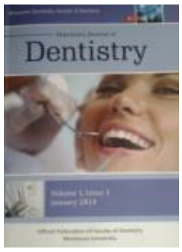

Effect of different Surface Treatments of Orthodontic Mini-Implants on their Primary Stability; An in-vitro study

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Abstract:

Objective: The effect of sand-blasting, acid-etching and anodic-oxidation (SLAO) versus Carbon dioxide laser (Co_2) laser radiation of orthodontic mini-implants (OMIs) is studied to evaluate their primary stability in fresh animal bone blocks.

Materials and Methods: 36OMIs from the same manufacturer(Hubit, Gyeonggi-do, Korea);made from Grade 5(Ti-6Al-4V) alloy. They were divided according to methods of their surface treatment into the following groups: group I—No surface treatment, group II—SLAO surface treatment, group III—CO_2 laser irradiation surface treatment. All OMIs were the manually inserted into prepared bone blocks of fresh bovines' femoral bone heads. Primary stability values for OMIs were measured by Periotest® device and then by Pullout-test device with non-axial forces and at pull-out angle ranged between 15° and 25° to each OMI longitudinal axis.

Results: Surface treatment of Grade 5 Ti-6Al-4V alloy OMIs by SLAO achieved the higher primary stability results of pull-out test followed by OMIs with CO_2 laser radiation surface treatment then the machined surface OMIs. Moreover, all OMIs studied groups have no statistically significant difference in perio-test® values

Conclusions: Within the limitations of this study, it can be concluded that :surface treatment of OMIs by each of SLAO and CO_2 laser radiation significantly affected their primary stability in fresh bone blocks.

Keywords: Mini-implants; Surface treatment; Primary stability; Perio-test; Pullout test; Skeletal orthodontic anchorage.

Introduction

OMIs were invented in orthodontic to achieve the absolute skeletal orthodontic anchorage[(1)]. OMIs overall stability in the maxillo-facial bones has always being a key factor for their success and come from the sum of achievement of each of the primary stability through the mechanical interlocking of OMIs in to the bone immediately after their insertion and the secondary stability, which is achieved later after a healing period by the osseointegration process[(2-5)]. A set of overlapping factors have a large impact on OMIs stability, some of which return to the clinical steps, others return on OMIs descriptions and the patient himself will be a contributing factor in achieving that success[(2)]. OMIs Surface modification have to be more recommended for improving their stability and the compensation for lack of other factors through increasing bone to mini-implants contact (BIC) and removal torque values (RTv). OMIs surface treatments required several techniques included sand-blasting, acid-etching, anodization and laser surface treatment techniques[(6-10)]. This study examined the effects of SLAO surface treatment versus CO_2laser surface treatment of OMIs. The primary stability of OMIs in fresh bovine bone blocks was evaluated by each of periotest® and pull-out test.

Materials and methods

OMIs surface treatment

A sample of 36 OMIs were used in this study, all were obtained from the same manufacturer(Hubit, Gyeonggi-do, Korea). and had the same selective criteria; tapered type screw, button shaped head with two holes, machined surface, 6 mm length, 1.6 mm diameter, have cutting ends for self-drilling and made from biocompatible Grade 5 Ti-6Al-4V alloy.The test sampleswere divided equally (n=12) into three groups;GroupI: OMIs with machined surface as gained from the manufacturer and acted as a control group.Group II: OMIs were undergoing SLAO surface treatment.Group III: OMIs were undergoing CO_2 laser radiation. Sand-blasting process of OMIs was doneby Sand-blaster machine(AX-B3 Sandblaster unit, Tianjin, China), whichsprayedaluminum oxide (Al_2O_3) particlesof 110-µmsize along each OMIroot surface for 1 minute under compressed aired pressure of 4 bars[11,12]. OMI acid-etching procedures were done by immersing them in two separate glass beakers containing different boiled acids for 3 minutes; 100 % hydrochloric acid (Conc HCL, SDFCL, Mumbai, India) and 60% concentrated sulfuric acid (H_2SO_4, El Nasr Pharmaceutical Chemical Co, Egypt)[12, 13]. OMIs anodization was prepared by including OMIs in an electro-chemical cellfor precepting titanium oxide layer(TiO_2) along the screwroot surface[8, 14-16].CO_2 laser surface treatment for OMIs ofgroup III was achieved by using Class 4 Invisible CO_2 laser Radiation (Smart Xide. DEKA, M.E.LA.s.r.L, Calenzano, Italy).The laser beam has been applied through the tip, which had 45° angle and focus distance to OMI surface. Laser beam was directedalong each OMI root surface for 60 s with sweeping movements from the top to the bottom and left to right[17,18].AllOMIsgroups were cleaned in adigital ultrasonic cleaner(MCS, P4820, China) using three steps; acetone, alcohol and deionized water by washing for 15 minutes in each solution respectively, in order to remove contaminations and then dried in an oven (Olidef, Ribeira˜o Preto, SP, Brazil) at 50°C for 24 hours[13, 19].

Bone preparation

Femoral heads from freshly-slaughtered cows, whose mean age was ranged between 14 and 18 months were selected for this study. Each femoral bone head was divided vertically under saline irrigation into blocks measuring 3-4 cm height and 6-7 cm long by manual saw cutting machine (Xinhai Mining Machinery Co., Ltd. China) and all their joint cartilage and soft tissue had been removed with a size 22 scalpel. A set of allowed pilot holes were drilled in the cortical surface of each bone block with a small head round bur (BR-45, diamond-bur, Mani, Japan) under cooling with physiological saline, the hand piece (T3, Sirona, Fabrikstrabe 31, Germany) was operated at speed of 1100 rapids per minute (r.p.m).The pilot holes were of 1.3mm diameter and marked with gutta percha points (Dentsply Maillefer, Ballaigues, Switzerland).The bone mineral density (BMD) was analyzed at each

OMIs insertion points by Cone Beam Computed Tomography (CBCT, I-CAT 17-19, USA) and processed with determined Software (OnDemand 3D 1.0.10.7510 App; Cybermed, Korea). AllBMD values of OMIs insertion points were ranged from 725.9 to 869.2 mgHA/cm3 and any OMIs insertion points with BMD outside that range were excluded from further analyses. Finally, each bone block was mounted in to a block of auto-polymerizing orthodontic acrylic resin system (Ortho-Jet; Lang Dental Manufacturing Co. Inc., Wheeling, IL, USA) with a labeled code number and stored at 4°C in the refrigerator(20).

Insertion of the studied OMIs groups

All OMI were inserted manuallywith their handle driver (Hubit, Gyeonggi-do, Korea) within pre-prepared pilot holes into the cortical layer of the bone block in a perpendicular insertion direction (at almost angle of 90º ±5)until the end of tight insertion with a distance of 5-10 mm between any two neighboring OMIs in the same bone blockto avoid any interference between them.

Measurement of OMIs primary stability byperiotest® and pullout test

The handpiece tapping head of the perio-test®device (Medizintechnik Gulden, Modautal, Germany) percussed each OMI head at a perpendicular contact angle to its long axis with keeping contact distance of 0.6-2.0 mm between them(figure 1, f).perio-test®values (PTVs) were measured more than one time for each mini-implant(21). The average value for each measurement time was used for further analyses.PTVs for each tested mini-implant were recorded referring to its primary stability.The pull-out test for OMIs in the current study was accomplished using the Instron model 3345 servo hydraulic Universal testing machine measuring system (Instron, model 3345, England). The machine was programmed to have the upper cross-head travel at a speed of 0.5 mm/minute until a maximum force of 1000 Newton was obtained. Measured data of OMIs primary stability for this testing were recorded using computer software program(Blue Hill 3 (Software version 3.3), which was connected to a load cell of 5000 N.Non-axial pull-out load with velocity of 0.5 mm/minute was applied to each OMI long axis until failure occurred. Pullout force was measured as a function of screw displacement in the bone until OMI lost their hold in the bone(20).

RESULTS

Data were analyzed with SPSS version 21 (IBM: Corporation, Armonk, NY, USA). The normality of data was first tested with Shapiro test. Qualitative data were described using numbers and percent. Association between categorical variables were tested using Chi-square test. Continuous variables were presented as mean ± SD (standard deviation). One-way ANOVA test was used to compare mean of more than two groups, while a post hoc LSD test was used for in-between groups' comparison. The average PTVs for each OMI measuring time was used for further analyses with agreement of 81.9% between 1st and 2nd measurement for each of Mean ± SD and Minimum-Maximum of PTVs. All OMIs studied groups have no statistically significant difference in perio-test® values for each of Mean ± SD and Minimum-Maximum values. One-way ANOVA test was used to compare mean ± SD of all OMIs groups with significant difference of 6.013 between them. Moreover, post hoc LSD test achieved statistically significant difference indication between OMIs groups as p-value was 0.006* (* significant p <0.05). Accordingly, OMIs of SLAO group achieved the higher primary stability results of pull-out testfollowed by the lasered group and finally the control group.

DISCUSSION

The current study presented two methods of OMIs surface treatment including SLAO surface treatment versus CO_2 laser ablation surface treatment that were compared to each other and to the smooth surface OMIs. Effects of these methods on OMIs primary stability in fresh bovine's bone blocks were examined by each ofperio-test®and pull-out test devices.In the current study, Group II of OMIs was surface treated by a combination of sand-blasting, acid-etching and anodic-oxidation respectivelyand this group achieved the higher primary stability results of pull-out test. Cho I-S et al [(11)] used sandblasted, large-grit, acid-etching and anodic-oxidation techniques for OMIs surface treatment and reported that, they may be effective procedures for qualifying the mechanical stability of OMIs, in addition to reducing tissue damage during their insertion.Jang T-H et al [(22)] used hydrochloric and nitric acids for acid-etching surface treatment of OMIs and reported higher roughness of OMIs surface, which enhanced their stability without reduction of their bone-cutting capacity compared with OMIs without surface treatment.In the current study, Group II was treated by two consecutive acid-etching methods by boiling the screw root part in 100 % hydrochloric acid then 60% concentrated sulfuric acid. Conc HCl and H_2SO_4 have great affinity to spread through the facets, which previously created by the sand-blasting process, smoothen out the irregular macro roughness and entirely removed embedded leaved fragments of Al_2O_3 particles that might be lifted after ultrasonic cleaning steps [(19, 23)].Karmarker S et al [(24)] evaluated the effect of surface anodization of OMIs in initial phase after their insertion on the interfacial strength between them and rabbit tibial bones and reported that this may enhanced OMIs primary stability.In the current work, OMIs of Group II, which were exposed to the anodic oxidation process and had preceptedtitanium oxide layer along their screw root part had achieved significant higher primary stability results of pull-out test followed by OMIs of the lasered group and finally OMIs of the control group.Choi S-H et al [(25)] reported differentmicroscopic surface profile of anodic oxidized OMIs than machined surface OMIs. However, there were no clinically significant difference between anodic oxidized OMIs and machined surface OMIs in the biomechanical stability after 3 and 12 weeks of orthodontic force loading.Laser ablation has been presented as a recent technique for dental implant and OMIs alteration of their surface topography [(18)]. Kang et al [(9)] used Neodymium- doped yttrium aluminum garnet (Nd-YAG)laser irradiation for surface treatment of stainless-steel OMIs and reported higher surface roughness of Nd-YAG laser irradiated OMIs with no significant difference in BIC and fracture resistance analysis between the laser irradiated OMIs and the smooth surface OMIs. In the current work CO_2 laser irradiation had resulted in thermal damage to OMIs surfaces included re-melting, alloying, cladding and alteration of its surface topography, which achieved significant higher primary stability results of pull-out test for OMIs of CO_2lasered group than OMIs of the control group.Bovines' femoral head bones were used as a test material in previous studies. In the current study, they were evaluated by CBCT and selected due to their similarity to the human upper and lower jaw bones in the homogenous trabecular structure and relatively the thin cortical layer (20).In the current study two methods, including periotest® and pull-out test were used to detect OMIs primary stability after their insertion in the animal bone blocks.It was noted in the current study, that all OMIs studied groups have no statistically significant difference in perio-test® values, which was represented by the successful OMIs primary stability, this refers that OMIs surface treatment by SLAO and CO_2 laser radiation surface treatment method had no effect on perio-test® values during evaluation of OMIs primary stability immediately after OMIs insertion in the prepared bovines' bone blocks.In the literature, Pull-out test was an agreed method for the evaluation of OMIs primary stability (20, 26-30).In the current study, we have modified pull-out testing of OMIs primary stability at angles of 15° and 25° beside at 0° axial loading angle. Non-axial pull-out load with velocity of 0.5 mm/minute was applied to each mini-implant, where it pulled out at an angle to mimic a more realistic situation, because OMIs were never loaded in an axial direction.OMIs of SLAO group achieved the higher primary stability results of pull-out test followed by OMIs of CO_2 lasered group and finally OMIs of the control smooth surface group.The difference between Perio-test® and Pull-out results for evaluation of OMIs primary stability in the current work can be explained by the fact that Perio-test® was often less than

accurate device for the detection of OMIs primary stability (31). Besides, its clinically significant is limited, since it cannot detect the mesio-distal mobility of OMIs. Moreover, this device can't determine the small changes in the implant bone surface (21).

CONCLUSION

Within the limitations of this study, it can be concluded that surface treatment of orthodontic grade 5 Ti-6Al-4V alloy OMIs by SLAO method achieved the higher primary stability results of pull-out test in fresh animal bone blocks, followed by CO_2 laser radiated OMIs than machined surface OMIs.

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