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ORIGINAL RESEARCH

SURFACE AND ELEMENTAL ANALYSIS OF TITANIUM MINISCREW IMPLANTS (FAVANCHOR AND ORLUS) AFTER CLINICAL USE IN ORTHODONTICS: A SCANNING ELECTRON MICROSCOPY AND ENERGY DISPERSIVE X-RAY MICROANALYSIS STUDYSanya Dua¹, Rajaganesh Gautam², Sonali Deshmukh³, Asmita Kharche⁴, Swathi PV⁵, Jayesh Rahalkar⁶¹Postgraduate Student, Department of Orthodontics and Dentofacial Orthopaedics, Dr. D. Y. Patil Vidyapeeth, Dr. D. Y. Patil Dental College and Hospital, Pimpri, Pune-411018, India sanyadua1001@gmail.com²Head of the Department and Professor, Department of Orthodontics and Dentofacial Orthopaedics, Dr. D. Y. Patil Vidyapeeth, Dr. D. Y. Patil Dental College and Hospital, Pimpri, Pune-411018, India rajaganeshgautam@yahoo.co.in³Professor, Department of Orthodontics and Dentofacial Orthopaedics, Dr. D. Y. Patil Vidyapeeth, Dr. D. Y. Patil Dental College and Hospital, Pimpri, Pune-411018, India sonalivdeshmukh@gmail.com⁴Associate Professor, Department of Orthodontics and Dentofacial Orthopaedics, Dr. D. Y. Patil Vidyapeeth, Dr. D. Y. Patil Dental College and Hospital, Pimpri, Pune-411018, India asmitakharche@gmail.com⁵Assistant Professor, Department of Orthodontics and Dentofacial Orthopaedics, Dr. D. Y. Patil Vidyapeeth, Dr. D. Y. Patil Dental College and Hospital, Pimpri, Pune-411018, India swathi.vibha@gmail.com⁶Professor, Department of Orthodontics and Dentofacial Orthopaedics, Dr. D. Y. Patil Vidyapeeth, Dr. D. Y. Patil Dental College and Hospital, Pimpri, Pune-411018, India jayeshrahalkar@gmail.com**Corresponding Author:** Rajaganesh Gautam, Head of the Department and Professor, Department of Orthodontics and Dentofacial Orthopaedics, Dr. D. Y. Patil Vidyapeeth, Dr. D. Y. Patil Dental College and Hospital, Pimpri, Pune-411018, India rajaganeshgautam@yahoo.co.in rajaganeshgautam@yahoo.co.in*Received: May 25, 2025; Accepted: Jun 25, 2025; Published: Jun.30,2025***ABSTRACT**

Background: Titanium miniscrew implants (MSIs) are widely used in orthodontics as temporary anchorage devices. However, these implants are susceptible to mechanical and chemical alterations during their clinical use. This study investigates the surface and elemental changes in two brands of titanium miniscrew implants, Favanchor and Orlus, after clinical exposure, utilizing Scanning Electron Microscopy (SEM) and Energy Dispersive X-ray (EDX) microanalysis.

Methods: Twenty titanium miniscrew implants (10 Favanchor and 10 Orlus) were retrieved after being used in patients for at least six months. Control samples of each implant type were analyzed in their as-received state. SEM was employed to assess the surface morphology, while EDX provided elemental composition data. Flexural strength was also measured using a Universal Testing Machine.

Results: SEM analysis revealed significant surface alterations in the retrieved implants, including dullness, blunting of threads, corrosion, and fractures. The retrieved Favanchor implants showed more severe damage, particularly in the body and tip regions. Elemental analysis indicated the presence of additional elements such as calcium, iron, cerium, and oxygen, which were not present in the as-received implants. The comparison of flexural strength revealed a significant reduction in strength for both implant brands, with Orlus showing less degradation than Favanchor. In particular, the flexural strength for the retrieved Favanchor implants was lower compared to the Orlus implants, indicating more significant mechanical degradation.

Conclusion: Both implant brands exhibited substantial surface degradation and elemental composition changes after clinical use, with Favanchor showing more severe damage. These alterations highlight the need for careful consideration when reusing miniscrew implants in clinical practice, particularly in terms of their structural integrity and elemental composition.

Keywords: Corrosion, Energy Dispersive X-ray, Flexural Strength, Scanning Electron Microscopy, Titanium Miniscrews

INTRODUCTION

With the advent of titanium miniscrews transforming the orthodontic landscape in the last two decades, enabled clinicians for the establishment of stable intraoral anchorage to accomplish enhanced therapeutic results¹. These devices are small, simple for the insertion and removal, thus allowing for immediate loading reducing overall treatment time thus making the treatment economical^{2,3}. With these devices, moderate to severe skeletal abnormalities of the patient are able to be overcome with tooth movements previously thought unattainable. Results with mini-screw implant supported anchorage are seen to be more predictable than other types of compliance dependent anchorage. The pioneering of skeletal anchorage use as in the form of Vitallium screw placement in the mandibular rami of dog mandibles can be credited to Gainsforth and Higley⁴. Similarly, in 1983 osteosynthesis surgical bone screws were used for the intrusion of maxillary incisors by Creekmore and Eklund⁵. Specific orthodontic application mini-implants with 1.2mm diameter were introduced by Kanomi in 1997 [6]. MSIs contain grade V titanium alloy - Ti-6Al-4V comprising of 6% aluminium, 4% vanadium, 0.25% (maximum) iron, 0.2% (maximum) oxygen, and Ti which gives it enhanced strength thus making it more durable for its use in implant placement. Grade 5 machined titanium leads to enhanced cellular adhesion and proliferation with a strong cytocompatibility; yet lacks osseointegration leading to easier removals as necessary for temporary anchorage devices^{8,9}.

Mechanical failure in the oral environment leads to MSIs being fractured occasionally with causation of gingival injuries as documented which have to be either removed or replaced¹⁰. The effectiveness is influenced by a number of parameters such as implant macro and microstructure qualities, implantation site characteristics and patient selection¹¹⁻¹³. Also due to the formation of stable passive titanium oxide layer, they have been observed to undergo corrosion during clinical use¹⁴.

Energy Dispersive Spectroscopy (EDS) and Scanning Electron Microscopy (SEM) are two complementary techniques used to characterize material surfaces. With their combination, analysis of elemental composition and visualization of surface features at high magnification is possible. EDS analyzes the elemental composition of a material by detecting X-rays emitted when the material is irradiated with an electron beam thus providing compositional information on a micro- or nanoscale. SEM uses an electron beam to produce a high-resolution surface image by interaction of electron beam with specimen atoms leading to scattering, leading to the release of

electrons and X-rays which are then detected and used to create a surface image¹⁵. These techniques have diverse applications in forensic science, failure analysis, quality control and materials research. The clinical result of these can be enhanced by carrying out implant retrieval analyses.

This study aimed to use SEM and EDS to conduct surface and elemental investigations of two distinct retrieved titanium miniscrew implants which are most commonly used in local population with the primary objective being investigation of how the tiny implant behaved when it came in contact with food, mouth fluid, surrounding tissues, and bone. This study aimed to analyze alterations in the surface morphology, elemental composition and flexural strength of 2 brands of miniscrew implants (Favanchor and Orlus) before and after clinical use.

MATERIALS AND METHODS

This in-vitro study utilized convenience sampling to select 20 samples of miniscrew implants, which were used for orthodontic treatment in patients treated at the Department of Orthodontics and Dentofacial Orthopaedics, Dr. D.Y Patil Dental College and Hospital, Pimpri, Pune. This study was approved by the Institutional Ethical Review Committee (Ref: DPU/806/9/2023). A waiver of consent was granted in accordance with the ICMR Ethical Guidelines 2017.

Inclusion criteria for the selection of the patients from whom the retrieved mini-screw implants used for testing was those who needed temporary anchorage devices during corrective orthodontic treatment for maxillary space closure for a minimum of 6 months. The exclusion criteria consisted of failed implants, patients with syndromes or autoimmune diseases, those who were pregnant or lactating, and individuals on medications such as antibiotics, antihistamines, cortisone, hormones, or any other medication that may interfere with the inflammatory process or adversely affect the periodontium.

Self-drilling orthodontic miniscrew screw implants of two commercially available brands were used in this study. They were divided into two groups: Group I: Favanchor, S.H.Pitkar Ortho tools Pvt Ltd, Pune (10 samples: 1 Favanchor miniscrew in as received state which acted as the control and 9 Favanchor miniscrews which were retrieved after their use in patients undergoing orthodontic treatment which formed the test group) and Group II: Orlus, Ortholution, Korea (10 samples: 1 Orlus miniscrew in as received state which

acted as the control and 9 Orlus miniscrews which were retrieved after their use in patients undergoing orthodontic treatment which formed the test group).

Thus, a total of 20 mini-screw implants were used. One miniscrew implant from each manufacturer was analysed with a scanning electron microscope in the as received state, and 18 miniscrew implants were retrieved ones which were retrieved after their use in patients. These mini screw implants were used in patients following consistent guidelines mentioned below.

A standardized clinical protocol was employed for the placement and utilization of all miniscrew implants, with a single operator executing the procedure in accordance with established departmental guidelines. The miniscrew implants were inserted and removed by the same operator, who followed the placement protocol recommended for a self-drilling miniscrew - implant. The miniscrew implants were retrieved after completion of their role in the orthodontic treatment of each patient. After removal, each retrieved miniscrew implant was washed gently and stored by completely immersing in fresh deionized water in an autoclaved glass vial that was duly labelled.

Thus the 20 samples were subjected to the following analysis:

1. Energy dispersive x-ray microanalysis (EDX) using Bruker XFlash 6130
2. Scanning electron microscopy (SEM) using FEI Nova NanoSEM 450
3. Flexural strength analysis was by using Universal Testing Machine (ACME Engineers, India. Model No. UNITEST-10).

One miniscrew implant from each manufacturer were subjected to the tests (SEM, EDX and Flexural strength analysis) before clinical use and 18 miniscrew implants (9 each from the two brands being tested) were inserted into patients. The miniscrew implants were placed in maxilla and were immediately loaded as per protocols used in the department according to the treatment plan. Implants were retrieved from the oral cavity after their role is completed in orthodontic treatment of each patient. Implants were gently washed and stored completely immersed in fresh deionized water in an auto-claved glass vial duly labelled. The miniscrew implants were examined using SEM for evaluation of their surface topography and digital images were acquired at different magnifications. Composition of elements adsorbed on the miniscrew implant

surface were evaluated with an EDX coupled to the SEM. Flexural strength were determined by using universal testing machine. Results from the three tests were analysed and subjected to intra-group and inter- group comparisons to assess the miniscrew implants' alterations after clinical use and contact with the oral environment. Analyses by energy dispersive x-ray microanalysis (EDX) and scanning electron microscopy (SEM) were done at 4 zones of each MSI: head, neck, body, and tip (Fig 1).



Figure 1. Showing mini-screw implants mounted on aluminium supporting discs using double carbon sided tape under the microscope.

SEM of all the samples was done under **FEI Nova NanoSEM 450** at an operating voltage of 15 kV with the miniscrew screws mounted on aluminium supporting discs using double carbon sided tape. Alterations of the surface such as crevice corrosion, corrosion surface damages, dullness, cracks, craters, fractures and blunting, were looked for in each zone.

Surface alterations categorised in this study were as follows:

- Craters: formation of cavities or holes
- Cracks: lines on the surface indicating splitting without separation
- Fracture: cracking or breaking of the material
- Dullness: loss of glossiness and finish
- Blunting: loss of sharp edges of the threads or the tip
- Corrosion Damage: crevice-like geometric patterns, pitting and fretting.

Each zone of every sample was scored with presence (1) or absence (0) for each of the attributes mentioned above. The maximum score for each zone (i.e. head, neck, body and tip) can be 9 for retrieved group and 1 for the control group for the presence of the attribute. The minimum score for each zone can be 0 for both the groups for the absence of the attribute.

After initial scanning of each zone, images of the damaged features or areas were captured. Multiple images of each zone of the MSI were taken; the number of images varied for each zone (about 2-4 images per zone of each MSI). Digital images were obtained at various magnifications (20-500 times) in an incremental manner.

An EDX detector (Bruker XFlash 6130) was used to investigate their elemental composition with an x-ray microanalysis detector. The quantitative analysis of the percentage of weight concentration of the probed elements was performed with an INCA micro-analyzer. The technical limitations of EDX spectroscopy in the electron microscope precluded the quantitative analysis of carbon in this investigation. Elements with lower atomic masses such as carbon (atomic number 6 and lower) are difficult to distinguish from each other using EDX. The carbon x-rays have low energy and are easily absorbed by the x-ray detector windows. Furthermore, there can be a significant carbon background signal because of hydrocarbon contamination. Hydrocarbons from the chamber surfaces, vacuum pumps, and sample surface migrate and react with the electron beam to form a black spot that is rich in carbon.

For each brand, 1 as received and 9 retrieved specimens were tested with a Universal Testing Machine (ACME Engineers, India. Model No. UNITEST- 10). Each miniscrew implant was blocked in the lower jaw of the machine with the head end of the miniscrew free. (Fig 2). The portion of the miniscrew between the endosseous thread and transmucosal collar was then exposed to a tangential load with a 0.5mm/min crosshead speed. Bending force was measured at 0.1 mm and 0.2 mm deflections.

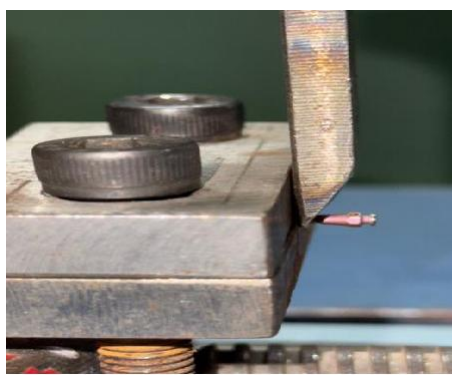


Figure 2. Showing miniscrew implants blocked in lower jaw of universal testing machine

RESULTS

The results of the study, as shown in Figure 3, 4, present scanning electron micrographs of the head, neck, body, and tip of Favanchor and Orlus miniscrew implants, highlighting various surface alterations after clinical use.

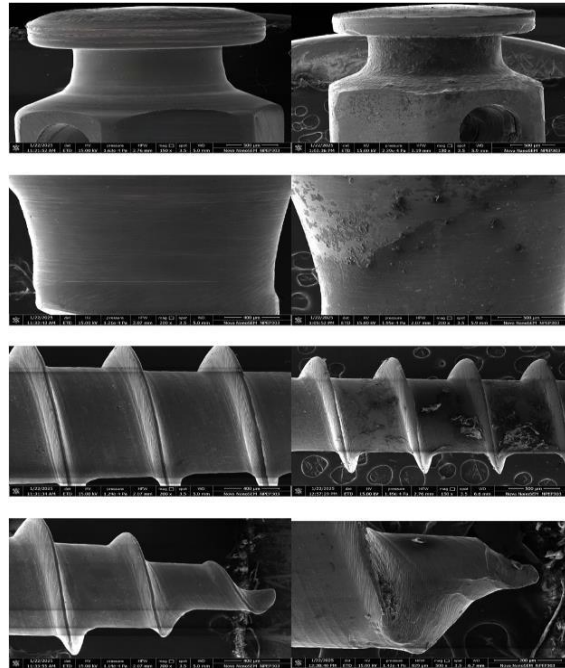


Figure 3. Scanning electron microscopic images of head, neck, body,tip of received FAVANCHOR titanium implants(left) and retrieved FAVANCHOR titanium(right) implants showing cracks, dullness corrosion, and blunting

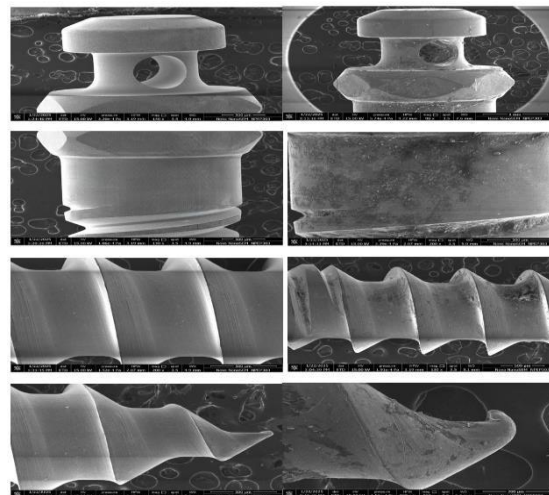


Figure 4. Scanning electron microscopic images of head, neck, body,tip of received ORLUS titanium implants(left) and retrieved ORLUS titanium(right) implants showing cracks, dullness corrosion, and blunting

Both Favanchor and Orlus implants exhibit dullness, cracks, and craters across all zones, with Favanchor implants showing additional fractures and blunting, especially in the body and tip regions. Statistical analysis, performed using SPSS version 20, involved non-parametric tests, including the Kruskal-Wallis test to compare elemental composition (EDX data), post-hoc Wilcoxon rank-sum tests with Bonferroni correction, chi-square tests for SEM comparisons, and unpaired t-tests for flexural strength. The findings are summarized in Table 1, which compares surface changes between Favanchor and Orlus implants, showing corrosion, dullness, cracks, craters, fractures, and bluntness, with Favanchor implants exhibiting more damage in the body and tip.

Table 1. Surface Changes on Mini-Implants (Favanchor vs. Orlus)

Implant Type	Corrosion	Dullness	Cracks	Craters	Fracture	Bluntness
Favanchor	Yes (Head, Neck, Body, Tip)	Yes (Head, Neck, Body, Tip)	More in Body & Tip	More in Body & Tip	Higher in Body & Tip	Similar in Body & Tip
Orlus	Yes (Head, Neck, Body, Tip)	Yes (Head, Neck, Body, Tip)	Less frequent	Less frequent	Higher in Body	Similar in Body & Tip

Table 2 details the elemental composition comparison, showing significant differences in titanium, aluminum, iron, and oxygen content between the two implant brands.

Table 2. Elemental Composition Comparison (Favanchor vs. Orlus)

Element	Head	Neck	Body	Tip	P- value for comparison within zones (Kruskal-Wallis test)
Titanium					
Favanchor- R	60.06	61.49	58.64	40.61	0.00006 *
Favanchor- C	62.32	70.6	73.12	44.71	
Orlus – R	57.92	69.03	61.47	53.30	< 0.00001 *
Orlus - C	64	76.17	71.78	51.95	
Aluminium					
Favanchor- R	5.6	3.96	3.15	12.56	< 0.00001 *
Favanchor- C	5.58	3.79	3.4	14.7	
Orlus – R	3.57	3.40	2.99	1.41	0.00001 *
Orlus - C	3.49	4.13	4.92	1.17	
Vanadium					
Favanchor- R	1.62	1.63	1.86	1.56	0.13588
Favanchor- C	2.65	1.55	2.37	1.05	
Orlus – R	1.32	2.01	2.27	1.40	< 0.00001 *

Orlus - C	0.6	0.56	0.2	0.32	
Nitrogen					
Favanchor- R	0.28	0	0	0	0.80779
Favanchor- C	0.21	0	0	0	
Orlus – R	0	0	0	0	-
Orlus - C	0	0	0	0	
Silicon					
Favanchor- R	0	0	0	0	-
Favanchor- C	0	0.15	0	0	
Orlus – R	0	0	0	0	-
Orlus - C	0	0	0	0	
Chromium					
Favanchor- R	0	0	0	0	-
Favanchor- C	0	0	0	0	
Orlus – R	0	0	0	0	-
Orlus - C	0	0	0	0	
Copper					
Favanchor- R	0	0	0	0	-
Favanchor- C	0	0	0	0.34	
Orlus – R	0	0	0	0	-
Orlus - C	0	0	0	0	
Chlorine					
Favanchor- R	0	0	0	0	-
Favanchor- C	0	0	0	0.54	
Orlus – R	0	0.18	0	0	0.97032
Orlus – C	0	0	0	0	
Phosphorous					
Orlus – R	0	0.05	0.05	0	0.83558
Orlus – C	0	0	0	0	
Sodium					
Orlus – R	0	0	0.10	0	0.80779
Orlus – C	0	0	0	0	

Table 3 compares the flexural strength of the implants, demonstrating significant differences between control and retrieved groups for both implant types.

Table 3. Flexural Strength Comparison (Favanchor vs. Orlus)

Implant Type	0.1mm Deflection	0.2mm Deflection	P-value
Favanchor	51.33 (R)	98.56 (R)	<0.05 (0.1mm), <0.05 (0.2mm)
Orlus	71.56 (R)	156.00 (R)	<0.05 (0.1mm), <0.05 (0.2mm)

Figures 5 and 6 present representative EDX plots of as-received and retrieved Orlus miniscrews, providing insight into the elemental composition of the implants before and after clinical exposure. Similarly, Figures 7 and 8 show the corresponding EDX plots for Favanchor implants, comparing the as-received and retrieved states. These figures reveal significant changes in elemental content, particularly in oxygen, iron, and calcium levels. Figures 9 to 11 graphically depict the flexural strength of the miniscrews at 0.1mm and 0.2mm deflections. Figure 9 compares the mean flexural strength of Favanchor implants in their as-received and retrieved states, while Figure 10 does the same for Orlus implants. Figure 11 further contrasts the flexural strength between the retrieved Favanchor and Orlus implants, showing a significant decrease in strength after clinical use. These figures collectively underscore the mechanical degradation and surface alterations in both types of miniscrews, reflecting their interactions with the oral environment and their impact on clinical performance.

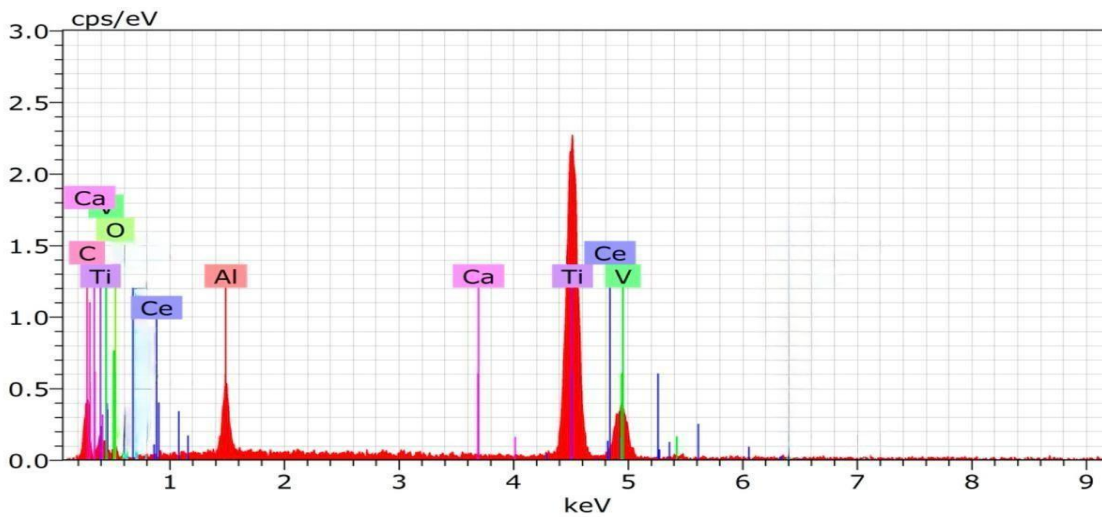


Figure 5. Representative graph of EDX plot of as-received Orlus mini-implant

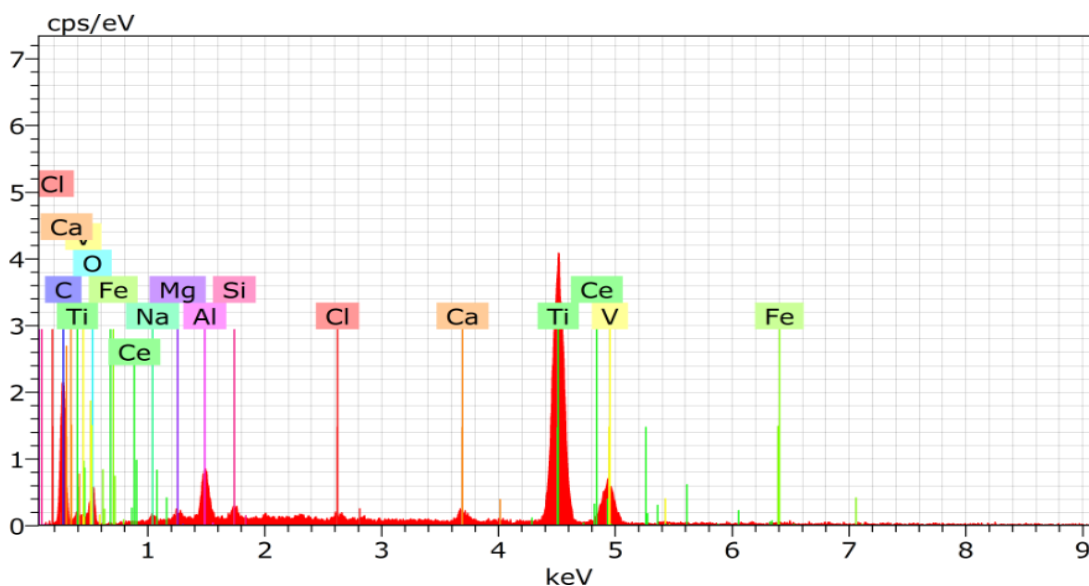


Figure 6. Representative graph of EDX plot of retrieved Orlus mini-implant

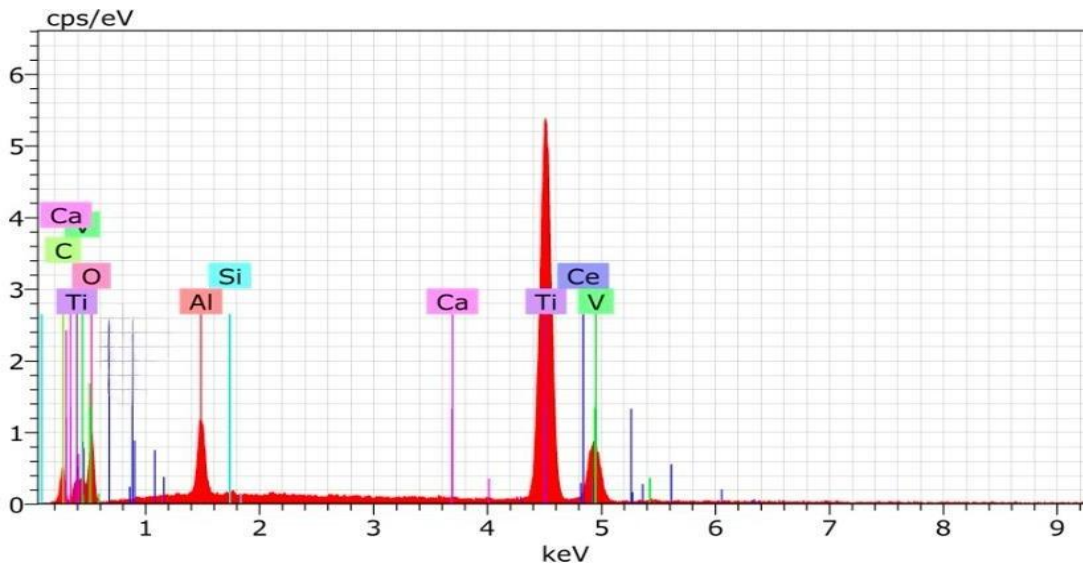


Figure 7. Representative graph of EDX plot of as-received Favanchor mini-implant

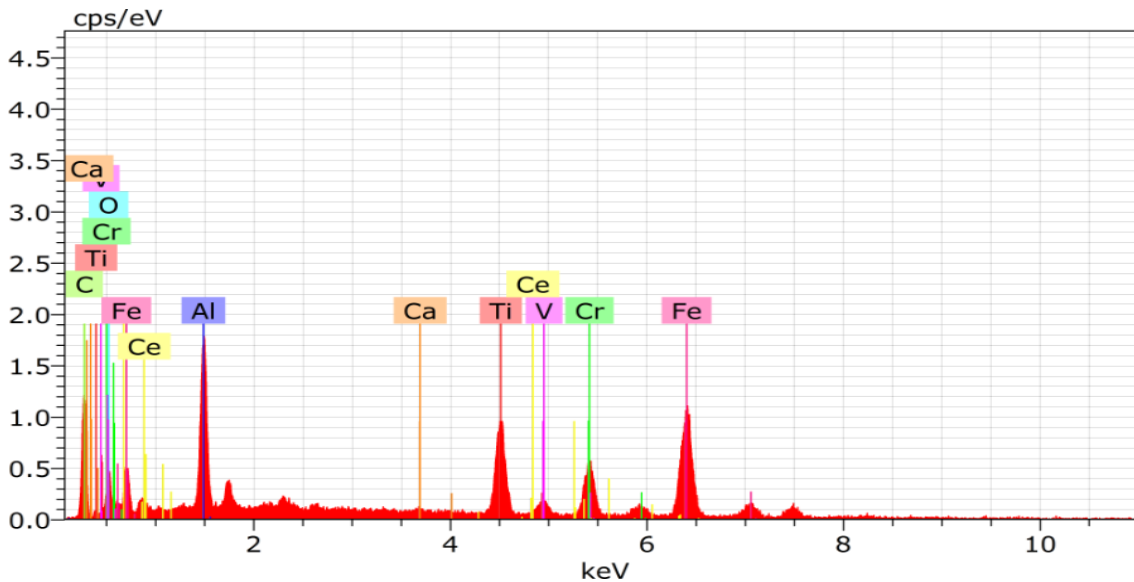


Figure 8. Representative graph of EDX plot of retrieved FAVANCHOR mini-implant

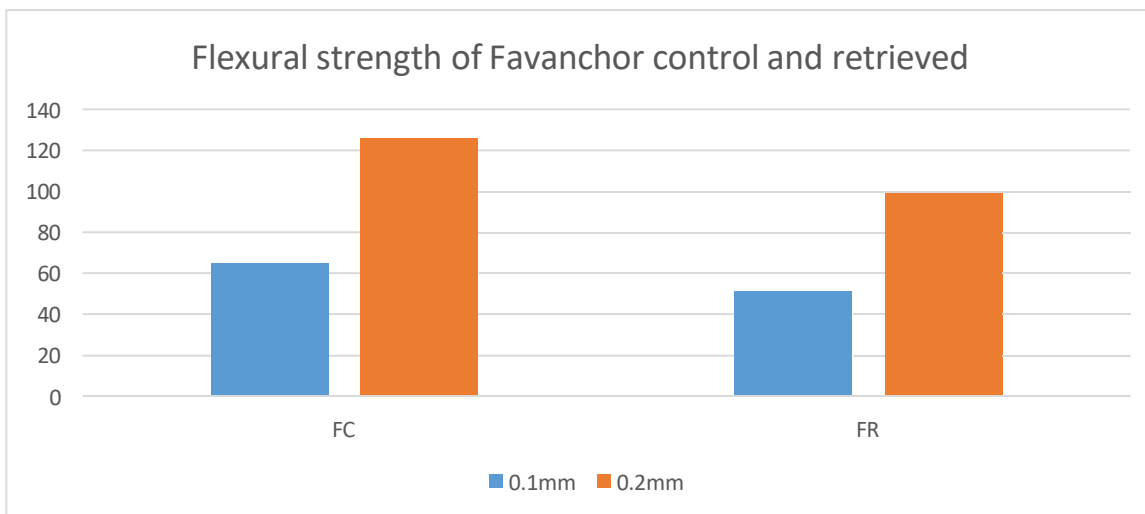


Figure 9. Graphical representation of mean flexural strength at 0.1mm in in Favanchor control and Favanchor retrieved at 0.1mm and 0.2 mm deflection

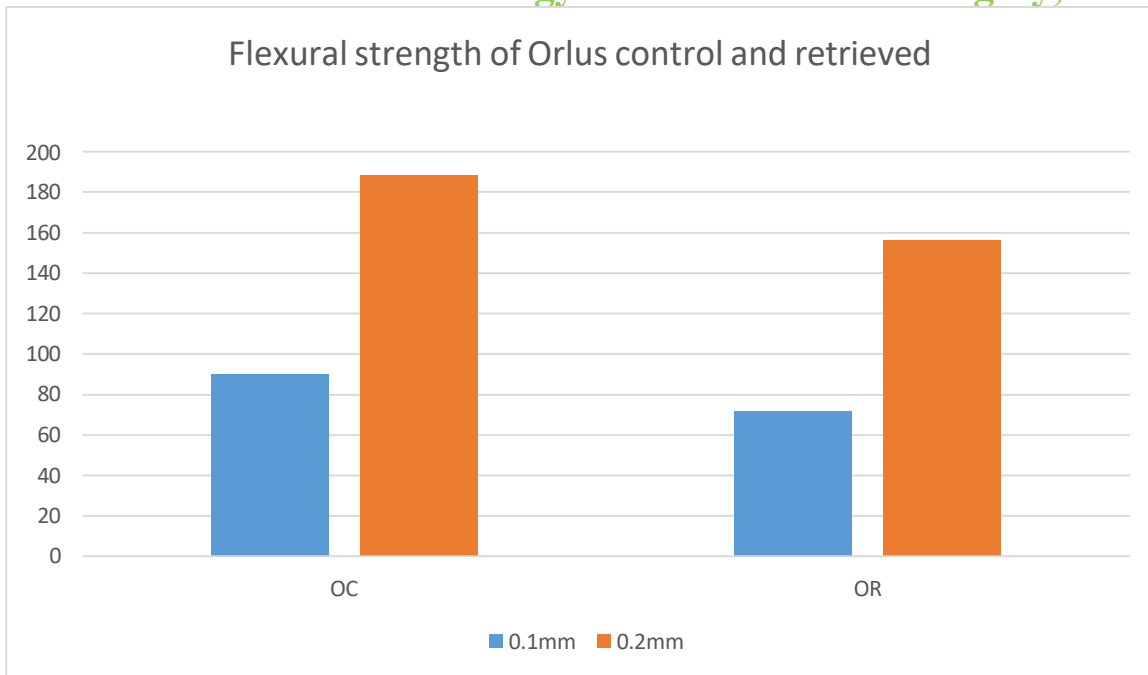


Figure 10. graphical representation of mean flexural strength at 0.1mm in in Orlus control and Orlus retrieved at 0.1mm and 0.2 mm deflection

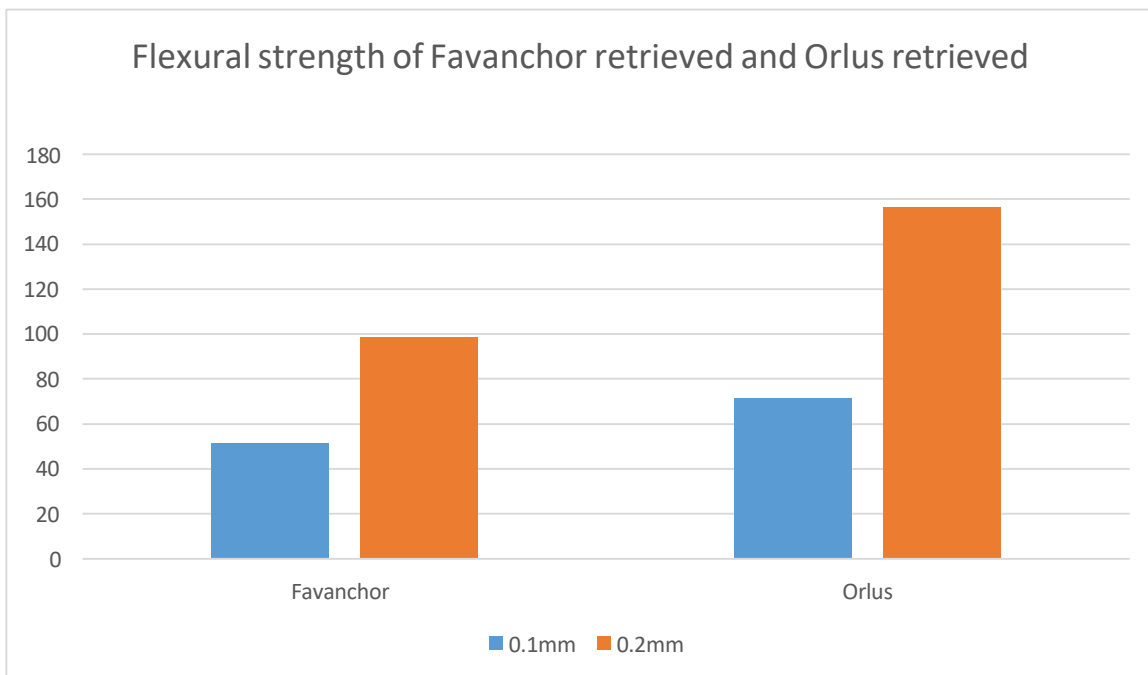


Figure 11. Graphical representation of mean flexural strength at 0.1mm in Favanchor retrieved and Orlus retrieved at 0.1mm and 0.2 mm deflection

Data analysis was performed using SPSS version 20 (IBM, Armonk, NY). Non- parametric tests were employed due to the nature of the data. The Kruskal-Wallis test was used to compare elemental composition (EDX data), followed by post-hoc Wilcoxon rank-sum tests with Bonferroni correction for pairwise comparisons. The chi-square test was utilized for intergroup and intragroup comparisons of SEM results. unpaired t-tests were conducted to

compare flexural strength between and within groups. Statistical significance was set at $P < 0.05$.

Iron had a mean value of 1.23 in the head region of retrieved Favanchor miniscrew implant, 0.28 in the neck region, 0.05 in the body region and 2.08 in the tip region which on comparison with the control Favanchor miniscrew implant {Head(H) = 0.51, Neck (N)=0, Body (B)=0, Tip (T)=0} was statistically significant ($p < 0.00001$). Similarly on comparison of the retrieved

Orlus miniscrew implant H=0.57, N=0.12, B=0.2, T=0.06 and in control was H=0.57, N=0.35, B=0.53, T=0.14 was statistically significant ($p=0.00053$).

Calcium had a mean value of 0.2 in the head region of retrieved Favanchor miniscrew implant, 0.18 in the neck region, 0.3 in the body region and 0.35 in the tip region which on comparison with the control Favanchor miniscrew implant {Head(H) = 0.15, Neck (N)=0.06, Body (B)=0.03, Tip (T)=0.35} was statistically not significant. Similarly on comparison of the retrieved Orulus miniscrew implant H=0.25, N=0.54, B=0.61, T=0.13 and in control was H=0.17, N=0, B=0.1, T=0.01 was statistically significant ($p<0.00001$).

Cerium had a mean value of 0.35 in the head region of retrieved Favanchor miniscrew implant 0.26 in the neck region, 0.38 in the body region and 0.04 in the tip region which on comparison with the control Favanchor miniscrew implant {Head(H) = 0, Neck (N)=0, Body (B)=0, Tip (T)=0} was statistically significant ($p=0.03638$). Similarly on comparison of the retrieved Orulus miniscrew implant H=0.09, N=0.23 B=0.21, T=0.06 and in control was H=0.6, N=0.56, B=0.2, T=0.32 was statistically not significant.

DISCUSSION

Our study discusses the surface changes seen on MSIs post retrieval and is compared to the implant in as received state. The emergence of retrieval analysis in biomedical material science provides valuable insights on the in vivo performance and durability of biomaterials within their designated environments.

Our study showed substantial changes in the surface topography of MSIs and the presence of impurities on their surfaces thought to result from contact with oral tissues, biological fluids, and other substances. Changes were seen in four different zones of implant i.e. head, neck, body and tip all thought to be unique due to different environmental exposures in the body. Our findings reveal substantial alterations in the surface topography of retrieved metal-supported implants (MSIs), characterized by the presence of cracks, craters, fractures, blunting, and the accumulation of precipitated impurities on the implant surfaces. These surface modifications are attributed to complex interactions between the implant and various biological factors, including oral tissues, bodily fluids, hematological components, exudates, saliva, and dietary elements¹⁶.

A comprehensive analysis of retrieved Miniscrew Implants (MSIs) revealed a significant degradation of surface characteristics, manifesting as a loss of gloss

and surface finish, resulting in a dull appearance uniformly across all examined zones. It is hypothesized that the insertion and removal processes of the miniscrews contributed substantially to surface wear, leading to a deterioration of their morphological integrity. Furthermore, thread blunting and tip dulling, characterized by a reduction in thread sharpness and tip acuity compared to new screws, were also attributed to wear-induced degradation during the insertion and removal process. Occasional fractures observed at the peripheral border or tip of the thread were ascribed to localized reductions in mechanical strength, rendering these regions more susceptible to failure.

Significant corrosion damage and crater formation were observed on the surface of retrieved MSIs, particularly in those that had been in place for extended periods which allowed prolonged exposure to oral tissues and biological fluids. Conversely, cracks and fractures were predominantly localized to the thread and tip regions, likely owing to the reduced material thickness in these areas, which rendered them more susceptible to mechanical failure and stress concentration. These results are in accordance with the study by Natarajan and Rao¹⁷.

The primary constituent elements of the retrieved Miniscrew Implants (MSIs) were obscured due to the adsorption of other elements from the surrounding biological environment onto the surface. Since Energy Dispersive X-ray (EDX) spectroscopy provides elemental data in terms of weight percentages, a noticeable reduction in the concentration of the parent (titanium, aluminium and vanadium) materials was observed when comparing the metal components of the titanium implants before and after recovery. This decrease in elemental content was attributed to the presence of elements such as oxygen, nitrogen, calcium, phosphorus, iron, sodium, chlorine, magnesium, and potassium. These substances, adsorbed from the surrounding biological environment, effectively masked the primary components on the implant surface.

The formation of a titanium oxide passive layer on the surface of titanium, resulting from its interaction with oxygen, is a well-documented phenomenon. This suggests that the observed increase in oxygen concentration may have contributed to the development or enhancement of the passive oxide layer on the retrieved MSIs.

The presence of calcium on the implant surface is primarily attributed to the interaction between the implant and blood, wherein proteinaceous substances are adsorbed, followed by mineralization through the precipitation of calcium and phosphorus ions. Furthermore, the adherence of bone particles to the miniscrew implant surface is a direct consequence of its contact with the surrounding alveolar bone, resulting in

the transfer and deposition of bone fragments onto the implant surface. This phenomenon highlights the implant's integration with the host bone tissue. The retrieved group exhibited higher levels of calcium, particularly in the body region, as indicated by the weight percentage. Calcium levels were present in both retrieved Favanchor miniscrew implant and retrieved Orlus miniscrew implants in the head region. In the neck region, calcium levels were present in both retrieved Favanchor and retrieved Orlus miniscrew implants, with higher levels in retrieved Orlus. Calcium levels were also present in both retrieved Favanchor and retrieved Orlus miniscrew implants in the body region, with higher levels in retrieved Orlus miniscrew implants. In the tip region, calcium levels were present in both retrieved Favanchor and retrieved Orlus miniscrew implants, with varying levels between the two.

Iron levels were higher in the retrieved Favanchor miniscrew implant compared to the control in the head region. In the neck region, iron levels were present in the retrieved Favanchor miniscrew implant, whereas they were absent in the control. The body region of the retrieved Favanchor miniscrew implant had iron levels, whereas the control had none. In the tip region, iron levels were higher in the retrieved Favanchor miniscrew implant compared to the control. The higher proportion of iron observed in the retrieved miniscrews, as indicated by the weight percentage data was attributed to their contact with blood. When compared to retrieved implants of both the brands, it was seen more in Favanchor miniscrew implant than Orlus miniscrew implant.

The retrieved miniscrew Implants (MSIs) showed a higher concentration of cerium in the head and neck regions compared to the body and tip regions. It was seen more in Favanchor miniscrew implant than Orlus miniscrew implants. Cerium, a element possessing antimicrobial properties, is a constituent of select mouthwashes and is also present in certain food items, such as tubers cultivated in cerium-rich soils and water sources. In the present study, the detection of cerium on the head and neck regions of the retrieved miniscrew implants (MSIs) was attributed to exposure to cerium-containing mouthwashes and ingestion of cerium-rich food sources, highlighting the potential for environmental and lifestyle factors to influence the surface composition of implanted devices.^{18,19} These findings corroborate with the study done by Patil et al.²⁰

Additionally, trace quantities of various elements, including chromium, fluorine, sodium, chlorine, magnesium, and potassium, were identified. These elements are ubiquitous in everyday substances, such as food, beverages, mouthwashes, toothpaste, and drinking water, suggesting that their presence on the implant surface is likely due to environmental

exposure and routine oral hygiene practices.

The outermost atomic layers of miniscrew Implants (MSIs) are crucial areas involved in the biochemical interactions at the implant-tissue interface. An escalation in corrosion severity can compromise the mechanical and biochemical properties of titanium-based mini-implants, potentially leading to diminished structural integrity and functionality. Furthermore, the release of elemental constituents from the mini-implants can modulate the inflammatory response, increasing the likelihood of adverse complications or implant failure. These findings underscore the importance of optimizing the corrosion resistance and biocompatibility of titanium-based mini-implants to ensure their safe and effective use in clinical applications. These regions significantly impact the need for high levels of standardization and surface control during MSI production.

This study had several limitations such as a small sample size, no effort made for categorization into age groups based on their growth status (growing or nongrowing), which could possibly influence bone density thus leading to further alterations in implant topography. Also the selected implants were not subject to pre-implantation SEM and EDX analysis suggesting that their surface characteristics and chemical composition were assumed to be consistent with the manufacturer's specifications, which were presumably established through proper manufacturing protocols and quality control measures. This assumption is based on the understanding that the implants were fabricated using standardized methods and materials, and that the manufacturer's quality control processes ensured that the implants met the required standards for biocompatibility and performance.

CONCLUSION

In conclusion, the implants in the as-received groups (both Favanchor and Orlus) showed no structural damage, with flexural strength being higher for the as-received Orlus miniscrew implants compared to Favanchor miniscrews. However, the retrieved orthodontic miniscrew implants (MSIs) displayed significant morphological changes, including surface dullness, thread and tip blunting, corrosion, crater formation, and occasional fractures. A comparison between retrieved and new MSIs revealed notable differences in surface elemental composition, with the retrieved MSIs containing additional elements such as oxygen, carbon, iron, calcium, cerium, fluoride, and sodium. Calcium was most prominently observed in the body region, with higher levels seen in the Orlus

miniscrews. Iron deposits were present in the body and tip regions of both implant types, with Favanchor showing more iron content. Cerium was found in the head and neck regions, more prominently in the Favanchor implants. Furthermore, there was a decrease in the flexural strength of both retrieved miniscrew implant brands. These findings underline the potential limitations in reusing retrieved miniscrew implants due to structural and elemental alterations.

DECLARATIONS

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Consent for publication

Informed consent was obtained from every participant for documentation and examination.

Competing interests

The authors declare no competing interests.

Ethical approval

Ethical approval was granted by the Institutional Human Ethical Committee

Informed patient consent

All patients' clinical records were obtained with informed consent.

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