutments were mounted on an imaging stand and processed for SEM. Images were captured in 3 randomly designated areas of interest on each abutment. Analysis of the implant polished abutment surface and plaque area measurements were performed using ImageJ image analysis software. Surface alterations were characterized by the number, length, depth and the width of the scratches observed.

Results: Glass filled resin scalers resulted in significantly more and longer scratches on all 3 abutment types compared to other scalers, while unfilled resin scalers resulted in the least surface change ($p<0.05$). Filled resin–graphite reinforced scalers, carbon fiber reinforced resin scalers and titanium scalers resulted in more superficial scratches compared to glass filled resin, as well as more scratches than unfilled resin. No statistically significant differences were found between scalers and abutments with regard to plaque removal.

Conclusion: The impact of scalers on implant abutment surfaces varies between abutment types presumably due to different surface characteristics with no apparent advantage of one abutment type over the other with regard to resistance to surface damage. Unfilled resin was found consistently to be the least damaging to abutment surfaces, although all scalers of all compositions caused detectable surface changes to polished surfaces of implant abutments.

Keywords: scaler, implant, abutment, biofilm, scanning electron microscopy

This study supports the NDHRA priority area, **Health Promotion/Disease Prevention:** Validate and test assessment instruments/strategies/mechanisms that increase health promotion and disease prevention among diverse populations.

Introduction

Long–term studies support the use of titanium implants with titanium abutments to restore edentulous areas and reinforce prostheses for partially or fully edentulous people.[1] While many implant systems have shown multiyear success rates of greater than 90% for fully edentulous patients and partially edentulous patients for both maxillary and mandibular implants,[2,3] there is lack of consensus among primary and secondary outcomes appropriate to evaluating implant outcomes such as implant survival, success or failure.[4] Recent systematic reviews[5,6] assessing the quality of randomized controlled trials (RCTs) published between 1989 and April 2011 and case series published between 2004 and 2008 reported several methodological and statistical flaws affected the reporting of these studies. Thus, it is important to use caution when interpreting the outcomes of the current studies in implant dentistry especially when long term success is being assessed.

For decades, osseointegration and the implant surface facilitating the osseointegration have been the primary goal in implant dentistry. As a results, a range of implant surfaces ranging from machined smooth to rough surfaces, are currently being used in implant dentistry.[7] Despite efforts to improve osseointegration by the modification of implant surfaces, current evidence has shown that bacterial colonization at the gingiva–implant interface can induce mucositis or periimplantitis and jeopardize the long–term success of implant rehabilitations.[8,9] This has

resulted in an emphasis on the surface of the prosthetic abutment as a means of minimizing plaque accumulation; most implant abutments now have a polished surface to eliminate roughness that may serve as a nidus for plaque formation.[10,11]

Although the soft tissue surrounding the tooth and implant resemble each other, there are inherent differences in the connective tissues.[12] There is no evidence for the presence of Sharpey's fibers between an implant or implant abutment and bone, however, a minimum width of peri–implant mucosa appears to be required to allow a stable epithelial–connective tissue attachment to form to the implant surface.[13–15] This width is analogous to the "biological width" around natural teeth as defined by Garguilo.[16] The location of the microgap between the abutment and the coronal aspect of the implant also influences the coronal height of bone contact.[17] The accumulation of pathogenic bacteria in this microgap can have an impact on the long–term success of the implant.[18] Peri–implant mucositis represents the host response of the peri–implant tissues to the bacterial challenge and it is similar to gingivitis representing the host response to the bacterial challenge in the gingiva. Although, both peri–implantitis and periodontitis lesions also have similar etiological factors and show similar clinical features,[19] critical histopathological differences regarding the extent and composition of inflammatory cell infiltration as well as the progression rate of the lesion were reported.[20] In periodontitis, a "protective" connective tissue development was shown as a self–limiting process as opposed to peri–implantitis where this process may occasionally be lacking.[21]

Although peri–implant infections may occasionally be linked to a different microbiota, including high numbers of peptostreptococci or staphylococci, the anaerobic composition of the biofilm is similar to those found in periodontitis.[22] Most importantly, despite similarities of bacterial biofilm formation on implant surfaces and on tooth surfaces, surface roughness might be an important factor influencing the biofilm formation. Mechanical and chemical interventions to disrupt the peri–implant biofilm demonstrate that microorganisms are involved in the disease process. However, there is no evidence that these factors are the origin of the development of peri–implantitis.[21,22] Nevertheless, thorough examination of implant structures at maintenance visits is essential. Changes in implant health can indicate that the implant is ailing or failing, or has failed.[23] As with the natural dentition, the removal of bacterial biofilm and calculus deposits around implants is crucial in the prevention and treatment of peri–implant diseases.[24–26] Previous studies also showed that certain pathological bacteria can induce mucositis and periimplantitis in patients receiving restorations supported with implants.[27,28] Performing professional maintenance regularly along with sufficient home care practices is necessary to maintain healthy implants. The main problem facing the dental professional, however, is removing plaque from implants without damaging the implant surface.[29,30] Previous studies have shown that bacteria attach to scratched or rough implant surfaces with greater affinity,[31,32] however, the efficacy of scaling implant surfaces to reduce inflammation caused by bacteria has been ambiguous when scratching is considered.[33] Scratches caused by scalers likely have a detrimental impact on subsequent bacterial growth due to the increased surface area for attachment.[34] Scratches and gouges are also known to impact the titanium oxide layer and alter the properties of the metal surface and possibly biocompatibility.[24]

Various scalers including plastic, graphite and titanium instruments have been specifically developed for use with implants.[29,35,36] Stainless steel instruments are contraindicated as they contaminate the titanium surface with other metal ions.[37] On the other hand, there is a concern that titanium scalers are sufficiently hard to damage the implant abutment surface, although there is limited data to support or refute this concern and titanium scalers are being widely used.[35] It is also unclear whether there is a qualitative difference between titanium, plastic and graphite scalers in plaque and calculus removal. Material strength, hardness and flexibility are issues in instrument design for subgingival instrumentation – the goal is plaque and calculus removal without abutment surface damage. Roughened implant abutment surfaces caused by different maintenance techniques have not been directly demonstrated to increase implant complications,[38] however, prevention of surface scratching will likely reduce bacterial colonization and the risk for peri–implantitis.

The purpose of the present study was to compare the impact of scalers of different material composition on the surface of three widely–used implant abutments following biofilm removal in vitro, by assessing surface topography of the abutment and presence of residual bacteria using scanning electron microscopy (SEM).

Methods and Materials

Study Materials

The 6 different scaler materials, including an amorphous unfilled resin scaler, a titanium scaler, a filled resin–graphite reinforced scaler, a prototype filled resin–carbon fiber reinforced scaler, a pro-

Table I: The Identification of Scalers Used in this Study

Scaler Names	Hu–Friedy Implacare™ scaler	Wingrove™ titanium scaler	Premier® Universal Implant scaler
Material and Scaler Type	Amorphous unfilled resin scaler; Columbia 4R/4L	Barnhart 5–6 Ti R661	Filled resin–graphite reinforced; Columbia 4R/4L
Manufacturer	Hu–Friedy Mfg, Co, Inc., Chicago	PDT Inc., Missoula, Mont.	Premier Dental, Plymouth Meeting, Penn
Unique ID	Scaler A	Scaler B	Scaler C
Scaler Names	Prototype A	Sabra scaler	Prototype B
Material and Scaler Type	Filled resin–carbon fiber reinforced scaler; a universal curette	Glass filled resin scaler; IS–1	Semi–crystalline unfilled resin scaler; Columbia 4R/4L
Manufacturer		Sabra Dental Products, Deer Park, NY	
Unique ID	Scaler D	Scaler E	Scaler F

totype universal curette, a glass filled resin scaler and a prototype semi–crystalline unfilled resin scaler provided by the sponsor were tested in this study. Detailed information on scaler names, material and scaler types and manufacturers is given in Table I. For ease of identification in the text, scalers are identified by a unique ID as listed in Table I. Fifty–four (18 per implant abutment type) titanium implant analogs and prosthetic abutments (Ti Anatomic Abutment–Straumann LLC, Esthetic Abutment–Nobel BioCare, and TiDesign–Astra Tech, Inc) were purchased from Straumann, Inc, Nobel BioCare and Astra, respectively.

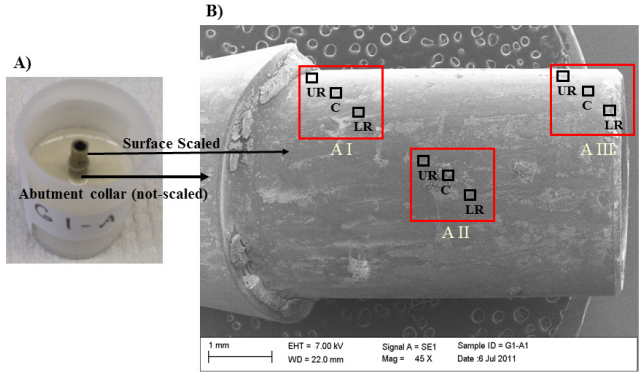
Implant–Abutment Block Preparation

Implant analogs were mounted in stone in individual sterile plastic vials (Nalgene®, Thermo Scientific, Rochester, NY) suitable for biofilm growth (Figure 1). The prosthetic abutments of each type were carefully mounted on the implant analogs. In total, 54 vials containing 3 types of implant–abutment structure (18 mounts/each) were prepared.

Biofilm Growth

Biofilm was grown on the implant abutments from the 3 manufacturers using a standard biofilm growth protocol from human plaque samples.[39] Briefly, Monday morning (baseline), subgingival plaque samples from the buccal and lingual surfaces of anterior and posterior teeth of a healthy volunteer were collected after an 18 hour non–brushing period. Permission to collect dental plaque samples with informed consent was authorized by The Forsyth Institute Institutional Review Board. The samples were placed in pre–prepared sterile culture tubes containing growth medium

Figure 1: Implant Analog–Abutment Mount Placed In Stone Model and a Representative SEM Image of an Abutment Illustrating the Areas of Interest Evaluated



Implant analogs were mounted in stone in a sterile plastic vial submerged with 10 ml growth medium for bacterial growth (see details in Methods and Materials). Images from each abutment were captured at 45X magnification. The abutment surface, "scaled surface", was studied by SEM. At the beginning of the study, the abutment collar surface as shown "non–scaled" was compared to the abutment surface to confirm surface characteristics are the same. On each abutment surface, three areas of interest were captured at 190X (depicted by red squares) and on each of these areas three regions (U=upper, C=center, and L=lower) were imaged at 1,000X and 10,000X (depicted by black squares). The images from each region were used for scratch and residual biofilm measurements.

containing pre–reduced, anaerobically sterilized (PRAS) Ringer's solution (Anaerobe System Morgan Hill, Cali). Ten ml of the medium containing dental plaque was pipetted into the vials submerging abutments, covered with aluminum foil with a loose seal and grown anaerobically for 1 week. The medium was replenished at the third and fifth day to support continuous growth.

Scaling/Instrumentation

On the seventh day of incubation, a trained and calibrated hygienist scaled the surfaces of each abutment for 60 seconds to remove all visible plaque.[34] All 6 scalers were used on each of the 3 implant types in triplicate (3 abutments/abutment type/scaler). Each scaler was used only once to ensure consistent sharpness. During scaling, vertical strokes from the bottom of the abutment to the incisal edge were made using similar force, which was standardized as part of the calibration exercise using a pressure gauge. After scaling, abutments were carefully removed from the implant blanks without touching the abutment surface and processed for scanning electron microscopy. Since the collar of the implant abutment and the abutment surface were polished to the same smoothness, as determined by SEM, the collar of the implant was left untouched and compared with the abutment surface used in this study for surface characteristics after scaling.

SEM Analysis

Immediately after instrumentation with scalers, the abutments were fixed in 4% gluteraldahyde (to fix the bacteria), followed by coating with 2% osmium tetroxide for contrast. The abutments were mounted on imaging stand (flat end pin specimen mount; Zeiss Specimen Mounts) using standard carbon adhesive tapes suitable for SEM imaging.

Each image for each abutment was captured at x45 magnification. Three randomly assigned areas of interest (same area on each abutment) were then captured at x190. The number of scratches/gouges, depth, length and the width of the scratches was measured for 3 predetermined surface areas of interest on each abutment (Figure 1). In addition, the amount of residual plaque was quantified on the surface of the abutments.

For each area of interest, 3 regions (upper, center and lower) were viewed at x1,000 and x10,000. Images from each region were evaluated for number of scratches, greatest scratch width, greatest scratch length, greatest scratch depth and amount of plaque remaining on abutment surface. Quantitative measurements were performed using ImageJ software (NIH image version 1.44, Bethesda, MD). The SEM imaging and measurements were performed by a single investigator calibrated against a gold standard.

Verification of Abutment Surface

SEM images were taken from the abutment surface and the abutment collar to verify the surface characteristics. In each implant abutment type, definitive manufacturing machine marks were apparent that were perpendicular to the direction of scaling on both the abutment and the collar. In each type of implant, the collar and abutment surface characteristics were identical.

Quantification of Scratches

Number, width, length and depth of scratches were evaluated at x1,000 and/or x10,000 magnification in the pre–designated areas of interest using ImageJ software. To quantify the number of scratches, a categorical scratch index was used: 0=none, 1=1 to 3 scratches, 2=4 to 6 scratches, 3=7 to 9 scratches, 4=10 to 20 scratches and 5=>20 scratches. Each abutment type was analyzed separately.

Scratch width was evaluated on x10,000 magnification images. Three points along the widest scratch were measured, and the average value was recorded. Length of the scratches was measured on images at x1,000 magnification. The longest scratch was measured 3 times in micrometers, and the average value was recorded for each specimen.

The depth of the scratch was determined by examining shadows, contour and contrast – the deepest scratches exhibited darker contrast and shadows. The scratch depths were graded on a scale of 1 to 4, with 1=superficial (only through plaque, metal still intact), 2=shallow, 3=moderately deep and 4=deep. Both x1,000 and x10,000 images were used to determine scratch depth.

Overall Comparison of Scalers

Different scaler types were compared in a composite index that was calculated as the mean of the scratch number, depth, width and the log10 of the scratch length for each implant type and across all implants.

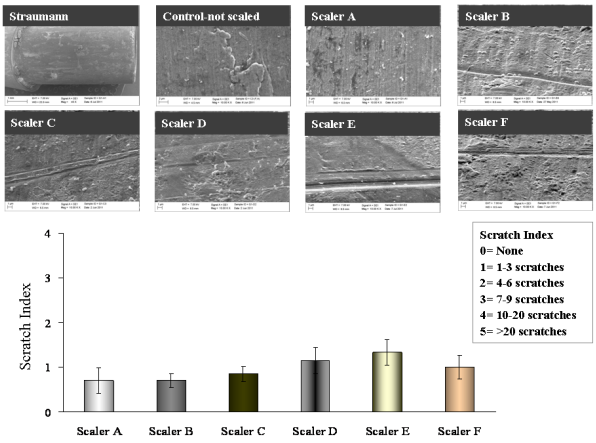
Residual Biofilm

The amount of dental plaque remaining on the abutment surface was measured at x1,000 magnification by a grading scale of 1 to 3, with 1=0 to 30%, 2=30 to 60% and 3=60 to 100%.

Intra–Examiner Calibration

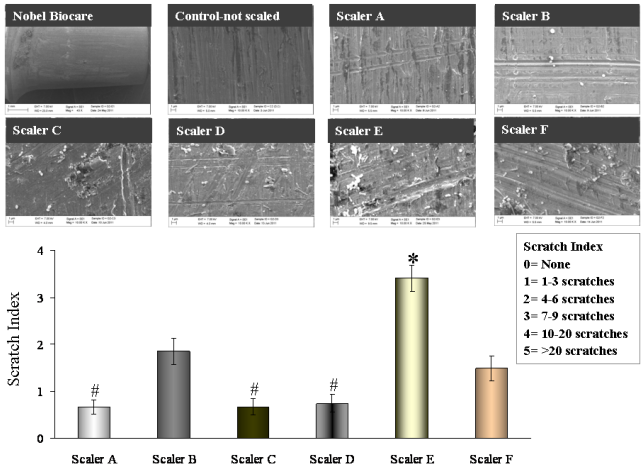
A single therapist performed the instrumentation procedures. The therapist was blinded to the material composition of the scalers and implant abutments used. Importantly, the therapist was blinded to the overall purpose of the study – she was told that it was a plaque removal study. Prior to instru-

Figure 2A: Comparison of Number of Scratches Based on a Scratch Index on Each Abutment Surface Following Scaling With All 6 Scalers Using SEM At x1,000 Magnification



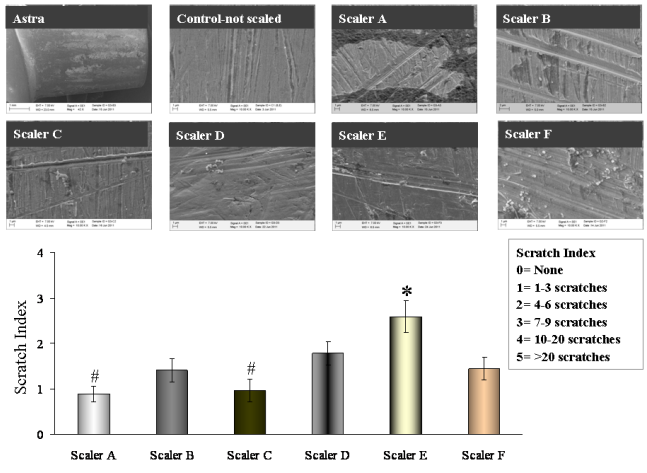
Number of scratches was counted on each Straumann abutment and averages were used for comparisons between scalers. Although the Scaler E and Scaler D resulted in the highest number of scratches, on average, all scalers caused similar scratching on Straumann implant abutments.

Figure 2B: Comparison of Number of Scratches Based on a Scratch Index on Each Abutment Surface Following Scaling With All 6 Scalers Using SEM At x1,000 Magnification



On Nobel BioCare abutment surfaces, Scaler E caused the highest number of scratches compared to all other scalers (*=p<0.05), while Scaler A, Scaler C and Scaler D resulted in significantly fewer scratches compared to Scaler E, Scaler B and Scaler F (#=p<0.05).

Figure 2C: Comparison of Number of Scratches Based on a Scratch Index on Each Abutment Surface Following Scaling With All 6 Scalers Using SEM At x1,000 Magnification



Similar to Nobel BioCare abutments, Scaler E resulted in significantly higher number of scratches on Astra abutment surfaces compared to all other scalers (*=p<0.05). Scaler A and Scaler C, although not statistically significant, were the least harmful to Astra abutment surfaces.

mentation, force applied to the instrument during scaling was standardized using a pressure–gauge. Intra–examiner calibration was calculated for percent agreement between 2 force measurements using Pearson's correlation coefficient.

Statistical Analysis

Six scalers were used on 3 different implant prosthetic abutments. Each scaler was tested on 3 individual abutments from each type of implant abutments. In total, 9 prosthetic abutments were used per scaler type. Assuming a minimum difference of 1 unit in index grading (scratch number and depth) between groups and 80% power at an alpha level of 0.05, a total of 3 scalers per scaler type used on each prosthetic abutment type (n=3) was required. Comparisons of surface scratch area, depth of surface scratches and mean area of residual bacteria were performed using repeated measures of analysis of variance (ANOVA) for within and between group comparisons using the Bonferroni post hoc test for multiple comparisons. A commercially available statistical program (SPSS) was used to analyze the data.

Results

Intra–Examiner Calibration, Instrumentation and SEM Imaging

The intra–examiner calibration for the use of standardized force was demonstrated >95% accuracy and agreement between repeated tests.

Scratch Assessments

Number of scratches: The number of scratches was compared between scalers on each abutment type using a scratch index. Scaler E resulted in the highest number of scratches on all abutment types and all surfaces; the difference was significant only

Figure 3: Evaluation of Scratch Width on Abutment Surfaces Following Scaling With All 6 Scalers Using SEM at x10,000 Magnification

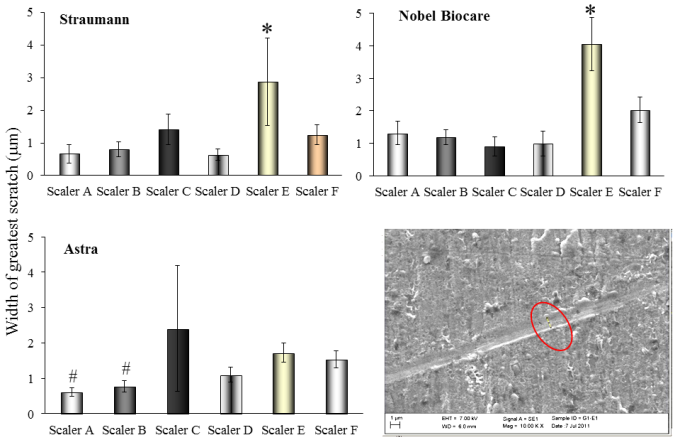
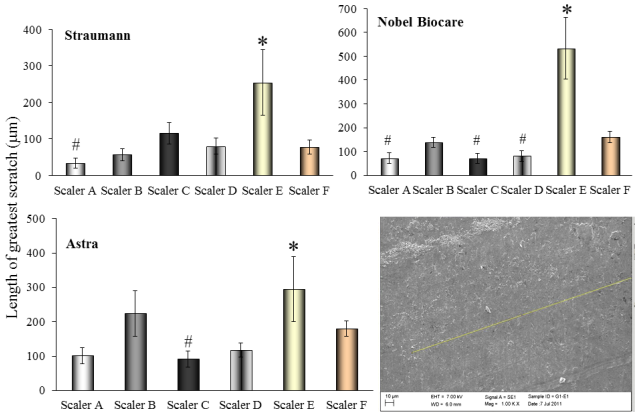


Image J was used to measure scratches at three points along the scratch (depicted by the red circle in micrograph) and the average value was recorded. Consistent with the number of the scratches, Scaler E were notable with the widest scratches observed on Straumann and Nobel BioCare abutment surfaces compared to other scalers (*=p<0.05). Scaler D, Scaler A and Scaler B on Straumann and Scaler C on Nobel BioCare abutment surfaces were the least harmful; the difference was significant only with Scaler C and on Nobel BioCare abutment surfaces (#p<0.05) compared to other scalers. Conversely, in the Astra abutment group, the widest scratches were observed on surfaces scaled with Scaler C although this observation was not consistent within the group, and the difference was not statistically significant. With regard to scratch width, Scaler A and Scaler B similarly showed the smallest scratches on the Astra abutment surfaces compared to all scalers (#p<0.05).

Figure 4: Comparison of Length of Scratches Observed Following Scaling with All 6 Scalers Using SEM at x1,000 Magnification



The longest scratch was measured three times in micrometers (depicted by yellow line on micrograph) using ImageJ and the average value was used in comparisons. Scaler E resulted in significantly longer scratches on all three abutment types (*p<0.05). Scaler B caused long scratches on Astra abutments with no significant difference. Scaler A, Scaler C and Scaler D resulted in short scratches on Nobel BioCare abutment surfaces; the difference was statistically significant compared to Scaler E and Scaler F. Scaler A was the only scaler showing statistically significant differences in scratch length on Straumann abutments (#p<0.05), while on Astra abutment surfaces, Scaler C were associated with the shortest scratches compared to Scaler E and Scaler F (#p<0.05).

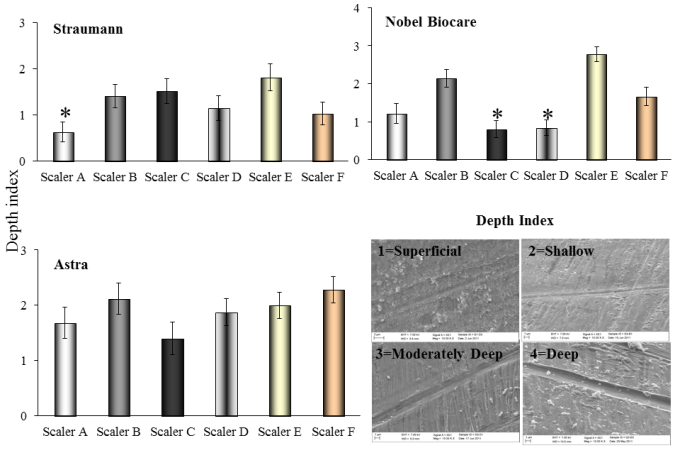
in Nobel BioCare and Astra implant abutments (Figure 2A, B and C, p<0.05) compared to other scalers. On average, all scalers caused similar scratching on Straumann implant abutments (Figure 2A), with slightly more observed on surfaces scaled with Scaler E and Scaler D. On Nobel BioCare abutment surfaces, Scaler E caused significantly higher numbers of scratches compared to all other scalers (*=p<0.05). Conversely, Scaler A, Scaler C and Scaler D resulted in significantly fewer scratches compared to Scaler E, Scaler B, and Scaler F (#=p<0.05) on Nobel BioCare abutments. Similarly, Scaler E resulted in significantly higher number of scratches on Astra abutment surfaces compared to all other scalers (*=p<0.05), whereas Scaler A and Scaler C were the least harmful to Astra abutment surfaces, although the difference was not statistically significant.

Width of Scratches: The mean scratch width was significantly higher with Scaler E on both Straumann and Nobel BioCare implant abutments compared to other scalers (Figure 3, p<0.05). Although the Scaler C appeared be associated with wider scratches, especially on Astra implant abutments, the difference was not statistically significant. Interestingly, the same scaler, Scaler C, was one of the instruments that showed the least damage (narrow scratches) on the Nobel BioCare abutment surfaces together with Scaler D, which showed a statistically significant difference compared to Scaler E and Scaler F (#p<0.05). With regard to scratch width, Scaler A were significantly less detrimental to the Astra abutment surfaces compared to all other scalers (#p<0.05).

Length of Scratches: The length of the scratches was also quantified and the averages were calculated for all scalers on each abutment surface (Figure 4). As with the width and the number of the scratches, Scaler E resulted in significantly longer scratches on all 3 abutment types (*p<0.05). On the Astra abutment surface, Scaler B also created long scratches, but the difference between other scalers was not statistically significant. On Nobel BioCare abutment surfaces, Scaler A, Scaler C and Scaler D resulted in the shortest scratches and the difference was statistically significant compared to Scaler E and Scaler F. Scaler A was the only scaler showing statistically significant differences in scratch length on Straumann abutments (#p<0.05). Similarly, Scaler C resulted in shortest scratches on the surfaces of Astra abutments compared to Scaler E and Scaler F (#p<0.05).

Depth of Scratches: A depth index was used to quantify the depth of the scratches on the scaled sur-

Figure 5: Comparison of Width of Scratches Based on a Depth Index on Each Abutment Surface Following Scaling with All 6 Scalers Using SEM at x10,000 Magnification



Scaler E caused the deepest scratches on most surfaces, but there were no statistically significant differences. On the other hand, Scaler D and Scaler C resulted in the most superficial scratches on Nobel BioCare abutments and the differences were statistically significant compared to other scalers (*p<0.05). On the Astra abutment surface, all scalers caused scratches similar in depth.

faces of each abutment type (Figure 5). Instrumentation resulted in varying degrees of scratch depth on the surface of each abutment type. Although Scaler E was found to cause the deepest scratches on most surfaces, the differences were not statistically significant. Conversely, Scaler D and Scaler C showed the most superficial scratches on Nobel BioCare abutments and the differences were statistically significant compared to other scalers (Figure 5, p<0.05). On the Astra abutment surface, all scalers caused similar scratch depth, while Scaler C showed more superficial scratches, however, the difference was not statistically significant.

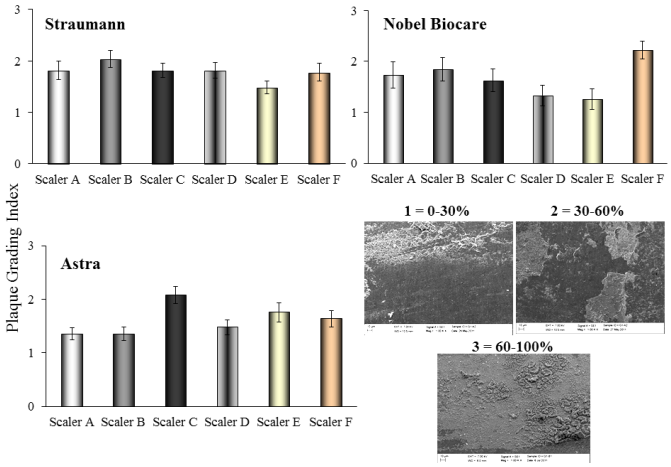
Biofilm Removal Efficiency

The efficiency of scalers in biofilm removal was tested by calculating the area covered by residual plaque in each area of interest on each implant abutment. All 3 abutment types showed similar amounts of biofilm still attached on their surfaces with no difference in efficiency of plaque removal between scalers (Figure 6).

Overall Comparison of Scalers

The composite index was able to show the overall differences between scalers when each of the assessments were evaluated for each of the abutment types (Table II). Among the 6 scalers tested, Scaler E was found to be the most detrimental scaler for all abutment types compared to all other scalers (p<0.05).

Figure 6: The Efficacy of the Scalers in Biofilm Removal from Abutment Surfaces



The area covered by residual plaque was calculated in each area of interest on each implant abutment using ImageJ software. The surfaces from all three abutment types showed similar amounts of biofilm attached on their surfaces with no difference in efficiency of plaque removal between scalers.

While none of the scalers resulted in complete biofilm removal with smooth and non–scratched abutment surfaces, Scaler A caused the least damage to the surfaces of all abutment types and this result was found statistically significant when compared to Scaler E, Scaler B and Scaler F (p<0.05).

Discussion

In this paper, implant polished abutment surface alterations caused by plaque removal with scalers in an in vitro model is reported. The experiment encompassed 6 scaler types across 3 implant types. While no major differences were seen between implant types in susceptibility to scaler caused damage, there was a significant difference between scalers in their ability to scratch the polished surfaces of implant abutments. Interestingly, while all visible plaque was removed by all scalers from all implant abutments, there was remarkable residual plaque on all surfaces examined by SEM. This finding is consistent with the findings of previous reports comparing the efficiency of hand scalers with ultrasonic and sonic scalers in plaque removal from implant surfaces.[40–43] However, it is difficult to compare the results of this study with those studies due to differences in methodology of plaque accumulation. Further, it is important to evaluate the efficiency of in vivo plaque removal of the scalers tested, in order to report the outcomes on plaque removal. This in vitro study evaluated 1 week old biofilm removal from implant surfaces that could be relevant to those clinical conditions where the peri–implant mucosal area is not cleaned daily. The present study aimed to demonstrate the in-

Table II: Overall Comparison of Composite Index for Scratch Number, Width, Length and Depth

Abutment Type	Scaler A	Scaler B	Scaler C	Scaler D	Scaler E	Scaler F
Straumann	0.88±0.43	1.17±0.51	1.46±0.49	1.21±0.52	2.10±0.67	1.29±0.41
Nobel	1.26±0.48	1.83±0.45	1.06±0.53	1.12±0.53	3.24±0.61	1.85±0.33
Astra	1.24±0.58	1.66±0.71	1.68±0.63	1.71±0.42	2.19±0.41	1.89±0.45
Overall	1.12±0.21#	1.55±0.34	1.40±0.31	1.34±0.31	2.51± 0.63 *	1.68±0.34

*Statistically significant compared to all other groups ($p<0.05$)
#Statistically significant compared to Scaler E, Scaler B and Scaler F ($p<0.05$)

fluences of the scalers on various implant surfaces rather than their efficiency in plaque removal. It is known that mechanical and chemical interventions to disrupt the peri–implant biofilm demonstrate convincingly that microorganisms are involved in the disease process and interventions have beneficial effects on the treatment of peri–implantitis.[22] However, the impact of surface roughness or residual biofilm in developing mucositis or peri–implantitis warrant more investigation.

A number of studies have been conducted to evaluate the efficiency and safety of different scaler material compositions on implants.[34,40,44–47] However, there are limited studies comparing these materials on different implant surfaces. Also, many studies evaluate the implant surface rather than the abutment, which is the clinical equivalent of treating a failing implant surface (exposed threads) rather than removing plaque from a polished abutment surface. In general, studies were conducted to test the different scalers and oral prophylaxis methods based on their influence on smooth, rough or coated and uncoated surfaces.[42,48,49] Mengel et al compared various scalers by SEM on 3 different implant and abutment surfaces including Screw–Vent implants (Dentsply), titanium plasma–coated full–screw implants (Straumann) and standard Brånemark implants (Nobel BioCare) in vitro for traces left on and substance removal from the implant/abutment surfaces.[50] The study compared titanium curettes, steel curettes, plastic curettes, rubber cups with Zircate prophy paste, the Cavitron Jet ultrasonic scaler with universal inserts and air polishing nozzles with Prophy–Jet cleaning powder, and the Densonic sonic scaler with SofTip disposable prophy tips and universal tips. The authors found that all instruments apart from the rubber cup and Cavitron Jet air polishing system left pronounced traces of the scaler material at the transition of the implant head to the titanium plasma coating of the full–screw implants.[50] The same authors conducted another in vitro study with uncoated, mechanically smoothed abutments and titanium nitride (TiN) coated abutments treated with titanium, steel and plastic curettes, a rubber cup, an ultrasonic scaler with a steel tip and an air scaler and cleaning powder. SEM was used to determine the extent of traces of instrument material, the roughness depth, and the quantity of titanium or TiN removed from the surfaces.[51] The study showed that the TiN–coated abutments displayed fewer treatment traces, less roughness depth and less surface removal after being treated with various instruments. The steel and titanium curettes and ultrasonic scaler with steel tip, however, caused the detachment of coating and greater initial roughness depth of coated implants.[51] An earlier in vitro study with titanium abutments that were treated with a metal scaler, plastic scaler, rubber cup, rubber cup with tin oxide and an air–powder abrasive reported that metal scalers roughened the titanium surface, while all other modalities tested appeared to smooth the titanium surface by removing surface debris and rounding off the sharp machined grooves present on the untreated abutment surface.[24] Commercially pure titanium and titanium–alloy abutments were used in another study comparing 5 oral hygiene methods: a gold–alloy–tipped scaler, a high–grade resin scaler, a graphite–reinforced scaler, an air–powder abrasive system and a rubber cup with tin oxide slurry to test the outcome of the scaling procedures using SEM.[49] This study introduced a standard force applied to the scalers. Interestingly, all tested hygiene methods either created significant surface alterations or left residual particles on the abutment surfaces, or both.[49]

In the present study, only hand scalers were used on 3 abutment types on smooth polished surfaces of abutments, not the implant screws. Although results of this study are parallel to some of the reported studies detailed above, in some aspects they differ. The tested scalers in the present study have unique characteristics and consisted of so called "innovative" materials (i.e., glass–reinforced or carbon–reinforced resin, etc.) and were expected to be superior or at least as

effective as the old materials, such as unfilled plastic or titanium. However, in some cases, the new materials caused more severe scratching and damage of the implant abutment surfaces tested. There was some variation noted between scaler types based upon abutment manufacturer. Notably, Scaler A, an amorphous unfilled resin scaler, was least harmful to the surface of all 3 abutment types. Our findings are consistent with an earlier in vitro study testing the impact of specific cleaning procedures on the surfaces of 3 implant types with different coatings and shapes (plasma sprayed; hydroxyapatite coated implants and smooth titanium surface screws) using SEM,[42] but this prior study evaluated implant surfaces,[48] not abutment polished surfaces, so the comparison is limited to resistance of apparent surface hardness. Among 6 different hygiene protocols measured, plastic curette, air–powder–water spray with sodium hydrocarbonate solution and chlorhexidine 0.1% solution rinse caused no or little surface damage to titanium surfaces.[42] In another study that compared the difference between smooth surfaces and rough surfaces demonstrated that smooth surfaces on titanium disks (not abutments) are more susceptible to surface alteration and non–abrasive techniques are recommended, while on the rough surfaces, abrasive systems including air–powder polishing and metal curettes were effective in preventing bacterial attachment and less harmful.[38] Overall, our findings are also consistent with an in vivo study (beagle dogs) where 6 different hygiene methods, including scaling with metal and plastic scalers, ultrasonic cleaning, air– and rubber cup–polishing and toothbrush use were tested on Bränemark abutments.[46] Plastic scalers were found to be safer on Bränemark abutment surfaces.

While this study is in vitro and reports removal of in vitro grown plaque that lacks the influence of saliva or width of peri–implant mucosa or location of micro gap, it is clear that caution should be used in the choice and use of hand instruments during maintenance visits for removing plaque from implant abutments. It would still be necessary to conduct further studies evaluating the causes of inadequate access for scaler use or the factors affecting the outcome of hygiene procedures on implant surfaces in in vivo conditions. If the goal is to maintain a smooth, polished abutment surface to discourage reformation of plaque, then the use of hand instruments that can easily cause significant scratching, such as titanium or glass filled resin, should be approached with caution.

Conclusion

Despite the new and innovative technology used in developing new materials to more efficiently and safely remove plaque and calculus from implant abutment surfaces, limitations still exist. In this study, all 6 scalers of different materials resulted in varying degrees of smooth surface alteration with obvious differences between them with regard to surface alteration on 3 different abutment types. Scaler E, a glass filled resin, resulted in significantly more and longer scratches on the abutments tested compared to all other scalers, while an amorphous unfilled resin scaler, Scaler A, showed the least surface alteration to all three abutment types with respect to number, length, width and depth of the scratches observed. Overall, the impact of different scaler materials varied slightly between implant manufacturers presumably due to different surface characteristics of the implant abutments. It may require a careful examination with appropriate dental history and radiographic evaluation to recognize the implants placed in the patient's mouth before making decisions on the prophylaxis systems to be used. Importantly, these findings do not apply to debridement of implant surfaces or the treatment of periimplantitis where rough implant surfaces and exposed thread surfaces are the target of treatment. Further investigation is required to determine the impact of various scaler compositions on rough implant surfaces.

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Acknowledgments

We thank Justine Dobeck for her assistance in SEM sample processing, and Donny Lee for his assistance with ImageJ analysis.

Disclosure

The authors declare no financial interest. This study was supported by Hu-Friedy, Inc. Hu-Friedy provided the scalers tested in this study.

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