Zentrum für Zahn- , Mund- und Kieferheilkunde der Universität Zürich

Klinik für Kieferorthopädie und Kinderzahnmedizin

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Skeletal Anchorage in Orthodontic Therapy

Kumulative Habilitationsschrift

zur Erlangung der Venia legendi

der Medizinischen Fakultät der Universität Zürich

vorgelegt von

Marc Andreas Schätzle, Dr. med. dent. et Odont. Dr.

Zürich, 02. Dezember 2009

Zusammenfassung der kumulativen Habilitationsschrift:

Skeletal Anchorage in Orthodontic Therapy

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Zürich, 02. Dezember 2009

Zugrundeliegende Originalarbeiten:

1. R. Männchen & **M. Schätzle**: Success rate of palatal orthodontic implants. A prospective longitudinal study. Clinical Oral Implants Research 19, 665-669, 2008.

2. **M. Schätzle**, R. Männchen, U. Balbach, C. H. F. Hämmerle, H. Toutenburg & R. E. Jung. Stability change of chemically modified SLA titanium palatal implants in humans. A randomized clinical trial. Clinical Oral Implants Research 20, 489-495, 2009**.**

3. **M. Schätzle**, R. Männchen, M. Zwahlen & N. P. Lang. A systematic review on the survival and success rates of osseous anchorage in orthodontics. Clinical Oral Implants Research 20, 1351-1359 2009

4. **M. Schätzle**, D. Golland, M. Roos & B. Stawarczyk. Accuracy of mechanical torque limiting gauges for mini screw placement. Clinical Oral Implants Research (accepted)

To Karen, Jaël and Nicolas

Introduction

In orthodontics, anchorage is a prerequisite for the application of therapeutic forces, and can limit their successful use. Its control is therefore essential. The term "orthodontic anchorage" denotes the nature and degree of resistance to displacement expected from an anatomic unit. Ideal orthodontic anchorage should thus result in a maximum of desired dental movement and a minimum of adverse effects.

Traditionally, in orthodontics, teeth as well as intraoral and/or extraoral appliances have been used as anchorage — minimizing the movement of particular teeth while other teeth are moved as desired. However, this always depends on the patient's unpredictable compliance (Nanda & Kierl 1992). Over the past decades, various case reports and scientific papers have documented the possibility of different types of temporarily placed anchorage devices (TAD) (Creekmore & Eklund 1983, Roberts et al. 1990, Triaca et al. 1992, Bousquet et al. 1996, Kanomi 1997, Umemori et al. 1999, De Clerck et al. 2002).

The TADs do not depend on patient's compliance (Creekmore & Eklund, 1983). Since regular orthodontic patients have a full dentition, or extraction sites to be closed, usually no edentulous alveolar bone areas are available to insert any kind of TADs. As a consequence, for orthodontic anchorage purposes TADs must be placed in other topographical areas of the oral cavity. New additional insertion sites were offered with the introduction of:

- diameter reduced temporary orthodontic anchorage devices such as miniscrews (<2mm) in various lengths (Kanomi 1997, Costa et al. 1998);
- titanium pins (Bousquet et al. 1996);
- L-shaped miniplates with the long arm exposed into the oral cavity (Umemori et al. 1999), and zygomatic anchors (De Clerck et al. 2002), both fixed by bone screws;
- length-reduced orthodontic anchorage devices such as titanium flat screws (Triaca et al. 1992);
- resorbable orthodontic implant anchors (Glatzmaier et al. 1996);
- palatal implants such as T-shaped orthodontic implants (Wehrbein et al. 1996), (Orthosystem®, Straummann AG, Basel, Switzerland), the Graz implant- supported pendulum (Byloff et al. 2000) as well as the subperiostally placed Onplant®.

In some cases, premature loss of the implant occurs prior to orthodontic loading. This may be due to lack of sufficient primary stability (mechanical retention). Clinical evidence and basic research have shown the importance of good primary stability prior to loading. Insufficient primary stability which is one of the most critical factors in osseointegration, causes inappropriate healing and a possible premature loss of the TAD (Friberg et al. 1991, Lioubavina-Hack et al. 2006). But if resistance during the insertion of the implant is too high, the TAD placement torque may generate a level of stress resulting in degeneration of the bone at the implant–tissue interface (Meredith 1998), and subsequent disturbance of the bone regeneration surrounding the implant thread. In order to eliminate the risks of too high an implant placement torque (IPT) which might cause bone stress, or strong tensional forces developing within the screw and leading to potentially screw fracture (Wilmes et al. 2006, Park et al. 2006), several manufacturers of mini screws nowadays offer mechanical torque limiting gauges to control placement torque during mini screw installation.

The dynamics of TAD loss (loss over time), however, are an important factor related to decision making in orthodontic treatment planning. Even though palatal implants have been used in orthodontic treatment for more than a decade (Wehrbein et al. 1996), only one prospective study comprising 9 patients has been published which demonstrates successful osseointegration and functional stability in all patients (Wehrbein et al. 1999). Furthermore, there is no systematic literature review available comparing the respective survival and failure rate of TADs with each other, and no attempt has been made so far to document longitudinally the characteristics of the transition from primary (mechanical retention) to secondary stability (biologic stability) in the maxillary bone of the palatal region in human beings.

The aim of the present series of studies was:

- to assess prospectively the survival rates of loaded palatal implants (Study I).
- to systematically review the survival and failure rates of TADs (Study II)
- to examine changes in stability of palatal implants, and to evaluate whether implants with chemically modified sandblasted/acid-etched (modSLA) titanium surface with enhanced wettability would have an enhanced bone apposition when compared with standard SLA surface (Study III)
- to determine and compare the accuracy of four available mechanical torque limiting gauges (MTLGs) for mini screw placement (Study IV)

Materials and Methods

In the studies presented here, the initial period (stability changes of palatal implants), and the end points (success and failure rate, risk factors) of TADs in orthodontic treatment are elucidated.

In the first prospective study, 70 patients (56 female, 14 male; age 25-6 ±10-8 years) were included in a cohort from March 1999 to November 2006. These patients received Orthosystem® (Straumann, Basel AG, Switzerland) palatal implants. The purpose was to assess the survival and success rates of these palatal implants. The indication for implant placement was based on the required anchorage for orthodontic therapy. The implants were orthodontically loaded after a healing period of 8-16 weeks (Mean: 12.8 weeks).

In a second study, a systematic MEDLINE search followed by a manual search was performed to identify randomized clinical control trials, as well as prospective and retrospective cohort studies on palatal implants, Onplants®, miniplates and miniscrews. Further inclusion criteria were a mean follow-up time of at least 12 weeks and a minimum of 10 units per TAD type having been examined clinically at a follow-up visit. Study assessment as well as data collection was performed by two independent reviewers. Reported failures of used devices were analyzed using random-effects Poisson regression models to obtain summary estimates with 95% confidence intervals of failure and survival proportions.

In the third study, 40 adult volunteers were prospectively recruited and randomly assigned to a test group (modSLA-surface) and a control group (SLA-surface) to examine stability changes of palatal implants with chemically modified sandblasted/acid-etched (modSLA) titanium surface compared with standard SLA surface, during the early stages of bone healing. Test and control implants had the same microscopic and macroscopic topography, but differed in surface chemistry. To clinically assess implant integration, resonance frequency analysis (RFA) was used to measure the implant stability. This technology has been proven to be capable of characterizing alterations in implant stability during early healing, and being sensitive enough to identify differences The technique has been confirmed as an accurate method for early assessment of osseointegration (Huang et al. 2003). To document implant stability changes, resonance frequency analysis (RFA) was assessed at implant insertion and at 7, 14, 21, 28, 35, 42, 49, 56, 70 and 84 days respectively. RFA values were expressed in an implant stability quotient (ISQ).

In the forth study, the torque outputs of six randomly obtained mechanical torque limiting gauges (MTLGs), of either screw driver or torque ratchet type, from 4 mini screw manufacturers were measured. Mounted on a joint, a universal testing machine applied a perpendicular force to a lever arm with a crosshead speed 1.0 mm/min. For each torque device, 10 repetitions of the corresponding target torque level were recorded after initial sterilization (1) and after 5, 10, 20, 50 and 100-times to evaluate the potential influence of sterilization on MTLGs. Descriptive statistics and mean values of breakpoints for each MTLG have been computed and compared to the reference values being indicated on the respective torque gauges provided by the producer.

Results

In the first study, among the total of 70 patients, two implants in two patients had to be removed shortly after insertion due to inadequate primary stability. Only one out of the 68 primary stable palatal implants did not successfully osseointegrate and was lost prior to loading. The overall rate of osseointegration of the 68 implants was 98.5%. After a mean healing time of 12.7 weeks, an individualized, rotationally stable suprastructure was installed in all 67 patients with successfully osseointegrated palatal implants. In November 2006, after a mean loading time of 18.8 months, all but one or 98.5 % of the 67 osseointegrated palatal implants remained stable under orthodontic loading.

In the second study, the systematic MEDLINE search followed by a manual search up to January 2009 provided 390 titles, out of which 71 abstracts justified the full-text analysis of 34 articles, resulting in 27 studies that met the inclusion criteria. A meta-analysis provided the following results: the failure rate for Onplants® was 17.2% (95% confidence interval: 5.9% - 35.8%), for palatal implants 10.5% (95% CI: 6.1% - 18.1%), for miniscrews 16.4% (95% CI: 13.4% - 20.1%) and for miniplates 7.3% (95% CI: 5.4% - 9.9%). Miniplates and palatal implants as torque resisting TADs showed a 1.92-fold (95% CI: 1.06 – 2.78) lower clinical failure rate than miniscrews when grouped together.

In the third study, immediately after implant insertion the ISQ values for both surfaces tested did not significantly differ and yielded mean values of 73.8 ±5 for the control and of 72.7 ±3.9 for the test surface. In the first 2 weeks after implant installation, both groups showed only small changes and thereafter a decreasing trend in mean ISQ levels. In the test group, after 28 days a transition point to increasing ISQ values was observed and 42 days after surgery ISQ values corresponded to those after implant insertion. For the SLA-control group the trend changed after 35 days and reached ISQ values corresponding baseline after 63 days. After 12 weeks of observation the test-surface reached significantly higher stability values of 77.8 ±1.9 as compared to those of 74.5 ± 3.9 for the control implants,

In the fourth study determining the accuracy of mechanical torque limiting gauges, one-way ANOVA with random effects revealed that there were significant differences between mean breakpoints values of six different MTLGs at each condition (manufacturer, indicated torque level and sterilization, (p<0.001)). For all but the Spider Screw MTLG, the sterilization process had a statistically significantly different influence at the various breakpoint torque levels.

Discussion

The use of TADs expands the range of conditions in which orthodontic treatment might be successful. It seems obvious that all TADs have the potential to provide some kind of anchorage, which enables orthodontic tooth movements that might not be possible with conventional anchorage methods. Despite their small dimensions, orthodontic temporary anchorage devices must maintain positional stability under orthodontic loading in order to serve as absolute anchorage. With TADs having been in use for more than a decade, numerous case reports and scientific papers have been published, documenting clinical feasibility. The dynamics of TAD loss is an important factor related to decision making in orthodontic treatment planning as well as the choice of the appropriate anchorage device since failures of TADs during orthodontic treatment might make continuation of the treatment plan difficult or impossible.

On the basis of the prospective clinical study presented here, and of a systematic review of the literature, it can be concluded that for the maxillary arch, palatal implants are a clearly superior treatment option when compared to all other skeletal anchorage devices, whereas in the mandible, miniplates yielded the most favourable results. Both palatal implants and miniplates offer safe and effective anchorage possibilities with a high survival rate (>90%), with little adverse effects or shortcomings during the treatment. Palatal implants as well as miniplates might simplify orthodontic treatment, and enhance the possibilities of tooth movements that might have been considered unfeasible without skeletal anchorage, so far. However, the relative effectiveness, efficiency, and indication list of all different temporary anchorage devices used for various clinical problems need to be evaluated further in prospective clinical control studies.

In implantology, numerous efforts have been made to simplify clinical procedures and to shorten and improve the osseointegration process by using new titanium surfaces (Buser et al. 2004, Oates et al. 2007, Bornstein et al. 2008). The main focus was on early stability changes corresponding to the transition from primary stability - provided by the implant design - to biologic stability provided by newly formed bone, defined as osseointegration (Berglundh et al. 2003). This transition period is crucial regarding the early loading and success rate (Glauser et al. 2004, Raghavendra et al. 2005).

The present findings for orthodontic anchorage implants confirm that surface chemistry is a key variable for peri-implant bone apposition. Increased wettability enhances the interaction between the implant surface and the biologic environment (Kilpadi & Lemons, 1994) leading to enhanced bone apposition (Buser et al. 2004). The present findings are also corresponding to clinical findings in mandibular dental dental implants, pointing out a potential for chemical modifications in a roughened implant surface to alter biologic events during the early transition from primary to secondary stability.

As palatal implants are temporary devices, being usually removed with a trephine bur including a small amount of adjacent bone after their orthodontic use, these implants may be of benefit to study the early pattern of osseointegration in humans including later histological analysis. The present results could confirm the palatal area as a potential experimental implant site in humans.

In a prospective clinical study assessing risk factors related to miniscrew failures (Motoyoshi et al. 2006), the implant placement torque (IPT) was identified as a risk factor for early screw failure. But before IPT can be put to reliable use in the clinic, its critical values for orthodontic mini implants have to be determined, and the manufacturers need to improve precision and reliability of their torque control devices. Significant variation was observed between individual devices from the same manufacturer. The torque output of each individual device deviated to a varying degree from the target torque value, and was influenced to an again varying degree by the sterilization process over time. These inconsistencies applied to all products tested.

Conclusions

- Based on a clinical study of a larger patient number, and on the available evidence from the literature, palatal implants and miniplates showed comparable survival rates of >90% over a period of at least 12 weeks, and longer survival time than miniscrews. Palatal implants and miniplates for temporary anchorage provide reliable absolute orthodontic anchorage (Study I & II).
- Chemical modifications in a roughened implant surface have a positive influence on biologic events during the early osseointegration process. These alterations may be associated with an enhanced healing process, which in turn may lead to alterations in clinical loading protocols for dental implant therapy. As palatal implants are temporary anchorage devices, and will be removed after use with a trephine, including adjacent bone, this type of implants offers an opportunity for further histological analysis (Study III).
- On application of the manufacturers' preset torque tools, significant variations were observed between individual devices. The torque output of each individual device deviated in varying degrees from target torque values and was influenced to a varying degree by the sterilization process over time (Study IV).

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