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A comparative surface evaluation of orthodontic mini-implants before and after en masse retraction—A SEM study

Alok Ranjan, Pravin Shetty[1], Rahul Despande[1], Anil Biradar[1], Waseem Khan[2] and Rohit Kulshrestha[3]

Abstract

OBJECTIVE: To evaluate the changes in surface morphology of two different types of mini-implants after clinical en masse retraction using scanning electron microscopy.

MATERIAL AND METHODS: Fifty mini-implants of Dentos (Korea, Absoanchor, BH-1817-08) and Orlus (Korea, Yesanchor, C-1817) were inserted in patients in a split-mouth design who required en masse anterior retraction and absolute anchorage. Surface characteristics of mini-implants such as pitch (distance between consecutive threads), flank width (distance between root and crest), and taper were studied using scanning electron microscope (FEI nanosem450) before and after clinical use.

RESULTS: Statistically significant difference (p value = 0.003) was found in a mean reduction of pitch dimension among the two groups with a mean difference of 25.000 μm. Also, a statistically significant difference was noted (p value = 0.001) in a mean reduction of flank width among Dentos implants as compared to Orlus implants. A statistically significant difference (p = 0.001) was seen in the mean reduction of taper dimension among Dentos group (0.0140 ± 0.02271) as compared to the Orlus group (0.0810 ± 0.05152).

CONCLUSION: A marked reduction in surface morphology such as the pitch, flank width, and taper of both mini-implants after retrieval was observed. Dentos group of mini-implants displayed better dimensional stability post-retrieval as compared to the Orlus group of mini-implants. All the mini-screws showed milling defects in form of scratches on observation under scanning electron microscopy despite a smooth appearance to the naked eye.

Keywords:

En-masse retraction, micro-implants, scanning electron microscopy

Department of Orthodontics and Dentofacial Orthopedics, Bharati Vidyapeeth Dental College, Navi Mumbai, [1]Department of Orthodontics and Dentofacial Orthopedics, Vasant Dada Patil Dental College, Sangli, [2]Department of Orthodontics and Dentofacial Orthopedics, Bharati Vidyapeeth Dental College, Navi Mumbai, Maharashtra, India, [3]Private Practice, Aesthetic Dental Center, Abu Dhabi, UAE

Address for correspondence:
Dr. Rohit Kulshrestha, Specialist Orthodontist, Private Practice, Aesthetic Dental Center, Abu Dhabi UAE.
E-mail: kulrohit@gmail.com

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Introduction

Every orthodontic appliance comprises two elements: an active and a reactive element which makes tooth movement possible.[1-3] The orthodontic anchorage can be classified according to the ratio of anterior teeth retraction to posterior teeth protraction. Minimum anchorage situation refers that 75% or more space closure occurs by mesial movement of posterior teeth, and absolute anchorage means that the majority of space closure is achieved by incisors retraction, whereas moderate anchorage situations are relatively symmetrical space closure 50:50.[4,5] It is, therefore, of paramount importance to classify individually each patient according to its anchorage requirement to ensure high-quality care. Unexpected and unplanned anchorage loss frequently results in a compromised finish.

In orthodontic treatment, mini-implants are extremely important as they offer stable anchorage. They provide a force vector favorable to attain various types of tooth movement by preventing unwanted effects and thus improving the control

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of resultant forces during orthodontic treatment. In orthodontic treatment, the teeth are exposed to the different magnitudes of forces and moments, and as per Newton's third law, these acting forces will generate reciprocal forces of the same magnitude but in the opposite direction. To avoid unwanted tooth movement, it is essential to divert these reciprocal forces.[6]

The design of mini-implant head can vary from having an orifice, hook, or button on the tip. The primary and secondary stability of mini-implants is greatly affected by the design of mini-implants. The retention of mini-implant is reliant on implant type, dimension, surface characteristics, insertion angle, insertion torque, force magnitude, anatomic location, root proximity, soft tissue characteristics, and primary stability. The most crucial factor is the availability of high-grade titanium alloy which ensures long-term loading, ease of removal, and patient comfort.[7] The thickness of the titanium oxide layer directly influences the stability of implants in bone.[8]

When implants were first introduced, their surfaces were initially polished smooth. Eventually, they were roughened (e.g., sandblasted, etched) which increased the surface contact area between bone and implant surfaces. Immediate loading in clinical practice could reduce osteointegration and thus leads to soft tissues not enveloping the mini-screw surfaces.[9,10] Manufactures usually supply information on outer diameter, length, and chemical composition. Depth, pitch, and lead angle of the thread and surface characteristics are rarely provided.[11-13] In regard to the retrieval of mini-implants currently, there is very little evidence on the profile of their surfaces during service, including structural alterations and changes in the mechanical properties. This can be decisive for mini-implant success, which relies on stable fixation, fracture resistance as well as the relative ease of removal. To fill this lacuna in literature, this study was done to compare the surface morphology changes of mini-implants by scanning an electron microscope before and after the retraction phase.

Material Methods

This study was a prospective study in which 50 titanium mini-implants of Dentos (Korea, Absoanchor, BH-1817-08) and 50 titanium Orlus (Korea, Yesanchor, C-1817) were used along with their respective mini-implant drivers (Dentos (LHD-B, GH 17 series) and Orlus (OS-DRH-01)). The number of mini-implants was decided by the power analysis which was performed. This study was approved by the Institutes Ethical Committee (VPDC/RES/2019/xxx). Power analysis was done to determine the sample size. The surface of mini-implants was evaluated by a scanning electron microscope (FEI nanosem450). Fifty subjects who fulfilled the criteria were selected for each group (26 males and 24 females). They belonged to the Indo-Aryan race, and their mean age was - 25.4 +-3.5 years. On explaining the study, a signed consent form was taken from the selected patients.

The criteria for inclusion and exclusion were as follows:

Inclusion criteria

a. Cases diagnosed and determined to treat with maximum anchorage protocol.
b. Extraction of all four first premolars.
c. Average to horizontal growth pattern.

Exclusion criteria

a. Cases diagnosed and chosen to treat with non-extraction treatment planning.
b. Cases diagnosed and chosen to treat with minimum anchorage.

Fifty subjects with malocclusion who required maximum anchorage were chosen. Surface characteristics of mini-implants including pitch (distance between consecutive threads), flank width (distance between root and crest), and taper were scanned [Figure 1]. Before clinical use, several areas of the head surface, trans-mucosal profile, and active thread of one mini-implants from both companies were scanned. Microscopic images were taken from the camera EOS 1200D EF-S 18-55 IS.

MBT 0.022 prescription brackets (Victory series, 3M Unitec USA) were bonded on the teeth and wire sequencing started from 0.014 Niti till 19 × 25 SS wires were reached as described by the MBT technique. Mini-implants of Dentos and Orlus (1.8 x 8 mm) were placed using a mini-implant driver by the same operator as per protocols followed by Marigo *et al*.[5] [Figure 2]. Dentos mini-implants were inserted between the second pre-molar and first molar on the right side of the maxilla, and Orlus mini-implants were inserted in the same region on the left side of the maxilla in the same patient. All mini-implants were inserted following the same procedure. Anesthesia—before insertion of local anesthesia, the oral cavity is thoroughly rinsed with 15 ml of 0.12% chlorhexidine (CLOHEX Plus) to reduce the intraoral bacterial flora. The mini-implants were inserted in the patients one month before the retraction phase. This was done to assess the stability of the micro-implant before starting the retraction. The average duration for retraction was 12+- 2.3 months. En masse retraction was carried out using power chains, and 200 gms of force was given. None of the implants failed. On completion of retraction, the mini-implants were removed and were cleaned by enzymatic

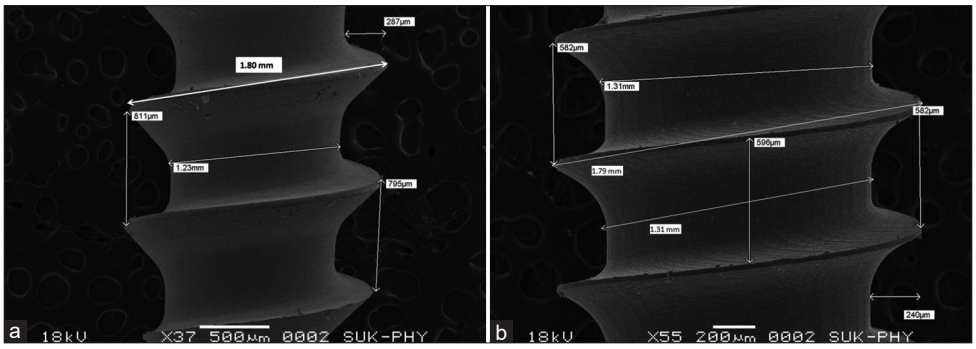

Figure 1: (a) SEM scan for Orlus mini-implant, (b) SEM scan for Dentos mini-implant

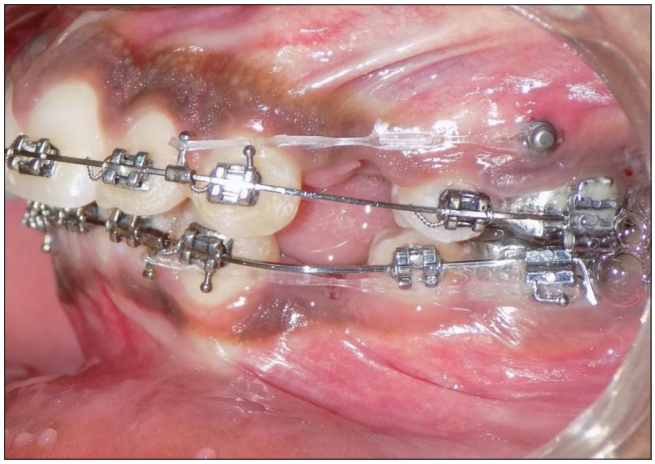

Figure 2: En mass retraction using mini-implants

detergent (Zymokleen) and distilled water [Figure 3]. The mini-implants were inspected by scanning electron microscope using different magnification before and after placement. Many areas of the head surface, trans-mucosal profile, and active thread were inspected.

The morphology of samples before and after use was compared to assess surface alterations in mini-implants after clinical use and on contact with the oral environment. The threads of mini-implants were counted, and the shape and dimensions of several parts of mini-implants were measured to accurately compare the pre- and post-changes. The pitch, flank width, and taper were also subsequently measured. The difference between the largest and smallest diameter of the thread divided by the length of the active part gave the taper value.

Statistical analysis

A master file was made, compiling all the data. It was then statistically analyzed using the Statistical Package for Social Sciences software (version 17) (SPSS Inc. Released 2008. Chicago: SPSS Inc). The data were subjected to descriptive analysis for mean, standard deviation, and 95% confidence interval. "P" value less than 0.05 was considered to indicate a statistically significant association. An Independent "t" test was performed for intergroup comparison.

Results

The mean difference and standard deviations of pitch dimension, flank width, and taper after insertion in Dentos and Orlus groups are shown in [Table 1]. A statistically significant difference (p = 0.003) was seen in the mean reduction of pitch dimension among Dentos (28.1000 ± 12.44053 um) as compared to Orlus (53.1000 ± 19.51894 um) [Table 2]. Statistically, a significant difference was seen in the mean reduction of flank width dimension among Dentos (32.7000 ± 28.11899 um) as compared to the Orlus group (74.6000 ± 47.31267 um) with *P* value = 0.027 [Table 3]. A statistically significant difference with *P* value = 0.001 in mean reduction of taper dimension was seen between Dentos group (0.0140 ± 0.02271 um) and the Orlus group (0.0810 ± 0.05152 um).

Discussion

In the following study, we compared the surface morphology of two different mini-implants before and after retraction in orthodontic treatment. The pitch, flank width, and taper of mini-implant were compared individually as well as the intergroup comparison was also done. A thorough understanding of biomechanical principles involved in the application of micro-implants should be known, and the complete assessment of anchorage should be evaluated at the start of the treatment.[10,13]

The factors which govern the stability of implants are material properties, angle of insertion, method of implant placement, the diameter of implants, insertion torque, and profile of implant surface.[14] But, very few studies have been carried out on the profile of the implant surface during placement, including structural alterations and changes in the mechanical properties. In the present study, it is shown that after retrieval of implants, there are significant changes seen in the different parts of

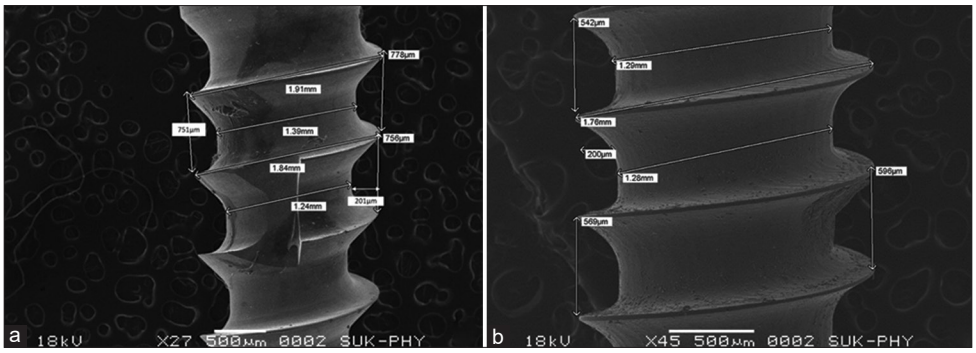

Figure 3: Mini-implants post-retrieval and SEM of the pitch, flank, width, and taper post-retrieval (a. Orlus group, b. Dentos group)

Table 1: Descriptive statistics for pitch, flank width, and taper in µm among both groups (DENTOS and ORLUS)

Group	*n*	Minimum	Maximum	Mean	Std. Deviation
Dentos					
Baseline Pitch	01	582	582	582.00	0.000
After Pitch	50	538	575	553.90	12.441
Baseline Flank Width	01	240	240	240.00	0.000
After Flank Width	50	133	235	207.30	28.119
Baseline Taper	01	0.4800	0.4800	0.480000	0.000
After Taper	50	0.4300	0.4900	0.466000	0.0227058
Orlus					
Baseline Pitch	01	811	811	811.00	0.000
After Pitch	50	719	780	757.90	19.519
Baseline Flank Width	01	287	287	287.00	0.000
After Flank Width	50	141	280	212.40	47.313
Baseline Taper	01	0.5700	0.5700	0.570000	0.000
After Taper	50	0.4000	0.5600	0.489000	0.0515213

n- Number of implants, std - Standard, unit of all parameters - um

implants like pitch, flank width, and taper. Surface structural alterations including adsorption of a calcified integument as a result of contact of the implants with biologic fluids were also observed.

A study was conducted by Patil *et al*.[15], on the morphologic, structural, and compositional alterations seen in used orthodontic mini-implants with the help of optical microscopy, they found that there is change in hardness and loss of gloss seen with various discolorations. The scanning electron microscopic images showed the materials precipitated on the surfaces were sodium, potassium, chlorine, iron, calcium, and phosphorus on the contact of the implant with biologic fluids such as blood and exudates forming precipitates like sodium chloride, potassium chloride, and calcium phosphorus. This study also suggested that there was discoloration with loss of gloss and significant changes in surface example irregularities like porosity, cracks, and reduction in taper width and pitch dimensions.

Placement of the implant in an intraoral site induces various phenomena, such as reduction of the pH of the early exudative phases; activation of cells including polymorphonuclear granulocytes and macrophages; and the release of proteins, enzymes, and oxidizing agents that might significantly modify the mini-screw implant surface reactivity.[16]

Cho *et al*.[17] evaluated several parameters like active tip width, mini-implant external diameter, the minor diameter of the internal thread, percentage of the minor diameter of the internal thread to external diameter, number of threads, pitch, angle of thread, flank width, pitch width, and taper to check the mechanical retention of the metallic structures of implants on the cortical and dense bone. In the current study, there is a statistically significant difference in the pitch dimension of the Dentos group before insertion and post-retrieval which affects the primary stability of mini-implants. A statistically significant difference in the pitch dimension is seen in the Orlus group after retrieval of implants along with physical features like loss of variation in color, gloss, and surface polish. On exposure to the oral environment, changes were observed in the head and thread of the screw.

Evaluation of flank width in the present study showed that there is a statistically significant difference in the Dentos group from the baseline. This signifies that the reduction in dimension of flank width was due to the resistance offered by maxillary bone during insertion of mini-implants and the orthodontic load which was applied during the retraction phase. There was a statistically significant difference found in the Orlus group in flank width of -74.600 µm which shows a marked reduction in dimension of flank width after retrieval of mini-implants. It is therefore important to take care during the insertion of mini-implants. Rapid insertion can damage the flank width. Failure of implants can occur as a result of an increased amount of heat generation due to increased insertion torque.[18]

The tapered part of the mini-implant is highly susceptible to fracture, and the same portion also provides retention.

Table 2: Comparing mean reduction of pitch value among DENTOS and ORLUS group

Groups	PITCH (in µm) Mean±SD	Mean Difference	*t*	df	*P*	CI (95%)	
						Lower	Upper
Group A							
Dentos	28.1000±12.44053	-25.00000	-3.416	18	0.003*	-40.37777	-9.62223
Group B							
Orlus	53.1000±19.51894						

CI - confidence interval *Statistically Significant, all parameters in um

Table 3: Comparing Mean Reduction of Flank width and Taper Value among DENTOS and ORLUS group

Groups	Flank Width (in µm) Mean±SD	Mean Difference	*t*	df	*P*	CI (95%)	
						Lower	Upper
Group A							
Dentos	32.7000±28.11899	-41.90000	-2.407	18	0.027*	-78.46550	-5.33450
Group B							
Orlus	74.6000±47.31267						
Groups	**TAPER Value (in µm) Mean±SD**	**Mean Difference**	***t***	**df**	***P***	**CI (95%)**	
						Lower	**Upper**
Group A							
Dentos	0.0140±0.02271	-0.06700	-3.763	18	0.001*	-40.37777	-9.62223
Group B	0.0810±0.05152						
Orlus							

CI – confidence interval *Statistically Significant, all parameters in um

A study carried out by Chen *et al*.[19] on the design of active tip taper shows that the resistance to fracture can be increased with conic design and with appropriate screws for self-drilling. Suzuki *et al*.[20] showed that the highest value of insertion torque was seen in conical screw although, and there is no correlation between the design of the mini-implant and the pull-out strength. In this study, it has been found that the taper of Dentos mini-implant was conical and no statistically significant difference was found post-retrieval of mini-implants. The taper dimension of Orlus mini-implants shows a statistically significant difference.

The metal surface is covered with a layer of protein, depending on patient and oral conditions. This conceals the surface topography of the alloy, the extent of the protein varying according to the conditions prevailing in the mouth of each patient as stated in the study done by Cho *et al*.[21] The morphology, surface composition, and electronic reactivity of the mini-implants surface layer are significantly altered by this. So, in the present study, we have also compared the surface profile of two different mini-implants that is Dentos and Orlus manufactured by different manufacturers with the same diameter.

There is a statistically significant difference with a *P* value of 0.003. The mean reduction in pitch dimension among Dentos is 28.1000 ± 12.44053 as compared to Orlus which is 53.1000 ± 19.51894 with a mean difference of 25.000 µm. This suggests that Dentos has better post-insertion dimensional stability for pitch as compared to Orlus. Primary stability mainly depends on the number of threads, thread shape, and pitch. Primary stability is directly proportional to the number of threads. As the number of threads increases, the implant–bone contact increases thereby friction force, resistance to displacement increase. Although both mini-implants had the same length, the number of threads was more in the Dentos group as compared to the Orlus group, which aided more in primary stability. The other parameter which affects primary stability is the flank width dimension which was compared between both the mini-implant groups.

There was a statistically significant difference between flank width dimensions with a *P* value of 0.003. Mean reduction of 32.7000 ± 28.11899 in the Dentos group was noted as compared to Orlus that is 74.6000 ± 47.31267. This suggested that there is more reduction in flank width of the Orlus group as compared to Dentos. Similarly, there is a marked reduction in taper value of the Orlus group (0.0810 ± 0.05152) as compared to the Dentos group (0.0140 ± 0.02271). Mechanical stability of Dentos group was higher than that of the Orlus group.

The mini-implant assessment was based on the shape of body, surface, pitch, taper, and number of threads. Mini-implants may suffer biodegradation due to toxic metal ions released into the oral cavity.[22] Several factors contribute to the degradation of the mini-implants like chemical composition of implants, the surface morphology of implants, chemical composition of saliva, biofilm, pH of the oral cavity, protein adsorption, physical and chemical properties of consumed food, medicines taken by patients, and oral hygiene habits.

Mini-screw surface corrodes in contact with the electrolyte because of the composition of biological fluids. Surfaces are much more rapidly corroded when mini-screws are loaded during service. Observation under optical microscopy showed signs of corrosion in the form of pitting or crevices principally on account of milling defects. Corrosion not only alters the nature of the surface but also the resistance and other properties of the material. In addition to it, products of corrosion can result in the formation of the fibrous capsule and chronic inflammation. The release of this in neighboring tissues may induce local and systemic reactions. The ideal biomaterial for mini-screw implants should have excellent corrosion resistance, biocompatibility, and sufficient mechanical strength to enable orthodontic mini-screws to withstand the torsional forces during insertion and removal. Though mini-screws often break at the neck in clinical practice, such fractures are often the result of miniscrew design.[23]

Zogheib *et al*.[24] did a study to evaluate the quality of surface finish, degree of contamination before and after use along with surface treatment of titanium orthodontic mini-implants (OMIs). They found out that after clinical use, OMI surfaces are additionally contaminated and sand-blasted mini-implants produce increase in surface roughness. Similar results were seen in the current studies which show wear and tear of the mini-implants. A similar study done by Maino *et al*.[25] shows that sand-blasted acid-etched surface of mini-implants has higher retention in bone due to surface roughness, and changes in surface characteristics need to be further investigated. Our study shows these changes in an *in vivo* scenario.

The stability of mini-implants not only depends on the surface morphology but also on other parameters like the site, cortical bone thickness, insertion torque, bone density, etc. The quality and make of the mini-implant are also of great importance. Many manufactures make mini-implants using substandard materials and protocols. These implants are more prone to fail in clinical conditions. Hence, the mini-implants used should be of the highest quality and finishing to obtain the best clinical results without causing any harm to the patients. As this study analyzes the surface morphology of the mini-implants which acts as the only entity for determining post-retention stability, other studies should be done to find out about the other parameters which will aid to bring about more stability of mini-implants.

Conclusions

- There is a marked reduction in surface morphology such as the pitch, flank width, and taper of mini-implant after retrieval in both types of mini-implants.
- The Dentos group of mini-implants showed better dimensional stability post-retrieval than the Orlus group of mini-implants.
- Despite a smooth appearance to the naked eye, all the mini-screws displayed milling defects in form of scratches when observed under scanning electron microscopy.

The association of the ideal characteristics of mini-implants morphology will allow the conscious and substantiated choice for its use in several clinical applications for orthodontic treatment.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent forms. In the form, the patient(s) has/have given his/her/their consent for his/her/their images and other clinical information to be reported in the journal. The patients understand that their names and initials will not be published and due efforts will be made to conceal their identity, but anonymity cannot be guaranteed.

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Nil.

Conflicts of interest

There are no conflicts of interest.

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