

## Investigation of surface element properties in explanted implants due to peri-implantitis: An in vitro study

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### Original Article

#### Abstract

**BACKGROUND AND AIM:** Osseointegration is the connection between alveolar bone and implant surface. After peri-implant diseases, the surface structure is changed, but the surface properties of the dental implant are crucial in re-osseointegration. This study aimed to examine the surface element levels of explanted implants due to peri-implantitis by scanning electron microscopy/energy-dispersive x-ray spectroscopy analysis (SEM-EDX).

**METHODS:** Ten explanted sandblasted, large grit, acid-etched (SLA) surface dental implants (Straumann Roxolid, Straumann GmbH, Freiburg, Germany) were used for the study. Explanted implants were washed with distilled water/air spray to purify blood and debris, dried with air spray, and waited for test time at room temperature. Explanted implants were examined using a SEM. The samples were not coated with gold, and images were taken at 115x and 8000x. SEM-EDX was performed at three-point for each sample to analyze relative concentration or weight percent (wt%) of carbon (C), oxygen (O), sodium (Na), aluminum (Al), titanium (Ti), and zirconium (Zr) with same SEM.

**RESULTS:** In the explanted implants, osseointegrated bone (0.1-0.5 mm wide) residues were observed in places, especially in the apical region. Regarding metal-to-metal labeling on the surfaces of dismantled implants, no findings such as surface scratches, fractures, and cracks were found. In explanted implants, the amount of C was relatively higher, while the amount of Ti was relatively lower.

**CONCLUSION:** Within the limitation of this study, it can be said that the C amount is high, and the amount of Ti is low in explanted implants relatively. Further research is needed to understand the effect of surface elements on re-osseointegration, where the number of samples is high.

**KEYWORDS:** Osseointegration; Dental Implants; Peri-implantitis; Scanning Electron Microscopy

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The dental implant is a titanium (Ti)-based biomaterial that is inserted into the alveolar bone by surgical procedure and replaces the root of the tooth to compensate for aesthetic, restorative, or functional conditions after tooth loss. Dental implants used to eliminate tooth deficiencies have been considered since ancient times, and various applications have been made for centuries. The first applications were found in ancient Egypt and South American civilizations.<sup>1</sup> During the historical development process, researchers have tested many metals for implant making.

While dental implants made of metals such as platinum (Pt), chrome (Cr), and cobalt (Co) have been reported for 15 years; aluminum (Al), silver (Ag), brass, and mild steel have been reported to be corroded.<sup>2</sup> After that Williams et al. reported that Ti was the most reliable metal as an implant material and it integrated bone,<sup>3</sup> Branemark et al. have demonstrated the use of pure Ti into the jaw bone. Later, this study group continued its clinical studies and demonstrated its long-term implant success.<sup>4</sup>

Branemark et al. first defined the term osseointegration as a direct link between the

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living bone and the implant surface.<sup>4</sup> After that the implant is placed in the prepared slot, bone apposition is formed towards the implant surface. This bone apposition is similar to the healing mechanism of bone fractures.<sup>5</sup> A bone bridge is formed within a few millimeters of the implant, and in about six weeks, the woven bone reaches the implant surface. Stabilization and immobilization of the implant are required for the formation of this bone bridge. Remodeling, which is the last stage of osseointegration, starts in the 3<sup>rd</sup> month of implant placement, continues for life, and is very important for the longevity of the implants.<sup>5,6</sup> Studies have shown that implant surface properties play an essential role in the bone healing process. More pronounced effects of morphological methods compared to physical-chemical methods were determined. It has been shown that rough surfaces positively affect bone healing.<sup>7</sup>

When the implant is placed inside the mouth, it creates a new and different surface for the accumulation of local microorganisms of the oral flora. In the study of Koka et al., 14 days after that the implants were opened to the mouth, periodontal pathogens began to accumulate on the surface, and at the end of the 28<sup>th</sup> day, they reached the level to form subgingival flora.<sup>8</sup> These bacteria, which can accumulate on the surface of the implants in the very early period when oral hygiene is insufficient, lead to inflammation of the peri-implant tissues and the onset and progression of the peri-implant disease. The peri-implant diseases were defined as the inflammatory process occurring in the tissues around the implant in the 1<sup>st</sup> European Periodontology Workshop.<sup>9</sup> Peri-implantitis, which appears as the most advanced form of peri-implant disease, according to the most recent definition, is a plaque-related pathological condition characterized by inflammation and the progressive destruction of the supporting bone.<sup>10</sup>

It has been shown in previous studies that osseointegration occurs on a clinically pure

dental implant surface.<sup>11</sup> However, regeneration of the alveolar bone lost as a result of peri-implantitis and thus the recovery of lost osseointegration in some parts of dental implant is still discussed in the literature.<sup>12</sup> At this point, the concept of re-osseointegration comes to the fore in researches. Although non-surgical and surgical periodontal treatments have been reported as clinically-acceptable results, surgical explantation is also offered as a solution in studies on peri-implantitis.<sup>13</sup> Besides, the use of hard tissue graft materials has been brought up during the surgical periodontal treatment.<sup>14</sup> However, one of the debates here is whether re-osteointegration will be restored.<sup>15</sup> As with osteointegration, the surface properties of the dental implant are important in re-osseointegration. Many studies in this field mostly focused on the effect of different surface modalities on the surface topology. The study which only examines the surface of explanted implants has not been frequently included in the literature. In this context, the purpose of the present study is to examine the surface element levels of implants explanted due to peri-implantitis.

## Methods

**Sample collection:** Ten commercially-available sandblasted, large grit, acid-etched (SLA) surface dental implants (Straumann Roxolid, Straumann GmbH, Freiburg, Germany) were used for the present study. These dental implants explanted from patients due to peri-implantitis (all explanted implants had at least 2/3 alveolar bone loss of total implant length). Explanted implants were washed with distilled water/air spray to purify blood and debris, dried with air spray, and waited for the test at room temperature. Only one explanted implant from one patient was used for standardization. Verbal/written consent was obtained from the patients for the use of dental implants in this study.

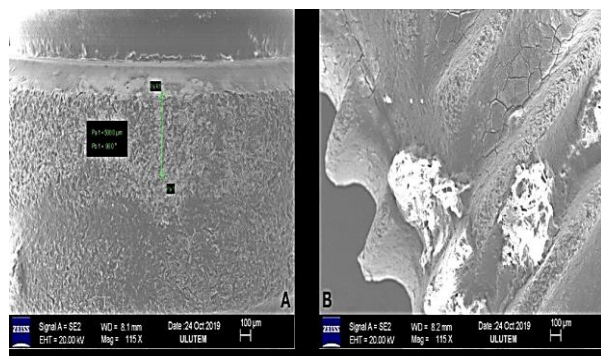
*Scanning electron microscopy (SEM) and SEM with energy dispersive x-ray spectroscopy*

(SEM-EDX): Explanted implants (n = 10) were examined using a SEM (Zeiss Gemini 300 FEG-SEM, Carl Zeiss, Oberkochen, Germany). The samples were not coated with gold, and images were taken at 115x and 8000x. SEM-EDX was performed at three-point for each sample to analyze relative concentration or weight percent (wt%) of carbon (C), oxygen (O), sodium (Na), Al, Ti, and zirconium (Zr) with the same SEM. For standardization purposes, the SEM-EDX examination was performed 1 mm below the implant neck.

**Qualitative/quantitative evaluation and statistical analysis:** The qualitative evaluation was performed to identify changes in the surface of the explanted implants. Descriptive statistics in terms of wt% of C, O, Na, Al, Ti, and Zr were given for each implant, and the average of three SEM-EDX measurements taken from each sample was given. Microsoft Excel software (Microsoft, Redmond, WA, USA) was used to prepare the data.

## Results

**Qualitative evaluation:** In the explanted implants, osseointegrated bone (0.1-0.5 mm wide) residues were observed in places, especially in the apical region. Regarding metal-to-metal labeling on the surfaces of dismantled implants, no findings such as surface scratches, fractures, and cracks were found. However, there were organic residues between the grooves (Figure 1).



**Figure 1.** Scanning electron microscopy (SEM) image of dental implant; A: Explanted implant neck view under 115X; B: Apex view of explanted dental implant under the 115X

**Table 1.** Scanning electron microscopy/energy-dispersive x-ray (SEM-EDX) value of dental implants

Wt%	C	O	Na	Al	Ti	Zr
EX1	37.52	21.17	0.61	0.07	34.88	5.75
EX2	39.24	22.24	0.65	0	32.49	5.39
EX3	31.14	18.56	0.46	0	42.96	6.87
EX4	34.35	19.65	0.50	0.02	39.30	6.19
EX5	32.73	17.13	0.41	0.03	44.30	5.41
EX6	27.45	19.86	0.30	0.01	45.87	6.50
EX7	29.73	20.18	0.10	0.01	39.13	10.84
EX8	35.13	14.56	0.01	0.03	47.40	2.88
EX9	32.13	17.24	0.02	0.01	43.52	7.07
EX10	31.86	17.97	0.04	0.04	44.65	5.44

Wt%: Weight percent; C: Carbon; O: Oxygen; Na: Sodium; Al: Aluminum; Ti: Titanium; Zr: Zirconium; EX: Explanted implant

In explanted implants, the amount of C was relatively higher, while the amount of Ti was relatively lower (Tables 1 and 2).

**Table 2.** Average scanning electron microscopy/energy-dispersive x-ray (SEM-EDX) value of dental implants

Wt%	Grup EX (n = 10) (mean ± SD)
C	33.12 ± 3.53
O	18.85 ± 2.23
Na	0.31 ± 0.25
Al	0.02 ± 0.02
Ti	41.45 ± 4.86
Zr	6.23 ± 1.99

Wt%: Weight percent; C: Carbon; O: Oxygen; Na: Sodium; Al: Aluminum; Ti: Titanium; Zr: Zirconium; EX: Explanted implant; SD: Standard deviation

## Discussion

In this study, it was aimed to compare the surface properties of the implants explanted with a standard implant with SEM-EDX. According to the results of the study, it can be said that the C density on the surface is higher in the explanted implants and the Ti density is lower. We think that the C increase observed in our study was caused by organic wastes remaining on the surface although the implants were cleaned with air/water spray. Also, it was observed that airflow removed better microbial plaque from the implant surface compared to other techniques;<sup>16</sup> however, it is shown that organic residues and airflow powder particles remain on the surface even after airflow.<sup>17</sup> Peri-implantitis is a chronic inflammatory disease that can

result in implant loss. In general, various modalities are tried in the prevention and treatment of peri-implantitis, and studies are still ongoing. Some of these studies are currently focused on re-osteointegration. Although the concept of osteointegration was fully documented, the concept of re-osteointegration still needs evidence.<sup>16</sup> One of the reasons for this is the topological differences between the root surface and the implant surface. However, another reason may be the surface changes of dental implants opened to the mouth due to peri-implantitis.

Surface topology examinations in dental implants are generally focused on roughness. Studies on surface element structure are few compared to other studies. Also, in re-osteointegration, as well as in osseointegration, the elemental properties of the surface are essential.<sup>18</sup> All of the explanted implants used in our study were removed with reverse torque using the carrier part because of this technique have not physical effect on the surface structure, although attention is paid in other methods. Besides, implants that are removed by applying force around the implant have mechanical changes due to their Ti properties.

According to the systematic review published by Saulacic and Schaller in 2019, the peri-implantitis prevalence of rough surfaces and turned surfaces were compared and no statistically difference was found between both surfaces. However, as stated by the authors, implants with rough surfaces are prone to dental plaque accumulation after that the neck parts are exposed.<sup>11</sup> In similar studies, the increase in surface roughness is

the increase of dental plaque accumulation, but it should not be forgotten that there is a two-way relationship. Because increased surface roughness also increases osteointegration.<sup>19</sup> In our study, standardization was tried to be achieved by using implants of similar surface roughness. However, the use of different implant systems in the world and the existence of different surface properties can be counted as the limitation of the study. It should be remembered that each surface will have its SEM-EDS properties.

### Conclusion

The surface analysis of the implants that failed due to peri-implantitis is innocuous since they do not bring any additional discomfort to the patients. In this context, within the limitation of the present study, it can be said that the C amount is high and the amount of Ti is low in explanted implants after the cleaning of implant surface similar to routine oral hygiene practices. It is thought that these results may change re-osteointegration. However, it is necessary to test whether different surface modification techniques that can be applied in the mouth can return dental implants to their original surface properties in further studies.

### Conflict of Interests

Authors have no conflict of interest.

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