Influence of Chemically-Modified Implant Surfaces on the Stability of Orthodontic Mini-Implants

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Skeletal anchorage using mini-implants has greatly improved the treatment options in orthodontics over the last years. In order to reduce failure rates, it is advisable to obtain primary and secondary implant stability. The aim of this study was to analyze the impact of a surface treatment on the primary and secondary stability of orthodontic mini-implants. A total of 40 (10 mm in length, 1.6 mm in diameter) mini-implants (MIS Implants Technologies Ltd.) were inserted in pairs in 20 adult male patients. Each pair consisted of one implant with a machined (non-treated) surface and another with a chemically-modified SLA surface. The primary and secondary stability were measured with a torque wrench. We observed significant differences in the secondary stability between the chemically-modified and the machined implant surfaces, the SLA treated mini-implants having higher removal torque values, hence better secondary stability. Statistically significant differences were also observed between the insertion and the removal time points in both types of implants. The torque values for the SLA treated mini-implants increased, while the torque values for the machined surface mini-implants decreased over time. The surface treatment of orthodontic mini-implants has a distinctive impact on the secondary stability of orthodontic mini-implants, the mini-implants with a chemically-modified SLA surface being able to achieve significantly better secondary stability compared to those with non-treated surfaces, in the same period of time.

Keywords: mini-implants, primary stability, secondary stability, SLA

Stable anchorage is a prerequisite for successful orthodontic treatment, but it is frequently insufficient. In such situations, titanium mini-implants have proven to be a successful solution, broadening the treatment options in orthodontics, virtually eliminating the patient compliance factor.

Titanium is one of the most biocompatible materials known and its surface has been intensively tested in recent years both in vivo [1, 2] and in vitro [3-5]. Several types of surface treatments have been tested (SLA, SLActive, anodized etc.), but the one that is most frequently used in orthodontic mini-implants is the chemically-modified SAL (sandblasted and acid-etched) surface.

The SLA surface treatment is the result of a large grit sand-blasting process with corundum particles (250-500 μm) that produces a macro-roughness on the titanium surface. This process is followed by an acid-etching bath using a high-temperature solution of hydrochloric acid and sulfuric acid (HCl/H2SO4) for a few minutes. This produces very fine micropits (2-4 μm) superimposed on the rough-blasted surface [6].

X-ray photoelectron spectroscopy demonstrated that the chemical composition of the SLA structure is titanium dioxide (TiO2).

Clinical evidence from dental implantology shows that primary and secondary stability are key factors for success, together with bone density, oral hygiene and loading protocols. Initial stability is dependent on the drilling protocol, but also on the geometry and surface treatment of the implants.

Unfortunately, mini-implant failure rates of 10-40% have been reported in the literature [7-11], possibly due to: insufficient primary stability, adjacent root damage at insertion, insufficient secondary stability, periimplantitis (if the mini-implant is not inserted in fixed gingiva).

The objective of this study was to determine whether a chemically-modified SLA implant surface had an effect on orthodontic implant stability over a six-month period.

Experimental part

Materials and methods

Twenty adult male patients, aged 20 to 38 years, received a total of 40 mini-implants (10 mm in length and 1.6 mm in diameter, MIS Implants Technologies Ltd.), inserted in pairs. The orthodontic mini-implants were used as temporary anchorage devices in the mandible, in different clinical situations.

To eliminate variations among individual patients and insertion locations, the mini-implants were placed using a complete random block design, therefore all the patients received two implants, one with a chemically-modified SLA surface and another one with a machined (non-treated) surface (fig. 1).

All the implants were inserted according to the manufacturer protocol, always using a small incision to gain direct access to the bone. The mini-implants were...
positioned at an angle of approx. 60-70 degrees, in order to maximize stability.

The implant placement was carried out using a hand piece until the last two threads engaged the bone, then a manual torque wrench (fig. 2) was used to place them into final position. Intraoperative recordings of the maximum insertion torques were taken for each implant. All the implants were immediately loaded with the same amount of force (250 gf) for a period of 6 months.

When the orthodontic treatment was finalized, the mini-implants were removed using the same torque wrench and the maximum removal torques were recorded for all the implants.

**Statistical analysis**

All the data were entered and analyzed using IBM SPSS Statistics version 21 for Windows (SPSS Inc., Chicago, IL). The level of statistical significance was set at p < 0.05. A mixed-model design ANOVA was carried out, after the following assumptions were verified: there were no outliers in any group, the residuals were approximately normally distributed, there was homogeneity of variances and covariances and the sphericity has not been violated.

**Results and discussions**

No implants were lost during the treatment period.

The insertion and removal torque values for the machined surface mini-implants ranged from 5 to 35 Ncm.

The insertion and removal torque values for the SLA mini-implants ranged from 5 to 40 Ncm and from 8 to 45 Ncm, respectively (table 1 and fig. 3).

The descriptive statistics of the measured values for the insertion and removal torques, for both types of mini-implants are presented in table 2.

The mixed-model ANOVA showed a statistically significant interaction between the mini-implant surface type and time (the insertion and removal time points) on implant stability (torque values), $F(1,38) = 39.37, p = 0.001$, partial $\eta^2 = 0.51$.

The simple main effect for time is presented in table 3. There was a statistically significant effect of time on implant stability both for the SLA implant type ($p = 0.001$) and for the machined-surface implant type ($p = 0.026$).

**Table 1**

<table>
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<th>M</th>
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<th>Diameter (mm)</th>
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</table>

M – machined surface; SLA – chemically-modified SLA surface

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**Fig. 1.** Orthodontic mini-implants (MIS Implants Technologies Ltd.): SLA (left) and machined surface (right)

**Fig. 2.** Manual torque wrench (MIS Implants Technologies Ltd.)

**Fig. 3.** Boxplot of the insertion and the removal torques for the machined surface (M) and the chemically-modified surface (SLA) mini-implants
The torque values were significantly different between the insertion and the removal time points for both the SLA (p = 0.001) and the machined-surface (p = 0.026) mini-implants (table 4).

Regarding the simple main effect of surface type on implant stability, there was a statistically significant difference in torque values between the two types of mini-implants at the removal time point (p = 0.036), but no statistically significant difference at the insertion time point (p = 0.502) (table 5).

In our study, the surface treatment proved to play a significant role in the secondary stability of orthodontic implants. These mechanical stabilities are essential for achieving a good anchorage in orthodontics.

The noninvasive methods used to assess the mechanical stability of orthodontic mini-implants, usually pose some disadvantages: the Osstell™ system (Resonance Frequency Analysis – RFA) requires a transducer which is difficult to adapt and to use with orthodontic implants, while the Periotest® system (Medizintechnik Gulden) can affect the primary stability of the implants due to the shocks it produces [12-16]. Therefore, in our study we assessed the primary and secondary mini-implant stability using a manual torque wrench.

Lima, Soares and Penha [17] also recommend, whenever possible, using the torque wrench provided with the implant system to insert the mini-implants, following the manufacturers’ indications. The authors stress the importance of good surgical-orthodontic planning in order to avoid the excessive use of torque, which may lead to mini-implant fracture and instability at the implant-bone interface.

Better clinical performance and less failure can be achieved by understanding the biomechanical properties of orthodontic mini-implants, as they vary greatly in shape and dimensions.

Motoyoshi et al. [18] showed that a minimum insertion torque of 5 Ncm is necessary for success. All implants in this study achieved rates over this value, but the SLA treated implants had greater torque values compared to the implants with the machined surfaces.

It is obvious that the dimensions of the mini-implants play a major role in increasing their stability, but diameters under 1.6 mm usually cannot provide sufficient stability. Several studies agree that a diameter of 1.6 mm has a high success rate for primary stability [10, 18]. Also, greater diameters, can sometimes be difficult to manage, because of space and friction related problems, especially in the mandible [7, 18].

Secondary stability is important for assessing the influence of the surface treatment. The implants with SLA

<table>
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<th>Time</th>
<th>Source</th>
<th>Type III Sum of Squares</th>
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<th>Sig.</th>
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Measure: torque (Ncm); M – machined surface; SLA – chemically-modified SLA surface

* The mean difference is significant at the 0.05 level; c. Adjustment for multiple comparisons: Least Significant Difference (equivalent to no adjustments)

<table>
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<th>Surface type</th>
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<td>2.31</td>
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treated surfaces had significantly higher removal torques, probably due to some degree of osseointegration, although the implants were immediately loaded. On the other hand, the implants with machined surfaces had significantly lower removal torque values compared to the insertion torque values. This would suggest poor tissue attachment for the machined surface mini-implants, especially when subject to immediate force loading.

Although not recorded in their study, Chaddad, Ferreira, Geurs and Reddy [19] also concluded that the SLA mini-implants had a higher level of osseointegration at the time of removal. This clinical observation was based on the higher values of the removal torque of the SLA mini-implants, in comparison with machined surface implants.

Similar to Chaddad et al. [19] findings, other reports in the literature imply a preference for roughened or coated surface treatments [20-22], suggesting that the increased surface area may improve early osseointegration.

The performance of the rough SLA surface seems to be superior to smooth machined surfaces with respect to removal torques and its high load-bearing capability.

Conclusions

A chemically-modified, rough surface treatment can improve the secondary stability of orthodontic mini-implants. The mini-implants with a chemically-modified SLA surface were able to achieve significantly better secondary stability compared to those with machined non-treated surfaces, in the same period of time.

A 1.6 mm diameter proved to be sufficient for obtaining a good stability.

Further investigations, with more precise methods are needed in order to gain full certainty of these findings.

References


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