IN VITRO STUDY OF INSERTION PARAMETERS OF ORTHODONTIC MINI IMPLANTS AND A RETROSPECTIVE CLINICAL STUDY OF THEIR SUCCESS RATES

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INTRODUCTION

The occurance of skeletal and dental anomalies is increasing year by year. According to a Hungarian epidemiological study conducted in 2000, the prevalence of anomalies was at 70.4%. These data also highlight the importance of orthodontic treatment. During orthodontic treatment, in case any kind of force used to move teeth, a force equal in magnitude, but opposite in direction should be accounted for (Newton's third law of motion, 1687). In order to achieve a successfull result, anchorage in form of a contralateral support is essential. Proffit defines anchorage as 'resistance to undesirable tooth movement'. Standard alternatives used for this purpose, like dental support (elastic intermaxillary ligature, accessory intraoral elements) and extraoral support (headgear, face mask) are becoming less prevalent nowadays, especially for adult patients. Absolute anchorage can be provided by conventional implants, miniplates, ankylotic teeth and mini screws.

Mini screws developed specifically for orthodontic purposes are usually applicable in variants between 1.4 mm and 2.5 mm in diameter and between 6 mm and 12 mm in length. Common property of the titanium screws is that there is no additional surface treatment after the metal-turning. Contrary to the conventional dental implants, in case of mini screws the stabilisation mechanism is provided by the mechanic lock. The lack of osseointegration makes the removal of orthodontic screws easy, hence they are called Temporary Anchorage Device (TAD) in the English terminology. We can distinguish self-tapping and self-drilling mini screws, based on their production. Self-tapping imlpants require predrilling prior to placement into the bone, which depends on the bone supply. In case of self-drilling mini screw, predrilling is not a requirement and their use is suggested in thinner, less compact bone (maxilla). For anchorage in areas of the mandible with thick cortical bone, predrilling is always suggested before placement of the mini screw, independently of the type of the implant being used.

Heat production should always be accounted for during predrilling. The thickness of the cortical bone influences the duration of the drilling and the temperature arising in the bone. Conclusion of the generally accepted studies show that the dangerous territory of heat production which puts the survival of the bone at risk, is 47 °C lasting for more than one minute. Obviously at higher temperatures the necrosis of the bone and the lack of healing occurs earlier.

AIMS

The literature lacks definite guidelines and general directions on how many times should the drills be used for predrilling so they certainly do not cause any thermal osteonecrosis during preparation of the bone. The clear signs of the unacceptable extents of the drill-wear and its consequences are also lacking for the oral surgeons and the clinicians. The signs of true heat production are often impossible to recognise. During procedures, similar effects are expected from worn or inadequate drills, without knowledge on the amounts of released heat.

Primary goal was to determine the amount of heat produced during predrilling of the mini screws at 100 rpm, 200 rpm and 1200 rpm and to compare the heat-load produced during the usage of new and worn predrills at the aforementioned revolutions.

Secondary goal was to determine the duration of the predrillings as a function of the examined revolutions in our in vitro study.

Tertiaty goal was to find an answer for the question: 'Does predrilling have an influence on the intraosseal heat-load caused by manual placement of the mini screw?'

Furthermore, based on the current results of our research another goal was to work out a method which is easy to apply in the everyday practice and helps reduce the produced heat during implant placement. For this purpose we tried to determine the heat-load measured during manual placement of the mini screw which was at room temperature and cooled down before placement. In the retrospective clinical study we were trying to decide which localisation and which type of tooth movement influences heavily the occurence of complications and the success of immediately loaded mini screws used in the practice.

MATERIALS AND METHODS

The determination of the heat-load during predrilling of the mini screw, as a funcion of wearing and speed/revolution

Our in vitro study took place at the Clinic of Dentistry and Oral Surgery of Pécs, in an air-conditioned room. The temperature was always set at 24 °C. For the research we used pig rib bone, which had an average thickness of 2.1 mm-2.3 mm of cortical. The carved ribs were placed in the bone fixing part of the apparatus used in the examinations. The

most important piece of the fixing apparatus is the clamp allowing firm fixation of the bone in the required position. This ensured the thermosensor to always be in the correct distance from the drilled cavity. The thermosensor was placed vertically, 1 mm away from the 'pilot-hole' cavities to be drilled. A sample with 4 holes marking the location of drilling and possible temperature measurement was placed on the clamp. The regulation of the drill's speed was also ensured. The apparatus was able to measure the drilling time in milliseconds and the heat produced from the start of the preparation until reaching the pre-determined depth of preparation, which was 5 mm. A separate unit measured the temperature with the help of resistance temperature reading probe, which has parameters of 0.1/1 Celsius degree sensivity and 1 measurement per second (EL-EnviroPad-TC, Laser Electronics Ltd., Salisbury, UK). The micromotor (W&H Implantmed SI-915) was set at the given resolutions. The current drill fixed in the handpiece was set to touch the bone surface. The timer was reset to zero and the weight generating the given pressure was calibrated. The drill was started by foot pedal. The handle holding the micromotor was eliminated so the drill could progress in the bone according to the given weight, until it reached the set depth of 5 mm. At this point the timer automatically stopped and at the same time we released the foot pedal, stopping the micromotor and lifted the drill out of the cavity. This way the cause creating the temperature was eliminated at the given time. We stopped the temperature registrating unit when the temperature dropped back to the base temperature. The next measurement was performed by moving the clamp with the rib to the next drilling position. For the following measurement the drill was changed according to the course of the study.

For measurement of the heat-load we used predrills of 1 mm diameter (112-MC-201). To simulate adequate wear of the predrills we used them on pig ribs 150 times and we sterilised them 150 times in autoclave (SterilClave 24 BHD, Cominox Co., Carate Brianza, Italy) before the actual measurements. We performed 240 cavity drillings on the carved, fixed rib bones, with 3 new and 3 worn predrills. With all 6 predrills, during the preparation of 40 cavities we registered the changes in temperatures in the bone at 100 rpm, 200 rpm and 1200 rpm. To identify the drills we milled strip markings on the shank. At 100 rpm and 200 rpm the axial pressure was 20 N, while at 1200 rpm the axial pressure was reduced to 5 N, in accordance to previous recommendations.

Determining drilling times as a function of revolution

Determination of drilling times were performed with the aforementioned method. The timer was reset before every drilling. When reaching the predetermined cavity depth of 5 mm, the timer automatically stopped (figure 20). We registered the drilling times at 100 rpm, 200 rpm and 1200 rpm aswell, so altogether we averaged from 3 times 40 drillings.

Measurement of the intraosseal heat-load produced during placement of the mini screw with and without predrilling

We randomly selected 10 predrilled cavities and with the help of a hand driver, orthodontic mini screws were immediately placed into them (similar to everyday clinical use). Jeil Dual Top Anchor system's (JEIL Medical Corp. Soul, Republic of Korea) mini screws of 1.6 mm diameter and 8 mm length were used in the study. During the manual placement we continuously registered the changes in temperature in the bone. Another 10 mini screws were placed into intact rib bone without predrilling, while also continuously registering temperature changes.

Effect of precooling of the orthodontic mini screws on the in vitro heat-load during placement

Preparation of the pig rib bone, measurement of the temperature and the enviroment settings were the same as in the previous in vitro experiments. In the first phase we used implants at room temperature, in the second phase we used precooled implants. In the second phase we not only cooled the mini screws, but we also cooled the inbetween piece of the adapter recieving the implant. A few hours prior to placement we placed the implant and the driver in a single-door refrigerator's freezer, which provided temperature between -0.4 and -0.7 °C.

Retrospective clinical study for evaluation of the success rate of mini implants
In our study we involved patients who recieved orthodontic treatment with mini implants as anchors in our department at the Department of Orthodontics at the Clinic of Dentistry and Oral Surgery of Pécs between November of 2014 and November of 2016. We

excluded patients with general health conditions influencing the treatment and patients with a habit of smoking.

For all patients we used one or more self-drilling mini implants with a 1.6 mm diameter and a length of 8 mm (JEIL DUAL TOP ANCHOR SYSTEM, JEIL Medical Corp. Soul, Republic of Korea). We considered mini implants successful if they stayed stable for the entire treatment and offered a stable anchorage independently of the treatment duration. On the other hand, mobile or lost implants were considered unsuccessful or failed. Inflammation around the mini implant or recognisable bone loss or trauma to the adjacent teeth were considered as complications, even without subjective symptoms from the patient. Prior to diagnosis and creating the treatment plan, a thorough anamnesis was taken to evaluate the general condition of the patient and informations were gathered regarding medications. After taking the anamnesis, extra and intraoral examination was carried out and the dental status was taken aswell. Alginate impressions were taken and the evaluation of the castmodels recording the occlusal relations also contributed to the establishment of possible treatment alternatives.

The exact location of the skeletal anchor was determined with the help of physical and radiographic examinations. Planning the localisation of anchor device was done with panoramic radiograph, which is a basic examination method when establishing orthodontic diagnosis. The lateral cephalogram not only helped the cephalometric analysis, but further helped to establish the skeletal age by classificating the status of the cervical vertebrae developement.

During our study, the most common indications for mini implants were alignement of impacted canines, treatment of aplasia, and preprosthetic orthodontic treatment.

For data processing and statistical analysis, versions 20.0 and 22.0 of SPSS® (SPSS, Chicago, IL, USA) were used. In every study period first we examined the normality of our data performing the Kolmogorov-Smirnov test. In case of normal distribution we used parametric tests and in case of non-normal distribution we used non-parametric tests. To compare the heat production of worn and new predrills at different speeds and to compare the drilling times at the examined speeds we applied the non-parametric Kruskal-Wallis test and Wilcoxon's signed-rank test. P-values less than 0.05 were considered statistically significant. A two-sampled t-test was used to compare temperature changes during placement of mini screws with or without predrilling. P-values less than 0.05 were considered statistically significant. To compare the measured temperatures during manual placement of the precooled and room temperature implants we also used a two-sampled

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t-test. We used khi square test ($\chi2$) to evaluate the occurance of different complications as a function of localisation of the mini implant. P-values less than 0.05 were considered statistically significant.

RESULTS

Results related the use of new and worn predrills

The drilling speed significantly increased the temperature measured in the bone (Kruskal-Wallis test) when using new ($p < 0.001$) and worn ($p < 0.001$) predrills. When comparing temperature changes in the bone during the use of new and worn predrills at 100 rpm and 200 rpm revolutions there was no significant difference (Wilcoxon test; $p = 0.345$ and $p = 0.736$). On the other hand, comparison of low speed of 100 rpm and high speed of 1200 rpm ($p < 0,001$) and comparison of 200 rpm and 1200 rpm both resulted in significant difference in regards of temperature changes (Wilcoxon's test). Predrilling at higher speed lead to a higher rise in temperature in the bone. The temperature changes in the bone was even more pronounced when using heavily worn predrills. The use of worn predrills resulted in higher temperature changes when compared to new predrills at the same speeds (Wilcoxon's test): 100 rpm ($p < 0.002$), 200 rpm ($p < 0.021$) and 1200 rpm ($p < 0.001$). The increased temperature noticed during the preparation of the cavities, continuously decreased after the preparation and reached the initial temperature after 30 seconds. From the data collected during predrillings, we noticed that the more worn the drills were, the higher the increase of temperature was. We made Scanning Electron Microscope images to trace the changes in the cutting edges and the tip of the used drills. The high amounts of usage and sterilisation made the tips blunt and the cutting edges rounded.

Results related to drilling times

The time necessary for predrilling was evaluated as a function of speed (rpm). The registered drilling times were significantly different at the different revolutions during preparation of the cavities (Kruskal-Wallis test, $p < 0.001$). Significant differences of drilling times were registered when comparing 100 rpm and 200 rpm (Wilcoxon's test, p

< 0.001), as well as comparing 200 rpm and 1200 rpm (Wilcoxon's test, p < 0.001). The duration of predrilling was significantly shorter than it was at 100 rpm or 200 rpm.

Results related to heat-load during manual placement

The temperature increase measured in the bone during manual placement of the mini screw after predrilling was 11.77 ± 2.06 °C. Manual placement of the mini screw without predrilling resulted in similar intraosseal temperature increase (11.33 ± 2.38 °C, p = 0.707; t-test). Our method (predrilling and placement) reflected the method used in everyday clinical practice, which means that manual placement of the mini screw happens immediately after predrilling in the bone (1200 rpm). The heat-load caused by the predrilling lasted for 10 seconds, while the temperature increase caused by the manual placement held the temperature of the bone above the dangerous threshold for 17 seconds. Conspicuously the temperature did not return to the initial temperature during the examined period of 140 seconds.

Results related to the precooling of the mini screws

When placing the mini implants (1.6 mm diameter, 8 mm length) at room temperature into the pig rib bone, the average temperature increase was 11.3 °C. This added to the human body temperature of 37 °C, exceeds the threshold temperature of 47 °C, which is considered hazardous for the healing of the bone. Not only the precooled mini implants resulted in significantly lower temperature increases (6.6 °C), but they were also able to decrease the initial temperature of the bone in the first few seconds.

Results of the retrospective study evaluating the success of mini implants

In a 2 year period between 2014 and 2016 we included 47 patients in the study. During that time 59 mini implants were placed to complement the orthodontic treatment. The average time for their function as skeletal anchors was 8.1 ($\pm$ 3.3) months. Based on the examined data, the success rate of these anchors was 89.8%. When evaluating the failure rates significant differences were not shown in regards to age and gender. Out of the 59 mini implants placed, a total of 6 cases presented inflammation around the mini implants (10.2%). In regards to localisation, the inflammation presented in 6.3% of the implants

placed in the palate, meanwhile in the buccal region, this number was 8.3%. We experienced an exceptionally high rate of inflammatory complications when placing mini implants in the ramus (33.3%), which is even more outstanding considering the low number of cases. Considering the loosening of the mini screws, there were significant differences in different locations. The loosening lead to necessary removal of the mini implants in 3.1% of the palatally placed implants and 20.8% of the cases when it was placed buccally. However this complication occured in 6 cases out of the 59, which means a failure rate of 10.2%. Regarding the type of treatment, loosening of the mini implant happened significantly more often in case of intrusion, compared to extrusion of impacted teeth (p = 0.036). During the study period, fracture of the implant occured once, in case of a mini screw placed in the ramus (figure 50). The cause of the fracture was unfavourable ratio of diameter and length of the predrill and the mini implant. Considering the low number of such cases, this lead to high failure rate (33.3%).

DISCUSSION

The use of mini implants as skeletal anchorage during orthodontic treatment enables a faster treatment and more precise end result. However temperature changes of the bone during the use of mini implants should always be accounted for. High temperatures in the bone can cause local circulatory disturbances and function modulation of the cell proteins. While the increase of temperature to 40°C can cause hyperemia, persistent increase up to 53°C can lead to complete disturbance and occlusion of the circulation. Generally a temperature of 47°C in the bone lasting more than 1 minute will inhibit the survival of the bone. Higher temperatures will cause the necrosis of the bone even earlier. According to Lundskog's study, denaturation of the intracellular ensimes and membrane proteins, dehydration of the cell, damage to the cell membrane and the process of carbonisation can happen as soon as 1-2 seconds at 90°C. According to Berman, a 30 second impact at 70°C or even 50°C can lead to irreversible ensimatic damages in the cortical bone. Our in vitro study unequivocally proves that increasing drill-wear, increasing pressure and decreasing watercooling can cause remarkable temperature increase during bone preparation. It is only natural that drills produce heat while being used, but the extent and the duration of the temperature increase is not at all negligible. There are many factors ifluencing the amount of heat, but the two main factors are:

　　　　- the break of intermolecular bonds, which releases heat

- the heat production of the non-preparing drill surface, caused by the friction

From another standpoint, other parameters that influence the temperature increase during bone drilling can be divided into 2 main groups:

1: drilling parameters: drilling speed, cooling, the progression pace of the drill, the pressure on the drill, the depth of preparation and whether there was predrilling or not (and the depth of the predrilling cavity aswell)

2: characteristics of the drill: diameter, working surface, striation, helix, tip angle and wearing

Most of the parameters can be easily controlled or modified, however some of the factors are predetermined (the thickness of the cortical for instance). Considering the quality of the alveolar bone and the condition of the adjacent soft tissues, correct positioning of the mini screw can increase the success rate. Some of the factors are harder to follow, like the progress of drill-wearing. The drilling time is heavily influenced by the thickness of the cortical bone and the quality of the bone's inorganic components.

Predrilling is an important matter when it comes to mini implants. When using mini screws the need for predrilling depends on the thickness of the cortical bone. The correctly chosen predrilling size and 'pilot hole' can help decrease the torque during the placement of the implant, thus also decreasing the microfractures in the bone. During predrilling, even at low speeds the extra temperature produced should be accounted for, because it can also cause necrosis in the bone. Mini implants with predrilling have significantly better primary stability after placement, than the mini implants that are placed without predrilling. However with time the stability of the mini implants that require predrilling can decrease, mainly because of less trabecular bone.

Furthermore the placement method can influence the produced temperature in the bone. The literature suggests that if predrilling is suggested (if the thickness of the cortical bone is between 1.5 mm and 2.5 mm), than prior to the use of a mini implant with 1.6 mm diameter, a predrill of 1 mm diameter should be used. The results of our study evaluating a mini implant system that doesn't require predrilling, that a 'pilot hole' with a 0.625 ratio (1 mm/1.6 mm) did not decrease the intraosseal heat-load. Furthermore, preparation of a 'pilot hole' can create further thermal damages in the bone. Following the conventional method, during a combination of predrilling and the immediate manual placement of the mini implant, the bone suffers from the damages of the 'dangerous zone' ($> 47°C$) for 27 seconds and for about 1 minute, the temperature of the bone is above $41.3°C$, if we apply our data to a system with a starting temperature of 37 °C.

To our knowledge only one in vitro study evaluated the thermal effects of the 'pilot hole' on a mandible modell. Nam et al. studied the produced heat during the preparation of a 5 mm deep cavity. They used 600 and 1200 rpm speeds and 5 N and 20 N pressure loads in their study. Nam et al. reported a significantly higher temperature increase, than the results of our present study. According to their results, preparation of a cavity with a new drill at 600 rpm and a 10 N pressure lead to 15.8 °C temperature increase. The same procedure at higher speed (1200 rpm), but lower pressure (5 N) induced a 11.4 °C temperature increase in the bone. Based on the results of our research, predrilling carried out at 100 rpm and 200 rpm increased the temperature by 2°C. Compared to the results of Nam et al., we registered lower temperature increase, even with higher revolution (1200 rpm), when using a new predrill. On the other hand, the use of a worn drill at 1200 rpm resulted in similar temperature increase (12.3°C in this present study, while 11.4°C in the previous one). The difference between the result of our present study and their previous study can be explained with the different temperature registering system (thermosensor vs. infra thermometer). The difference can also be caused by the difference of the study modells (pig rib with a 2 mm thick cortical bone, vs. beef rib bone). On top of all this, in our study at lower revolutions, we pressured the drills with a bigger axial load (20 N). The cause of this was that at 600 rpm, with a 5 N pressure, the drill is unable to prepare the cortical bone adequately. It is important to mention that similarly to Nam et al.'s study, during the course of the study we did not use cooling liquids either, thus enabling comparison of the previos and the present study's results. Relating to the predictable temperature increase, in case of drilling at low speed, cooling has little advantage. Cooling helps to lower the temperature and also helps to lower the friction and helps remove the bone debris from the drill's grooves, which would lead to further temperature increase. The necessity of a cooling liquid is questionable, when using a worn predrill at high speeds (1200 rpm). Nonetheless, drilling carried out at higher speed significantly accelerated the procedures during the course of our study (2.8 seconds, 1.1 seconds and 0.1 second at 100 rpm, 200 rpm and 1200 rpm, respectively). In our opinions all the drilling times are clinically acceptable. In our study we measured the heat-load caused by the manual placement with or without preceding predrilling. During the predrilling we used 1 mm predrills, before the placement of 1.6 mm mini implants. These results suggest that predrilling did not decrease the heat-load measured during the placement of the mini screws (11.77°C ± 2.06°C with predrilling, 11.33°C ± 2.38°C without predrilling). With the combined use of predrilling and manual placement, the

heat-load affecting the bone is cumulative, and after predrilling, during the manual placement we measured a temperature above 41.3°C for a minute and we experienced a temperature of 47°C, exceeding the 'threshold' for 27 seconds. Contrary to this when the mini implant and the driver was cooled down to 0.4°C before use, not only we avoided 'dangerous' temperatures to the bone, but we also decreased the temperature of the bone at the begininng of the procedure, with the help of the precooled mini implant. When using mini implants, we are able to reduce the intraosseal heat-load by adequately preparing for the manual placement: cooling down the implant and the hand driver in the freezer. By using this simple method we can avoid critical temperatures above 47°C, which would risk the survival of the bone.

Based on their survival and success rates, orthodontic mini implants can tremendously help to create stable anchorage during orthodontic treatments. However, to avoid complications a number of critical points should be accounted for. One of these is the location of the implant placement. According to a study carried out by Turley et al. we can achieve the biggest stability by placing the mini screws in the keratinised tissues. Another study, by Cheng, Miyawaki et al. suggests that mini implants placed in the palate have similarly high success rates, close to 100%. Park et al. tried to find the fundamental factors, that are essential for the successful use of mini implants. To a certain extent their results correspond with our results in that inflammation was more frequent in the case of mini implants, which were placed in the buccal fold. This can be explained with the difference in the mucosa, the labial areas are more prone to the effects of the muscles and are harder to clean for the patient. The attached mucosa of the palatal region is more favourable for the mini screw. Our results confirm this: during the orthodontic treatment loosening of the mini implants occured in 3.1% of the cases when placed palatally, while in the case of skeletal anchorage placed in the buccal fold, loosening was experienced in 20.8% of the cases. Lee et al. chose the palatal suture as their location of the mini implants for intrusion of molar teeth. Keratinised soft tissue with thin bone enables faster intrusion and the patients reported better comfort. Skeletal anchors have an emphasized role in the treatment of upper molar elongation after the loss of lower molars. The elongation of upper molars is presented in 24 % of patients.

The stability is affected by the quality and quantity of the cortical bone. In case of a mini implant placed in a cortical bone with less than 1 mm thickness, the skeletal anchorage is not ensured. To determine the thickness of the cortical bone and the most favourable anatomic location for the mini implant, the most precise diagnostic equipment is the CT.

Favourable areas well known for the use of skeletal anchors are: the alveolar process of the maxilla and the palate on the upper jaw, and the retromolar area, the interradicular and the interdental areas of the alveolar process on the lower jaw. Our results suggest that loss of the implant is significantly more frequent if its placed in the buccal fold (which is often not ideal when considering the thickness of the cortical), compared to those cases when its placed palatally (3.1 %). However this did not play a role in the occurance of inflammation, as it was similar in the two areas compared. Other than the thickness of the cortical bone, attention should be paid for the thickness of the soft tissues aswell, when choosing the localisation of the mini screw, in order to improve stability. Eger et al. published the possibility of measuring the thickness of gingival tissues with the help of ultrasound. The thickness of the mucosa shows individual diversity both in the maxilla and the mandible, thus the thickness of the mucosa determined with the help of ultrasound can contribute to the choice of a favourable location for the mini implant. Along with the thickness of the cortical bone, it also weighs in the exact choice of the length and type of the mini implant. The results of our study show that immediately loaded mini implants used for retraction of anterior teeth had only 81.2 % success rate and almost every fifth anchor device had to be removed because of implant loosening during distalization. At the same time significant differences in the occurance of implant loosening can only be shown in intrusion and extrusion cases.

Data in the literature is dividing in regards to the need and length of healing time before loading the implant. Büchter et al. found in their study on pigs, that if the immediate load was less than 900 cNmm, loss of the implant did not occur. According to several authors the required force for retraction of canines was defined as 155-250 grams, for which a stable mini implant can ensure adequate anchorage. Roberts et al. concluded in their study that the ideal extent of force is 100-300 cN, under this load implants proved to be stable. This force corresponds with the forces used in the everyday clinical practice. They measured size of the force, however the exact point of force impact and its distance from the bone surface was not studied. For the stability of the implant, size of the force and the location of impact is equally important. To explain this Shantavasinkul et al. conducted an in vitro study, in which they loaded self-drilling mini screws (Tomas Sd; Dentaurum, Ispringen, Germany) of 1.6 mm diameter and 6, 8, 10 mm length with 200 cN force. They placed all mini implants in 6 mm deep in composite analog bone modells (Sawbones; Pacific Research Laboratories, Vashon Island, Wash., United States). With the help of a 3 dimensional imaging technique, described in a previous study, they registered the

changes of the bone surrounding the implants under loading. The impact of the force was 3 mm far from the neck of the implant in every case. This way in the case of different sized implants (6 mm, 8 mm and 10 mm) the distances between the bone surface and the location of force impact was 3 mm, 5 mm and 7 mm respectively. With the limits of the study modell included, they recieved the following result: moving away from the bone surface, the mini implant can tolerate less force. According to this statement, the success rate of the mini implant can be increased if the impact of the load is closer to the bone surface. Because of this, it is suggested to choose mini implants with a shorter neck and the most favourable location for their use are the areas where the gingival tissues are thin. Based on these results we can conclude that immediate loading of the mini implants is possible without complications and the size of the force and the location of its impact plays a big role in the stability. Contrary to enosseal dental implants, in the case of mini screws the stability is ensured by the mechanic lock. For this reason, according to general consensus the diameter and the length of the mini implant do not play a significant role in regards to the outcome. Tseng et al. reported 100 % success rate only in the case of 12 mm long mini implants. Other authors also agree that bigger length can increase stability, however the risk of damaging the roots is also greater when placing these implants. For safe use, 6-8 mm long implants are suggested and we followed this guide in our studies aswell.

Fracture of mini implants occurs in 0.5-1.4 % of the cases. Most of the times this happens at the neck of the implant, because mechanical stress concentrates in this point. With the use of adequate driving torque (3-10 Ncm), the occurance of this complication can be reduced, avoided. During our study, fracture of the mini implant happened once, out of 59 cases. Another complication can be the injury to the adjacent teeth's roots, when placing the mini implant. Some studies mention this complication to occur in 1.3 % of the cases, while other studies have this occuring more frequently, in 3 % of the cases. A post-operative X-ray and frequent vitality test of the adjacent teeth is required in order to monitor damage of the adjacent roots, especially if the patient complains of pain. To avoid root injury, some suggest an oblique placement in the area where the interradicular area is wider. During the 2 year study period, this complication did not occur at all. Injury of the soft tissues is a very rare complication and the chance of inflammation around the mini implant can be minimized by maintaining good oral hygiene. Kuroda et al. evaluated pain and discomfort by the patients with the help of a survey, including 75 patients. When a mucoperiostal flap was made prior to the placement of the mini implant or mini plate,

35 % of the patients still felt pain at the location of the surgery after 1 week. When a surgical flap was not performed, only 8 % of the patients felt minimal pain the day after the procedure. We can conclude that in order to have a successfull outcome, thorough anamnesis and diagnosis are essential, aswell as the determination of the ideal and exact location of the mini implant. By performing the adequate surgical technique, thermal osteonecrosis and injury to the roots of the adjacent teeth can be largely avoided.

THESES OF THE DISSERTATION

Characteristics of predrilling of the mini screw

In areas of the mandible with thick cortical bone (where the cortical is more than 2 mm thick) predrilling is neccessary in preparation for the mini screw. During our in vitro study we registered the temperatures during cavity preparations carried out with 1 mm diameter predrills, prior to placement of mini implants with 1.6 mm diameter. With constant axial loads of 20 N, we modified the drilling speeds (100 rpm, 200 rpm, 1200 rpm) during the course of the study. Based on the results of our study, we do not suggest predrilling, because of temperature considerations. However, if predrilling is required, it is suggested to be carried out at 100 rpm or 200 rpm. Our study unequivocally proves that increasing wear of the drills leads to significant temperature increase during bone preparation. The significant difference shown in temperature changes when comparing new and worn predrills reveals that the use of worn predrills should be avoided, especially at high speeds (1200 rpm). A worn predrill used at 1200 rpm speed can increase the intraosseal temperature by 12.3°C. *Substantial heat-load can have disadvantegous effects on the integrity and longevity of the mini implant.* This is a fundamental aspect of predrilling, because there are no guidelines by the manufacturer regarding the extent of use and the extent of wear cannot be valued by the naked eye.

Evaluation of drilling times

Regarding the drilling times, the faster the procedure is, the less the bone is exposed to unnecessary temperature increases. Although drilling times were acceptable at all three examined revolutions, paying regard to consequential temperatures, we suggest the predrilling to be carried out at low speeds (100 rpm, 200 rpm).

Characteristics of manual placement of the skeletal anchor

In our study we compared the heat-load resulted by the manual placement of self-drilling mini implants with or without predrilling. Based on the results we can state that predrilling does not reduce the temperatures created by the manual placement of the mini implant. *Nevertheless immediate procedure following the predrilling can cause even more serious heat damage, because the bone does not have enough time to return to its base temperature.* Before the manual placement of the skeletal anchors we examined, time should be left for the bone to 'cool down' (minimum 30 seconds), if predrilling was carried out.

The effects of cooling down the mini implant

When using mini implants heat-load created in the bone should always be considered. In order to reduce the amount of this heat-load, thus to avoid thermal osteonecrosis, adequate preparation for the manual placement of the mini screw is required. Based on our in vitro study prior to placement, it is suggested to cool down the implant and the hand driver in a freezer. With this simple method we can cut the temperature created in the bone to almost the half of it (11.3°C vs. 6.6°C). Further in vivo animal and clinical human examinations are necessary to explore the real advantages (the possibility of less post-operative pain, less frequent premature loosening of the screw).

Evaluation of the success rate of the mini implants

For the purpose of a successfull outcome, *determination of the mini implant's ideal, exact location* is crucial. *By carrying out the adequate surgical technique*, thermal osteonecrosis and injury to the adjacent teeth's roots can be avoided. Based on our study, successfull use of the mini implants was experienced in 89.8 % of the cases in our own practice. Regarding inflammatory complications we can say that even with careful placement, it is a relatively common complication, which could be heavily influenced by the bad oral hygiene habits of the patient, although we did not measure this objectively. Our study concluded that loosening of the implant should be accounted for in case of immediately loaded implants with 1.6 mm diameter and 8 mm length, if it is placed in the buccal fold. Contrary to this palatinally placed mini implants enable exceptional skeletal

anchorage. Regarding the type of tooth movement, loosening of the implant is more frequent in intrusion cases than in extrusion cases. Determination of optimal healing time and the extent of the 'ideal' load is the aim of our future studies, as these can further improve the success rates of mini implants.

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