6-25-2020

Retrospective Evaluation of the Survival Rate of Buccal Mini-implants and the Factors Associated with their Survival

Ledjo Palo
lpalo@uchc.edu

Recommended Citation

Retrospective Evaluation of the Survival Rate of Buccal Mini-implants

and the Factors Associated with their Survival

Ledjo Palo D.M.D.

D.M.D., University of Connecticut School of Dental Medicine, 2017

A Thesis

Submitted in Partial Fulfillment of the

Requirements for the Degree of

Master of Dental Science

At the

University of Connecticut

2020

APPROVAL PAGE

Masters of Dental Science Thesis

Retrospective Evaluation of the Survival Rate of Buccal Mini-implants and the Factors

Associated with their Survival

Presented by

Ledjo Palo D.M.D.

Major Advisor_____

Sumit Yadav, B.D.S., M.D.S., PhD.

Associate Advisor_____

Aditya Tadinada, D.D.S., M.D.S.

Associate Advisor_____

Madhur Upadhyay, B.D.S., M.D.S.

University of Connecticut

2020

TABLE OF CONTENTS   **Page**

ABSTRACT

Objective: The aim of this study is to evaluate the success rate of common mini-implants used on the buccal side of both the maxilla and mandible for orthodontic purposes. All orthodontic mini-implants placed at the University of Connecticut residency from July of 2013 till April of 2020 by various residents and faculty. The location and outcome of the implant was measured as success if the implant was stable or if it failed.

Materials and Methods: Records of all mini-implants placed on the buccal aspect of both maxilla and mandible of patients receiving orthodontic treatment at the University of Connecticut Orthodontic Department from July 2013 to April 2020 were included. Both photographs and notes of the treatment were analyzed. The age, sex, malocclusion type, location of mini-implant and the dates of placement were recorded. The dates of any failures and or re-insertion at the same or different location were also recorded to the best of our abilities. The same measurements were made by 2 different operators, S.A. and L.P. The results were compared between both operators for reliability.

Results: A total of 157 buccal mini-implants were placed in 65 patients during the period from July 2013 to 2020. The mean age of these patients was 29.95 ± 12.7 years (range 13-64 years). Thirty-three patients were female (mean age: 31.6 ± 13.7 years), and twenty-two patients were male (mean age: 26.73 ± 11.1 years). No significant differences were found in relation to age. Males had a significantly higher failure rate than females 44.8% vs 25.3% respectively. The mandible had more failure rates than the maxilla, 39.1% vs 23.1% respectively. A statistically significant correlation was not found between the anterior-posterior location of the implants on the dental arches. In terms of the types of implants the failure rates were as follows: 26.9% for the

buccal alveolar mini-implants, 36.4% for the infrazygomatic, and 75% for the buccal shelf mini-implants.

Conclusion: Buccal-alveolar and infrazygomatic implants placed in the residency setting have a lower survival rating that shown in previous literature and the procedures are highly technique sensitive. Buccal shelf orthodontic mini-implants showed a very poor survival rate in the residency setting. Orthodontic mini-implants are more stable in female patients, and are more successful in the maxilla than the mandible. The success of mini-implants is higher when placed in patients with Class I and Class II skeletal relationships as well as when they are used for anchorage and molar protraction rather than distalization and/or intrusion as well as Class III patients.

BACKGROUND

<u>Introduction</u>

     Different terms have been used for orthodontic mini-implants in the literature such as mini-implant, miniscrews, microscrews, temporary anchorage devices (TADs) and temporary skeletal anchorage devices (TSADs). All of them designed to aid in orthodontic anchorage, and minimize side effects.[39] There is no general consensus on the nomenclature.[32] The use of the term temporary anchorage devices includes what commonly are referred to in orthodontics as mini-implants which typically are placed by an orthodontist or surgeon with a minimally invasive procedure. It also includes mini-plate type devices generally placed by surgeons with a more invasive procedure that requires at least 2 visits. Mini-implants generally have a conical shape with a head that emerges from the mucosa and that allows connection with orthodontic appliances. Length and diameter vary widely between makes and their surface is generally smooth, which limits osseointegration.[11]

     In this publication we will refer to the single screw made of titanium or steel and used for orthodontic anchorage as a mini-implant. The introduction of mini-implants to the field of orthodontics has been one of the most popular and beneficial modalities for treatment planning and anchorage preservation due to its simplicity of placement and removal, low cost, and minimal need for patient compliance.[28] Skeletal anchorage expand the envelope of discrepancies in which orthodontic treatment can be successful.[30] Skeletal anchorage devices are used by orthodontists for a range of clinical applications. These include protraction, distalization, intrusion, extrusion, cross bite correction, anchorage reinforcement and can be designed to apply forces in a number of different directions commonly not possible with fixed appliances alone.[1] The first application on

TADs was in 1945, when Gainsforth and Higley placed vitallium screws in the ascending ramus of 6 dogs aiming to retract their canines. It was not until almost 30 years later that the first human case report was published. Publications regarding the mechanically retained mini-implants increased dramatically from a few papers in the 1980s to above 5000 papers up until year 2017, indicating a huge interest in skeletal anchorage. Unfortunately, the vast majority of these papers are case reports and biological science research and very few clinical trials have been published.[1] The majority of clinical trials that have been published have included all types of temporary anchorage devices as well as all common locations including the palate. In this study we will only look at mini-implants which are placed on the areas of the dental ridge and buccal/labial to in both jaws. Common types of these orthodontic mini-implants include what are known as buccal-alveolar or inter-radicular, ridge, infrazygomatic and buccal shelf implants to name a few. The most common use of these orthodontic mini-implants is anchorage preservation. When used for anchorage, mini-implant reinforcement is associated with 2.4 mm less anchorage loss compared with conventional anchorage means.[27]

One of the drawbacks of orthodontic mini-implants is their failure rate and variability within the orthodontic literature which ranges between 5% and 20%.[2] The stability of mini-implants is a clinical challenge to accomplish because it is not based on osteointegration, but it depends on mechanical locking of threads into the bony tissues. How closely they interact consequently could resist the orthodontic loading forces. Mini-implant success has been defined multiple different ways. Functional maintenance of the mini-implants in bone until the end of its planned active treatment is a logical definition.[4] However, treatments, and duration vary widely. For this another definition has been put forth to try and standardize the process. This second definition is as follows: Mini-implant failure has been defined as the removal or the replacement

of mini-implant because of mobility or loss of a min-implant in less than 8 months following placement.[45] The limitation of this definition is that on many occasions the orthodontic mini-implants are kept in the mouth for a shorter or longer period than 8 months due to the fast nature of their mechanics.

Many retrospective studies and systematic reviews have reported that the success rate of orthodontic mini-implants exceeds 80%.[43] Two recent meta-analysis even though looking at slightly different studies came to the conclusion that the average failure rate of orthodontic mini -implants was 13.5% .[1,29] Often these include palatal mini-implants which are proven to have a different survival and this rate does not reflect the true success rate of interradicular mini-implants which are in fact less successful than palatal ones. Parasagittal insertion of the mini-implants in the anterior palate has one of the highest success rates and these rates and its high success rates should not be translated to all mini-implants. Hourfar and colleagues found a success rate of 98.4% for the mini-implants placed in the palate and 71.0% for those mini-implants placed on the interradicular area on the buccal side. It has been suggested that risk factors associated with the instability of mini-implants could be categorized as host factors, mini-implant factors, and surgical management factors. For example, the host factors associated with failure of mini-implants include age, sex, vertical skeletal relationship, oral hygiene, cortical bone thickness, root proximity and the jaw receiving the insertion. On the other hand, mini-implant factors include make, material, shape, diameter, length and surface characteristics of the mini-implants. Finally, surgical management factors include insertion torque, angle, placement height (in the movable or attached mucosa), the necessity for pre-drilling or flap surgery, insertion by a manual or motor-driven method, experience of the clinician and latency period after loading.[43]

When it comes to mini-implant factors almost all of them have been looked at extensively many of which showing little to no correlation between them and success rates. Chaddad and colleagues found in their study that surface characteristics of their mini-screws did not show a statistical significance. Machined titanium mini-implants had an overall 82.4% survival rate and sandblasted and acid etched mini-implants had an overall survival rate of 93.4% survival rate. Yadav and colleagues found that the removal torque of mini implants both in tibia and femur of rabbits were higher in implants with surface area that was grit blasted and acid etched even though the surface area of grit blasted alone with no etch was higher. Their histomorphometric results showed a significantly higher percentage of bone-implant contact with the rough surface implants than the machined ones. Both the thread design and diameter of mini-implants have a great impact on their primary stability. The intraosseous conical design seems to be superior to the cylindrical design. [48] A recent meta-analysis by Yi determined that self-drilling and self-tapping mini-implants had similar failure rates. Gritsch et al, placed stainless steel and titanium mini-screws in pigs. His study in pigs showed that stainless steel implants showed a slightly better survival rate 87.5% vs 81.3% and 62.5% vs 50% when compared to titanium mini-implants respectively at 2 different time points. Nevertheless, in the US most mini-implants that are approved for use are made out of titanium. With regard to mini-implant size, it has previously been concluded that mini-implants with a diameter between 1.1 and 1.6 mm provide the best success rates. Similarly, mini-implants longer than 5-8 mm are more stable than shorter ones.[1] Long mini-implants are associated with greater incidences of sinus bicortical performations. However as the length of the implant increases their ability to contact the lamina dura of the teeth does not increase proportionally, rather the angle and technique might have a better impact on its prognosis.[38] Schatzle found approximately two-fold increased failure rate was identified for mini-implants with diameter <1.2mm compared

to mini-implants with a diameter of 2mm or more. 8mm mini-implants were significantly more stable than the 6mm mini-implants and the success rate in the maxillary was significantly higher than that for the mandible.[43]

Patient specific factors have also been associated with the success rate of mini-implants. Antoszewksa found that only a few factors were found to be associated with statistically significant higher success rates of mini-implants, including deep bites, placement in the attached gingiva of the maxilla, and en-masse distalization of teeth. Similarly, Moon proposed from a sample of 778 mini-implants that the patient's vertical growth pattern could be a risk factor for survival of the mini-implant with the patients with increased FMA and distally curved condyle exhibiting significantly reduced survival of the mini-implants. This is believed to be due to weaker musculature and thinner bone in these patients. Bayat et al found that when it came to orthodontic mini-implants, heavy smokers had up to 5 times the failure rate of mini-implants than light smokers and non-smokers. The success of the orthodontic mini implants may be correlated to an increased implant-to-bone contact area rather than the properties of the screws themselves or other proposed factors. Thus. their success usually depends on the bone quantity (bone volume/amount of bone present) and bone quality (bone density) which can be influenced by many factors, including heredity, race, environment, nutrition, and lifestyle.[1]

Lastly operator specific factors also play a role in the survival of orthodontic mini-implants. Azeem and colleagues found no significant correlation in failure rate according to various predictor variables, except for mini-implants installed by lesser experienced operators, which showed significantly more failure. It would be easy to assume that novice clinicians would be more likely to insert the mini-implant in such a way that it contacts an adjacent root. Kuroda et al found that the proximity of the interradicular mini-implant to the lamina dura of the tooth was positively

correlated with its failure. Contact with the rots of the neighboring teeth during insertion resulted in 3 times more failures than when implants were inserted away from adjacent roots.[24] There was a tendency for a higher failure rate with increased insertion torque, and all mini-implants were stable if the insertion torque was within the range of 5 to 10 Ncm.[38] The mucosa through which the mini-implant is inserted is a factor that affects the implant's survival. Topouzelis and Tsaosoglou found out that a mini-implants placed in attached gingiva had a 24 times greater success rate than those placed on movable mucosa. Early or late loading of orthodontic mini-implants is another debated topic in the literature. However, considerable variation between different anatomical insertion sites has been reported. Aly and colleagues concluded that immediate loading of mini-implants is a safe technique, with a greater success rate than delayed loading, and can withstand up to 250 g with a good success rate. Garfinkle et al found that immediate or delayed loading of orthodontic mini-implants had a surprisingly similar failure rate.

<u>Rationale</u>

The success rates of temporary skeletal anchorage devices have been looked at almost since their introduction. The technology and understanding of the techniques for use of the traditional orthodontic mini-implants have evolved and new types of devices and applications have come on the market for almost every need in orthodontics. Many of the previous studies have included all types of skeletal anchorage in their analysis and all types of locations. Our study intends to show the rates of survival of the mini-implants placed on the buccal aspect of the maxilla and mandible in a residency setting which could give a better idea of what a new orthodontist is to expect. Our study also aims to find factors that can affect the survival of orthodontic mini-implants in hopes that it can aid orthodontist in predicting which case is predisposed to have a more successful and efficient outcome.

HYPOTHESES

<u>Null Hypothesis</u>

Hypothesis I

Mini-implant success depends on bone to implant contact therefore we hypothesize that success rate will be higher in the posterior region of both jaws.

Hypothesis II

Success rate of orthodontic mini-implants will be higher in the mandible than the maxilla due to increased cortical bone.

Hypothesis III

The success rate of mini-implants will not be affected by age, sex, gender or type of malocclusion.

SPECIFIC AIMS

Specific Aim 1: Determine the survival rate of orthodontic mini-implants placed on the buccal side of the mandible and maxilla in patients undergoing orthodontic therapy in a residency setting.

Specific Aim 2: Establish a correlation between other patient's treatment related factors such as age, sex, location of the mini-implant, number of implants, purpose of mini-implant and type of malocclusion to implant survival.

MATERIALS AND METHODS

Study Design

This study was a single multi-provider center retrospective evaluation of survival of all mini-implants placed for orthodontic use. The data was obtained from the records of all growing and adult patients treated by multiple providers both experienced and inexperienced under the guidance of experienced providers. It was approved by the Institutional Review Board at the University of Connecticut. (IRB#20x-173-1)

Inclusion Criteria

- Patients over 10 years of age at the beginning of treatment

- Good quality pre- and post-treatment records

- All types of malocclusions

Exclusion criteria

- Medical history of significant craniofacial syndromes

- Patients undergoing orthognathic surgery

- Patients younger than 10 years old (immature bone)

- Patients who received orthodontic min-implants with incomplete records

- Patients who received orthodontic mini-implants prior to July 2013

Patient records were screened at the University of Connecticut and identified only by their TO number until the time of data examination. All mini-implants on record placed by both faculty and residents at the University of Connecticut from July 1st 2013 to February 2020 were analyzed and screened for any exclusion criteria by two primary investigators S.A. and L.P.

Outcomes (Primary and Secondary)

The primary outcome measure was weather the mini-implants were successful or not.

The secondary outcome is whether or not any other factors such as sex, age, location, and purpose

of the implant were a factor that was correlated to its success or failure.

Data Collection

Records were selected for review from the University of Connecticut Orthodontics clinic.

All records of patients treated both by faculty and residents from July 2013 to March 2020.

Previous mini-implants were placed in the program before July of 2013 however the records of

those patients were not saved in paper format and many of them were incomplete/hard to analyze.

74 patients were found to have had orthodontic mini-implants placed the buccal side on record.

From those 74 patients 9 were excluded due to incomplete records, wrong type of mini implants

and lastly one was a duplicate. The patients were identified by their ID number simply and not by

any other private information. Patient demographic information such as age and gender were

recorded. Patient's initial anterior-posterior skeletal relationship was recorded but their vertical

relationship, smoking status, and hygiene were not recorded.

Data Analysis

The data was recorded as well as analyzed by 2 independent investigators S.A. and L.P.

Both investigators looked through the patients' chart, photos and x-rays to identify the exact time

and location of the mini-implant being placed. Both investigators judged independently if the mini-

implant was successful or failed. Their results were compared to each other for reliability. Once

inter-examiner reliability was confirmed to be acceptable the averages of both the investigators

was taken and used for the statistical analysis.

Statistical Analysis

The statistical analysis included a descriptive analysis of the population, consisting of mean and standard deviation for quantitative variables and percentages for qualitative variables. Non-parametric tests such as Mann-Whitney test (for group of two- gender, side, arch) and Kruskal-Wallis test (for group of three or more- age, tooth level, malocclusion, purpose and location) were conducted to evaluate the level of significance. Survival analysis used Kaplan–Meier function to draw the curves and a Log-rank (Mantel-cox) test to compare variables. Multivariate regression model analyses were used to investigate the factors associated with the failure of mini-implants. The p-value of <0.05 was deemed to be statistically significant. Krippondorff's alpha was calculated for inter-rater agreement. Statistical analyses were computed using Graph Pad software (La Jolla, Calif).

RESULTS

Out of 157 buccal mini-implants, 51 (32.5%) mini-implants in were lost during the observation period. This suggests that the survival rate for the 157 mini-implants was 67.5%. The survival analysis indicated a significant difference between male and female patients ($\chi^2 = 6.482$, p-value = 0.011), and the 13-month survival rate was 68.4% for male, and 80.2% female patients. No significant difference was found for the survival rate of mini-implants in reference to age groups ($\chi^2 = 1.08$, p-value = 0.583). Significant difference was found in the patients with different malocclusion (Angle's classification) ($\chi^2 = 7.876$, p-value = 0.02). 13-month survival rate was 74.4% for Class I, 86.7% for class II, and 65.3% for Class III subjects.

Significant difference was found on comparison of the success maxillary and mandibular buccal mini-implants, with the failure rate of 23% and 39% respectively. Right and left side did not show any significant difference in mini-implant survival rates ($\chi^2 = 0.143$, p-value = 0.706).

The comparison of survival rates between buccal alveolar, infrazygomatic, buccal shelf and palatal mini-implants (data extracted from our previous study) showed a significant difference ($\chi^2 = 49.84$, p-value<0.0001), and 13-month survival rate was 75.5% for buccal alveolar, 72.7% for infrazygomatic, 31.3% for buccal shelf. The comparison of the anteroposterior location of mini-implants showed no significant difference between groups ($\chi^2 = 0.2945$, p-value = 0.9611). 13-month survival rate was 80% for mesial to canine, 75.4% for canines to second premolars, 75.3% for second premolars to second molars, and 66.7% for distal to second molar region.

The multivariate regression model analyses are presented in Table 1. Duration and location (buccal, infrazygomatic or buccal shelf) were identified as predicting factors for the failure of mini-implants (p<0.05) (Table 1).

DISSCUSSION

Our data indicates that common orthodontic mini-implants placed on the buccal aspect of both jaws in a residency setting generally were placed with minimal complications and achieved their intended goal. However, the survival rate of our mini-implants was on the lower end of ranges normally expected.[1,2,10,23,27,28,30,51] These survival rates make sense when taking into account the fact that most mini-implants were placed by residents with limited experience in mini-implant placement. This finding is corroborated by Azeem and colleagues who found no significant correlation in failure rate according to various predictor variables, except for mini-implants installed by lesser experienced operators, which showed significantly more failure. They found that orthodontic mini-implants placed by inexperienced operators were 1.5 times more likely to fail than those placed by experienced faculty. One factor consistently tied to interradicular failure is contact with the lamina dura of the roots. When a mini-implant is placed near the root of the

adjacent tooth less osseous tissue forms around the implant which results in more mobility making failure more likely to become lose and fail.[38] Similarly Rodriguez found a survival rate of 78.45% similar to ours and found most significant indicators to success to be surgery related, making mini-implants for orthodontic anchorage, a technique sensitive procedure with a steep learning curve.

The inter-operator reliability was very good. Krippendorff's alpha was 0.87, 0.95, and 0.81 showed excellent inter -rater agreement for the mini-implant failure (yes/no), location of mini-implant (buccal alveolar, infrazygomatic, or buccal shelf) and purpose of mini-implants, respectively. Both evaluators agreed on whether or not a mini-implant was successful or failed so indicating that the data was reliable. The mini-implants placed on the buccal had a 13-month and 24-month survival of 82.6 % and 77.1% respectively in the maxillary arch and 70.4% and 68.3% on the mandibular arch respectively (Figure 4). These findings are consistent with the findings from Papagergiou who's Meta-analysis showed significantly higher mini-implant failure in the mandible 19.3% than the maxilla 12% respectively. Thus, we rejected our second null hypothesis which said predicted that the mandibular mini-implants would have better survival due to the increased cortical bone in the mandible. In our study right and left side showed no statistically significant difference. Figure 5 shows the survival timeline which is remarkably close. This finding is to be expected however many theories have been put forth for when a side experiences higher failure than the other. Such theories include but do not end with the theory that more people chew more on one side of the mouth and as such the bone on the left and right side are different in dimension and consistency but also differential mechanical forces from food being chewed. The other theory that could give an answer to this question is the theory that the hygiene quality differs in different sides of the mouth. One other reason why one side could fail more than the other if it

was true is that the clinician's preference and dental chair set-up could give the advantage to one side versus the other.

There was a statistically significant difference between genders with the implants having a higher survival rate in females than males, 80.2% vs 68.4% (Figure 3). Orthodontic mini-implants have better survival in females than they do in males. This is believed to be due to the quality of bone that females have which seems to be more ideal for the stability of mini implants. The Kaplan-Meier graph (Figure 2) comparing age groups showed lower failure in the older group however this was deemed to be non-statistically significant. The theory is that the bone in younger individuals is not yet mature and mini-implants should be avoided in patients under 12 years old. This is the opposite of what Tsai and colleagues found in their analysis of 254 mini-implants which showed a positive correlation of failure with age.

There was an increase in failure rate with the distance the mini-implant was placed away from the midline, however this difference was not considered to be statistically significant. Figure 6 shows the chances of survival over time. Implants placed between the canines in both arches had a 13-month survival rate of 80%. The survival rates were 75.4% and 66.7 for when implants were placed distal of the canines to the premolars and distal to the second molars respectively. It seems in our study that as you move more posteriorly the failure rate of implants increases, however when looking at the survival plot (Figure 6) they appear remarkably close. Thus, we reject our first null hypothesis that posterior implants would have a higher survival rate than anterior ones. Our findings show no difference unlike those studied by Papagergiou in which the highest failure rate was between the second molars and the lowest being between the first and second premolar. In another systematic review they found a failure rate of 9.2% between maxillary first molar and second premolars, 9.7% between maxillary canines and lateral incisors and 16.4% for the

infrazygomatic mini-implants. Mandible failure rates were 13.5% between first molar and second premolars, 9.9% between mandibular canines and first premolars.[24] An explanation for this is likely that in most study including ours infrazygomatic, buccal shelf and even retromolar pad implants all of which tend to have a higher failure rate normally are included in the analysis as implants placed distally in the arches. These implants also are often used for whole arch distalization which in itself requires a higher anchorage and load due to the number of teeth included in the segment which is higher than when compared to anterior segment retraction or molar protraction the two most common uses of interradicular mini-implants in the more mesial locations along the dental arches. Excessive force can possibly lead to failure of these implants. Furthermore, these distal implants can come in contact with the lamina dura of the teeth during distalization. Contact between the mini-implant and the root is observed during distalization of an entire arch leading to increased mobility.[38]

The purpose/use of the mini-implants showed that the highest failure rate in our sample was in implants used for distalization with a 46% failure rate, followed by intrusion with a 23.5% failure rate, followed by retraction with a 22.1% failure rate and the implants used for anchorage reinforcement only were 100% successful. The reasons for these findings have similar explanation to what's proposed above. This can also have something to do with the next parameter we looked at which was the patient's skeletal relationship. Our findings showed that different malocclusions yielded a different result with the 13-month survival rate being highest for CII, followed by Class I and then Class III malocclusion with 86.7%, 74.4% and 65.3% respectively. Figure seven shows the stark contrast between the Class I and II malocclusion and Class III malocclusion which has the worst prognosis regarding orthodontic mini implants. This is perhaps related to the type of the mechanics/loads needed with the use of mini-implants. Many of the implants used in CII were

used for retraction of the upper anterior segment when 2 premolars are extracted on the upper arch, a procedure which has shown higher survival rates of mini-implants. The opposite would be true in Class III malocclusions in which often the entire lower arch needs to be distalized with posterior implants such as buccal shelf or ridge implants which in many studies including ours have shown higher failure rates. These findings would reject our last hypothesis which predicted that patient demographics would not be a factor in implant failure as, sex and skeletal malocclusion proved to be associated with mini-implant survival

The comparison of survival rates between buccal alveolar, buccal shelf and infrazygomatic mini-implants showed a significant difference. Figure 9 depicts this well. Our study showed 72.7% and 71.9% survival rate for the buccal alveolar implants for the 13-month and 24-month survival respectively. These numbers are lower than the average numbers in the literature to date. They can be explained by the fact that most were placed by inexperienced technicians which is a high predictor of failure. Many of the implants that failed were also re-placed with new implants but often in the same or near location to the one that failed in the first place. This would further drop the survival rate of these mini-implants as found by Baek and colleagues in which study the initial maxillary buccal mini-implants had a failure rate similar to ours at 75.2% but the survival rate of the implants placed for the second time in the same/similar location to the one that failed had a 66.7% failure rate indicating that the second implant replicated in the same patient under similar conditions had an increased chance of failure.

Lastly, we wanted to examine the survival rates of the different types of mini-implants. Our data showed a significant difference when it came to the specific type/location of the mini-implants that were placed. As expected, the palatal implants that were analyzed from the same cohort, but not included in this study showed the lowest failure rate of 9.1% for both the 13 and

24-month period. The next best survival rate was shown to be in the buccal alveolar mini-implants which had a failure rate of 24.5% and 28.1% for the 13 and 24-month period respectively. These numbers were higher than what the latest systematic reviews showed,[1,2,10,24,28,29,31,52] however the reasons we believe this is lower has mostly to do with clinician's experience. The next best survival was for the infrazygomatic implants which showed a failure rate of 27.3% and 35.4% respectively for the 13-month and 24-month timeframe respectively. This number was slightly lower from that reported by Uribe and colleagues which was 21.8%. That study included a similar demographic of patients with perhaps the only factors being their implants having been placed by more experienced clinicians and their observation time was shorter than ours. It is possible that if their cohort was monitored past the 8-months period their survival rates would've come closer to ours. The lowest survival was observed in our sample of buccal shelf implants which showed a 68.7% failure rate at 13-month and 78.2% failure rate at 24-months respectively and is too poor of survival to be considered useful in clinical practice for novice clinicians.

CONCLUSION

Placement of orthodontic mini-implants is a technique sensitive process and interradicular and infrazygomatic mini-implants placed in the residency setting have a lower success rate than what appears in literature. In our sample buccal shelf orthodontic mini-implants showed a very poor survival rate. Orthodontic mini-implants are more stable in female patients, and patients who have a Class I or II skeletal profile. Mini-implants are more successful in the maxilla than the mandible but the anterior-posterior location does not seem to be an important factor. The survival rates of orthodontic mini-implants used for anchorage and molar protraction were better than those used for than distalization and/or intrusion. More quality studies on the mini-implants placed on the

buccal for orthodontic reasons would be needed. Our study supports previous literature that the placement of orthodontic mini-implants in ideal patients by a skilled technician can be beneficial in achieving superior results than with conventional orthodontics alone.

TABLES AND FIGURES

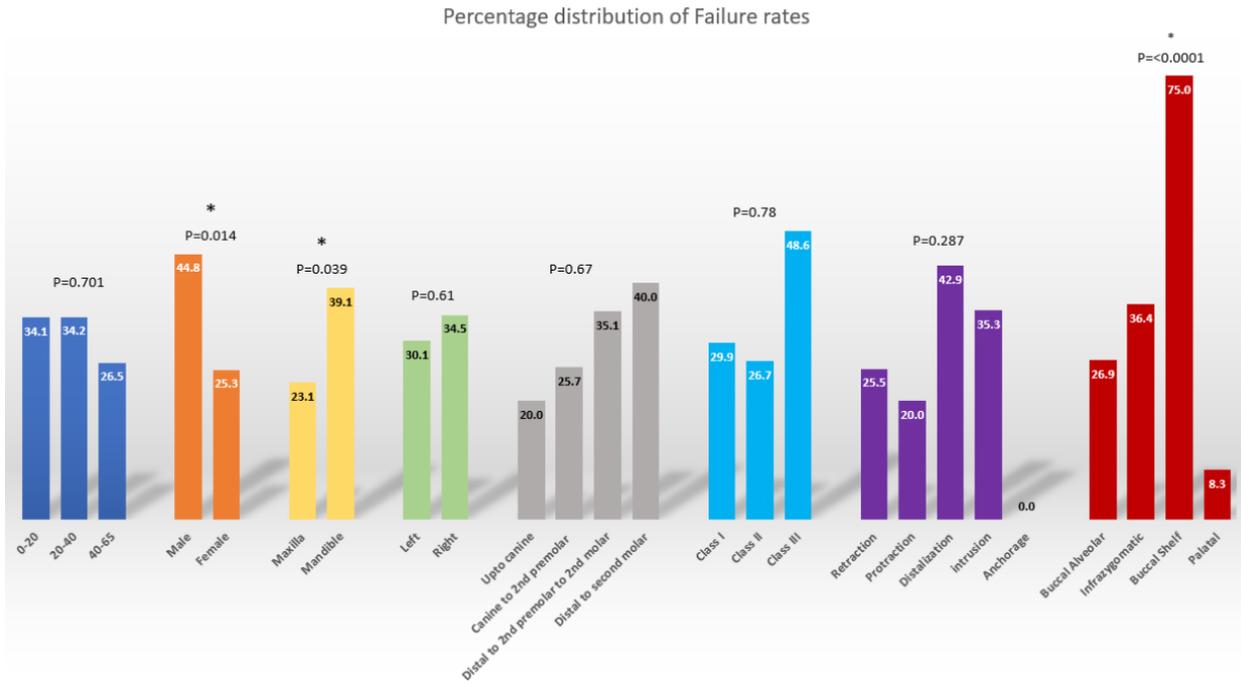**Figure 1. Percentage of failures bar graph.** What percentage of failures happened?

Percentage distribution of Failure rates

Figure 2. Kaplan-Meier graph in relation to age. Three age groups 10-20 years old "Growing",

20-40 years of age and 40-65 years showing the survivorship of all mini-implants combined.
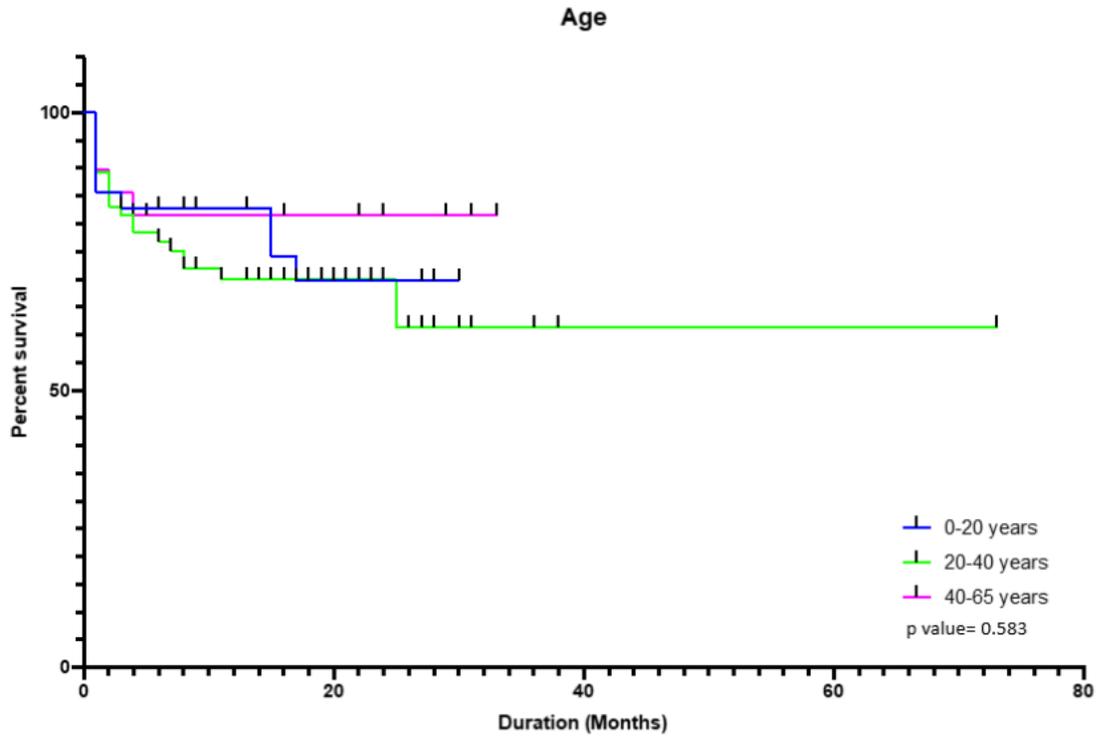
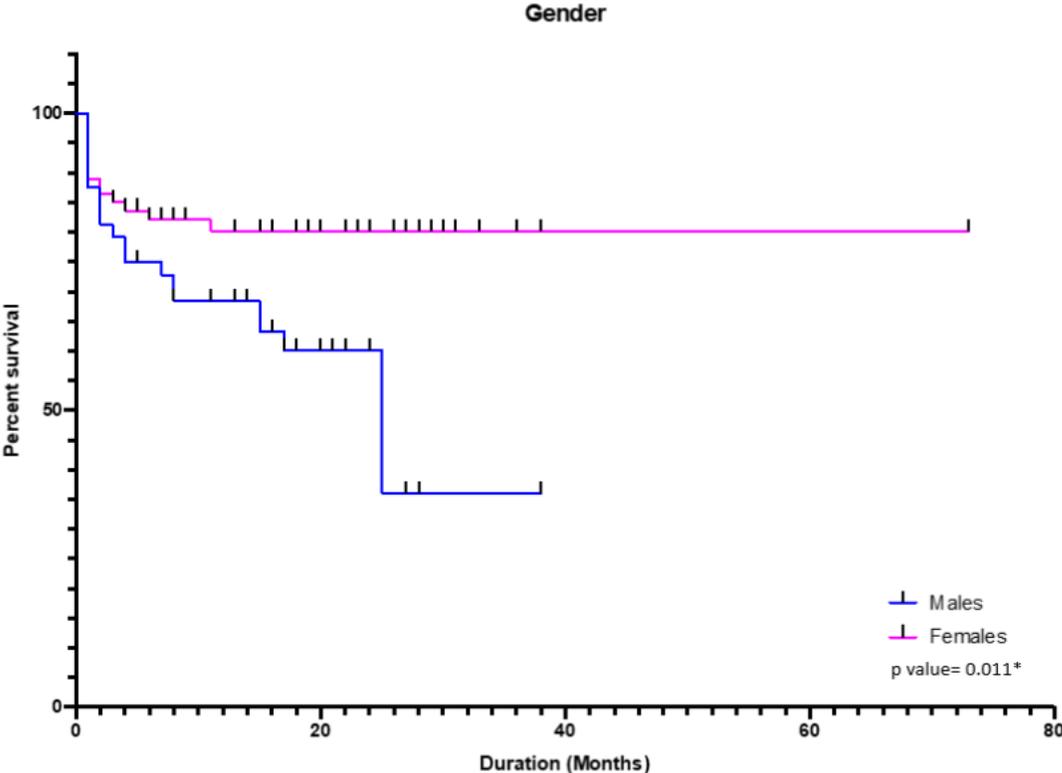**Figure 3. Kaplan-Meier graph showing survivorship of implants in relation to sex:**

Figure 4. Kaplan-Meier plot showing survival in relation to the arch where mini-implant was placed.
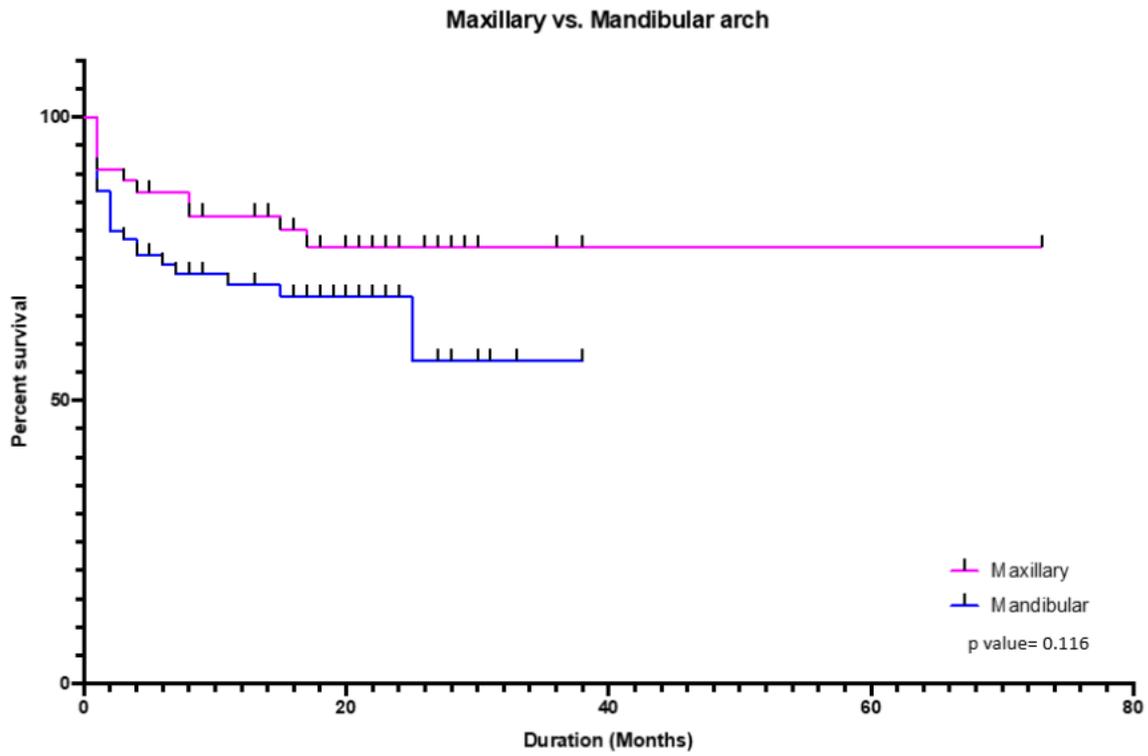

Maxillary vs. Mandibular arch

Figure 5. Kaplan-Meier plot showing survival in relation side in which implant was placed
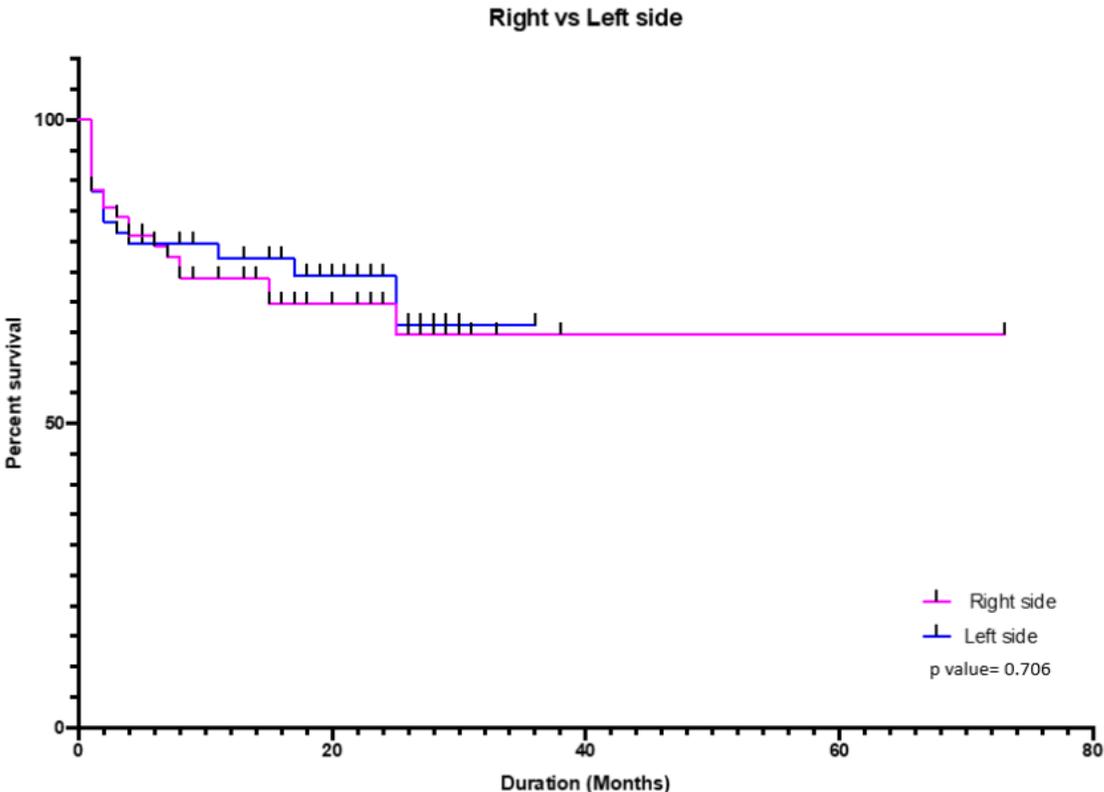
Figure 6. Kaplan-Meier plot showing percentage of survival based on location in the arch. 4
locations were chosen, mesial to canines, canine to second premolar, second premolar to second
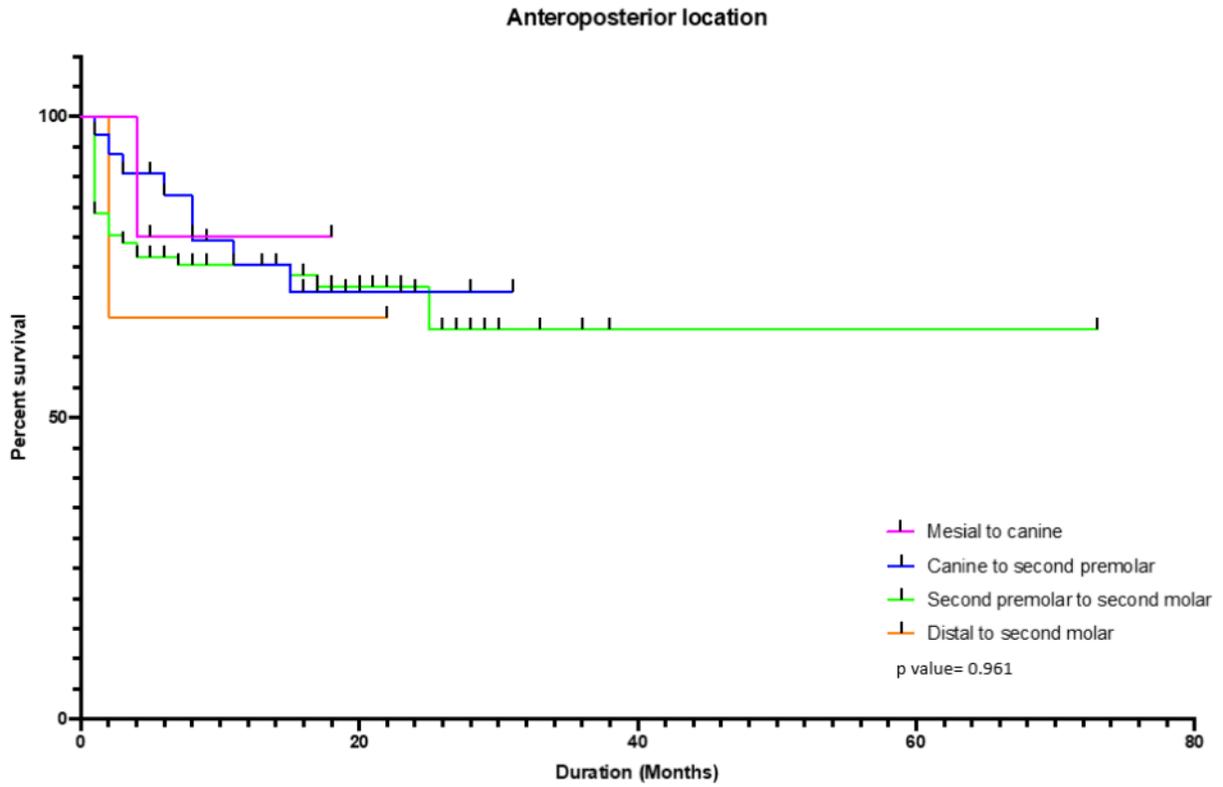molar and distal to second molar.

Figure 7. Kaplan-Meier plot relating survival to type of malocclusion. A statistical significance was observed in particular with the class III malocclusion which showed the worst survival of all the types of malocclusions.
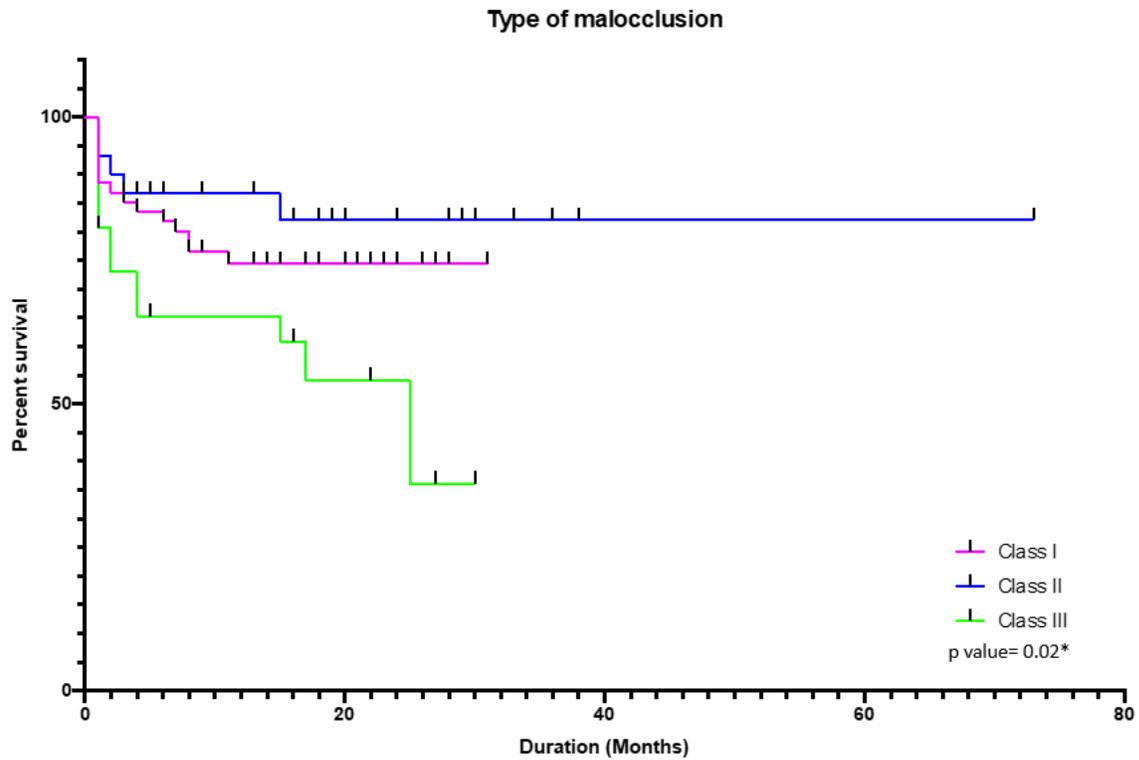
Figure 8. Kaplan-Meier Plot relating the use of mini-implant to survival. Implants used for anchorage had a perfect survival while protraction, distalization had acceptable outcomes. Implants used for intrusion and in particular implants used for distalization had a very poor prognosis in our sample
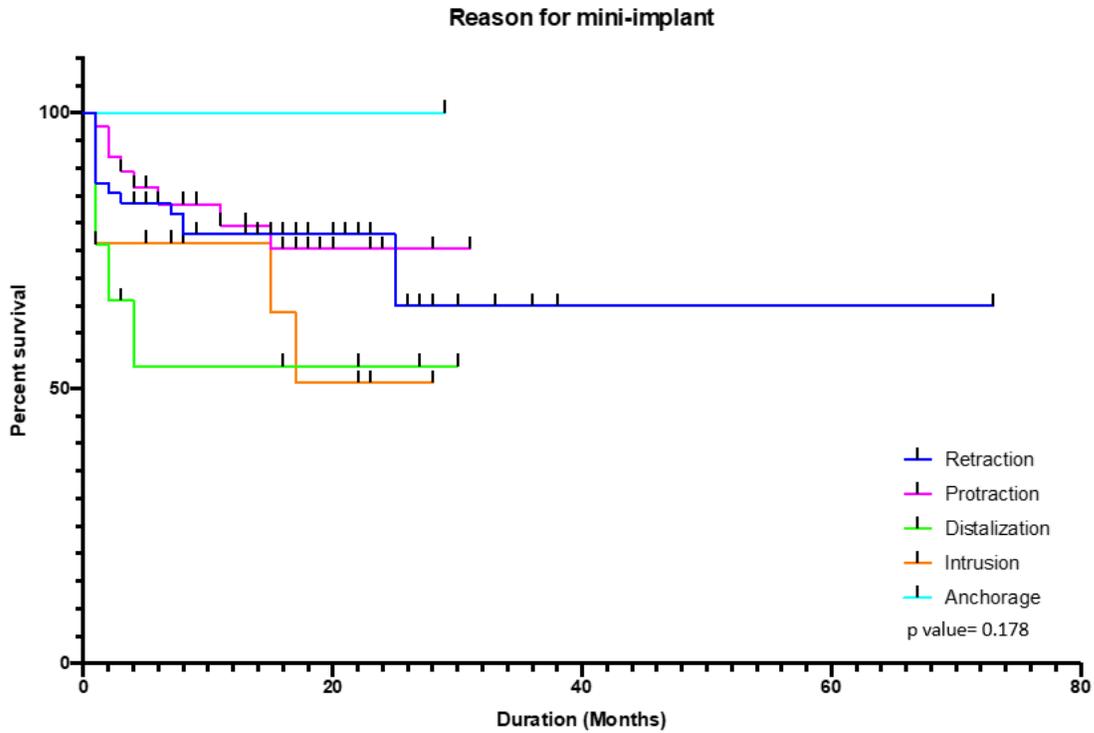
Figure 9. Kaplan-Meier plot of the type (by location) of mini-implant used and its survival rate. Palatal implants from a second study undergoing with our sample showed a very good survival, while the buccal alveolar implants and infrazygomatic implants showing somewhat acceptable outcomes. The buccal shelf implants in our sample showed extremely poor survival.
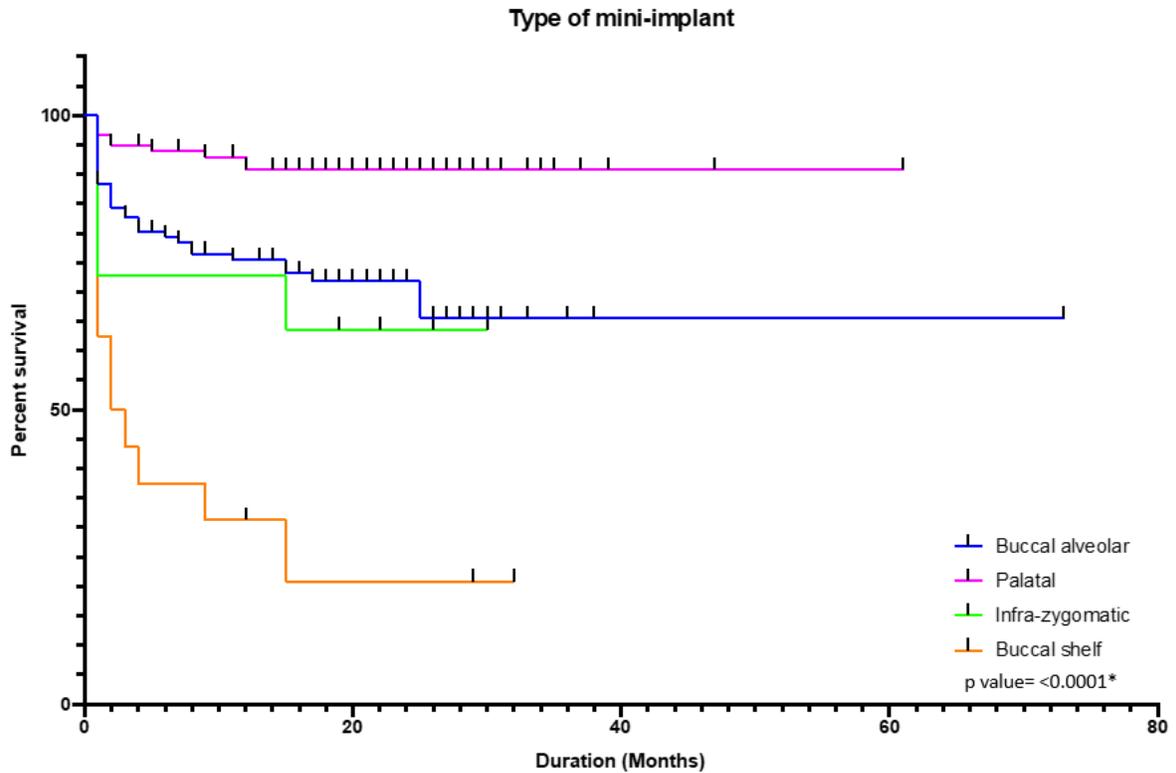
Table 1. Multivariate regression model analysis. Duration and location (buccal, infrazygomatic or buccal shelf) were identified as predicting factors for the failure of buccal mini-implants ($p<0.05$)

Variable	|t|	Estimate	Standard error	95% confidence interval	P value
Intercept	3.993	0.551	0.138	0.2780 to 0.8233	0.0001
Age	0.9381	-0.042	0.045	-0.1318 to 0.04697	0.3498
Sex	1.833	-0.119	0.065	-0.2483 to 0.009424	0.069
Duration	8.58	-0.023	0.003	-0.02822 to -0.01765	<0.0001
Arch	1.736	-0.112	0.065	-0.2400 to 0.01556	0.0847
Side	1.444	0.089	0.062	-0.03297 to 0.2117	0.1509
Tooth level	1.663	0.096	0.058	-0.01809 to 0.2095	0.0986
Malocclusion	0.3838	0.016	0.042	-0.06743 to 0.09992	0.7017
Location	2.32	0.125	0.054	0.01844 to 0.2314	0.0218

REFERENCES

1. Alharbi et al. Mini-implants failure rate in orthodontics: systematic review and meta-analysis. European Journal of Orthodontics 2018; 40 (5) 519-530

2. Aly et al. Success rates and factors associated with failure of temporary anchorage devices: A prospective clinical trial. Journal of Investigation Clinical Dentistry 2018. 9-312331

3. Antoszewska et al. Five-year experience with orthodontic mini-implant implants: A retrospective investigation of factors influencing success rates. American Journal of Orthodontics and Dental Orthopedics. 2009. 136. 158-159

4. Azeem et al. Failure rates of mini-implants inserted in the maxillary tuberosity. Dental Press Journal of Orthodontics. 2019 24 (5): 46-61

5. Baek et al. Success rate and risk factors associated with mini-implant reinstalled in the maxilla. Angle Orthodontist 78 (5) 895-901

6. Baumgaertel S. Temporary skeletal anchorage devices: the case for mini-implants. Am J Orthod Dentofac Orthop. 2014;145:560.

7. Bayat & Bauss. Effect of smoking on the failure rates of Orthodontic Mini-implants. Journal of Orofacial Orthopedics. 2010 17 117-124

8. Chaddad et al. Influence of surface characteristics on survival rates of mini-implants. Angle Orthodontist 2008 78 (1) 107-113

9. Chang et al. Primary failure rate of 1689 extra-alveolar mandibular buccal shelf mini-screws placed in movable mucosa or attached gingiva. Angle Orthodontist. 2015; Vol 85, No 6. 905-910.

10. Creekmore TD, Eklund MK. The possibility of skeletal anchorage. J Clin Orthod. 1983;17:266–269.

11. Crismani AG, Bertl MH, Celar AG, Bantleon HP, Burstone CJ. Mini-implants in orthodontic treatment: review and analysis of published clinical trials. Am J Orthod Dentofac Orthop. 2010;137:108–13

12. Dalessandri et al. Determinants for success rates of temporary anchorage devices in orthodontics : a meta-analysis (n>50). European Journal of Orthodontics 2014 36 303-313

13. Frost HM. Wolff's law and bone's structural adaptations to mechanical usage: an overview for clinicians. Angle Orthod. 1994;64(3):175–88.

14. Gainsforth BL, Higley LB. A study of orthodontic anchorage possibilities in basal bone. Am J Orthod Oral Surg. 1945;31:406–416.

15. Garfinkle et al. Evaluation of orthodontic mini-implant anchorage in premolar extraction therapy in adolescents. American Journal of Orthodontics and Dentofacial Orthopedics. 2006 04 642-653

16. Gritsch et al. In vivo evaluation of immediately loaded stainless steel and titanium orthodontic screws in growing bone. PLOS ONE 2013 8 (10) e76223

17. Hourfar et al. Influence of interradicular and palatal placement of orthodontic mini-implants on the success (survival) rate. Head and Face Medicine. 2017 13:14

18. Jeong et al. Analysis of time to failure of orthodontic mini-implants after insertion or loading. Journal of the Korean Association of Oral and Maxillofacial Surgery. 2015 41 240-245

19. Jing et al. Factors affecting the clinical success rate of mini-implant implants for orthodontic treatment. The international Journal of Oral and Maxillofacial Implants. 2016 31: 835-841

20. Kuroda et al. Root proximity is a major factor for screw failure in orthodontic anchorage. American Journal of Orthodontics and Dentofacial Orthopedics. 2007. 06 S68-S73

21. Manni et al. Factors influencing the stability of mini-implants. A retrospective study on 300 miniscres. European Journal of Orthodontics. 2011. 33 388-395

22. Melo et al. Risk factors associated with the failure of mini-implants. – A ten-year cross sectional study. Brazilian Oral Research 2016. 30 (1) E124

23. Melsen B. Mini-implants: Where are we? J Clin Orthod. 2005;39:539–547;

24. Mohammed et al. Role of anatomical sites and correlated risk factors on the survival of orthodontic mini-implant implants: a systematic review and meta-analysis. Progress in orthodontics. 2018. 19-36

25. Moon et al. Relationship between vertical skeletal pattern and success rate of orthodontic mini-implants. American Journal of Orthodontics and Dentofacial Orthopedis. 2008 08 (32). 51-57

26. Nienkemper M, Wilmes B, Pauls A, Drescher D. Multipurpose use of orthodontic mini-implants to achieve different treatment goals. J Orofac

27. Papadopulous et al. Clinical Effectiveness of Orthodontic Mini-implant Implants: a Meta-analysis. Journal of Dental Research. 2011. 90 (8); 969-976

28. Papadopulous et al. The use of mini-implant implants for temporary skeletal anchorage in orthodontics: A comprehensive review. Oral Surgery Oral Medicine Oral Pathology Oral Radiology Endodontics. 2007 103:e6-e15

29. Papageorgiou et al. Failure rates and associated risk factors of orthodontic mini-implant implants: A meta-analysis. American Journal of Orthodontics and Dentofacial Orthopedics. 2012. 142: 577-595

30. Reynders. Mini-implants in orthodontics: A systematic review of the literature. American Journal of Orthodontics and Dentofacial Orthopedics. 2009. 135 564.e1-564.e19

31. Reynders et al. Insertion torque and success of orthodontic mini-implants: A systematic review. American Journal of Orthodontics and Dental Orthopedics 2012; 142: 596-614

32. Rodriguez et al. Implants for orthodontic anchorage: success rates and reasons for failures. Implant Dentistry 2014 23; (2): 155-161

33. Romano & Consolaro. Why are mini-implants lost: The value of the implantation technique. Dental Press Journal of Orthodintics. 2015. 20 (1). 23-29

34. Sarul et al. Effect of the length of orthodontic mini-screw implants on their long-term stability: A prospective study. Angle Orthodontist 2015. 85 (1):33-38

35. Schatzle et al. Survival and failure rates of orthodontic temporary anchorage devices: a systematic review. Clinical Oral Implants Research. 2009. 20. 1351-1359

36. Sharifi et al. Effect of insertion method and postinsertion time interval prior to force application on the removal torque of orthodontic mini-implants. The International Journal of Oral & Maxillofacial Implants. 2015. 30: 30-40

37. Suzuki et al. Evaluation of optimal length and insertion toque for mini-implants. American Journal of Orthodontics and Dentofacial Orthopedics. 2013. 144 (2): 251-259

38. Topouzelis and Tsaousoglou. Clinical factors correlated with the success rate of mini-implants in orthodontic treatment. International Journal of Oral Sciences. 2012. 4: 38-44

39. Tsai et al. A prospective study of factors associated with orthodontic mini-implant survival. Journal of Oral Sciences. 2016. 58.4.: 515-521

40. Tsui WK, Chua HD, Cheung LK. Bone anchor systems for orthodontic application: a systematic review. Int J Oral Maxillofac Surg. 2012;41:1427–38

41. Turkoz et al. The effect of drill-free and drilling methods on the stability of mini-implants under early orthodontic loading in adolescent patients. European Journal of Orthodontics. 2011. 33: 533-536

42. Uesugi et al. Prognosis of primary and secondary insertions of orthodontic mini-implants: What we have learned from 500 implants. American Journal of Orthodontics and Dentofacial Orthopedics. 2017. 152.2: 224-231

43. Uesugi et al. Stability of secondary inserted orthodontic mini-implants after failure of the primary insertion for maxillary anchorage: Maxillary buccal area vs midpalatal suture area. American Journal of Orthodontics and Dentofacial Orthopedics. 2017. 153.1. 54-60

44. Uribe et al. Failure rates of mini-implants placed in the infrazygomatic region. Progress in Orthodontics. 2015. 16:31.

45. Viwattanatipa et al. Survival analyses of surgical mini-implants as orthodontic anchorage. The American Journal of Orthodontics and Dentofacial Orthopedics. 2009; 136: 29-36

46. Weichmann. Success rate of mini-and micro-implants used for orthodontic anchorage: a prospective clinical study. Clinical oral Implant Residency. 2007. 18: 263-267

47. Wilmes et al. Impact of bone quality, implant type, and implantation site preparation on insertion torques of mini-implants used for orthodontic anchorage. International Journal of Oral and Maxillofacial Surgery. 2011. 40; 697-703

48. Wilmes et al. Impact of implant design on primary stability of orthodontics mini-implants. Journal of Orofacial Orthopedics. 2008.1: 42-50

49. Wu et al. Factors associated with the stability of mini-implants for orthodontic anchorage: A study for orthodontic anchorage: A study of 414 samples in Taiwan. Journal of Oral and Maxillofacial Surgery. 2009. 67: 1595-1599

50. Yadav et al. Biomechanical and histomorphometric properties of four different mini-implant surfaces. European Journal of Orthodontics. 2015. 37 (6): 627-635

51. Yi et al. Comparison of the success rate between self-drilling and self-tapping mini-implants: a systematic review and meta-analysis. European Journal of Orthodontics. 2017. 39 (3): 287-293

52. Zhang et al. Osseointegration of Orthodontic Micro-screws after immediate and early loading. Angle Orthodontist. 2010. 80 (2): 354-360