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Evaluation of Primary Stability and Factors Affecting the Long-Term Stability in Miniscrew Implants: A Clinical Study

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ABSTRACT

Background: This study is aimed to determine the clinical success rate of orthodontic mini screw implants by investigating the initial(from insertion till force application) & long term stability & to evaluate the various factors associated with the Stability of mini screw implants.

Material and methods: The data consisted of 50 mini screw implants in 21 patients with age ranging from 14 to 26 years was selected for the study - all these patients who underwent fixed orthodontic treatment with mini-screws placed as orthodontic anchorage. Micro implants of 1.5 X 9 mm Titanium mini-screws(S.K. Surgicals, Pune) were inserted during fixed orthodontic treatment. All screws were examined for initial Stability- after the insertion, before force application and for long term stability-minimum one month after force application. The examination of Stability was done by manual examination for mobility. Each response variable was dichotomous; the value was recorded as 0 if mini screw loosened (failed) or one of the mini-screws was stable (successful). All the data was recorded on an excel sheet and subjected to statistical analysis.

Results: the overall success rate was 88 %. The success rate was higher in younger individuals but deceased as age advanced; males had a higher success rate as compared to females; maxilla had a higher success rate as compared to mandible mid-palatal & maxillary buccal area had a higher success rate than other sites; firm tissue had a higher success rate than movable tissue type although this difference was statically insignificant except for the jaw involved and tissue type.

Conclusion: the Stability of the mini screw implants cannot be guaranteed or predicted. For this reason, any treatment plan should consider the possibility of failures.

Keywords: Orthodontic anchorage, primary and secondary Stability, miniscrew, miniscrew failure.

INTRODUCTION

Orthodontic anchorage is defined as *"resistance to unwanted tooth movement."* Maintaining anchorage in orthodontics is important, and keeping it during treatment had been difficult in the past. There are times when movements of some teeth are undesired, but movements may be difficult to avoid due to Newton's third law of motion, which states that every action has an equal and opposite reaction. Many methods to maintain anchorage has been developed by way of various intraoral and extraoral appliances. However, these techniques are not reliable to achieve proper anchorage goals.

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Intraoral methods generally show some loss of anchorage. Extraoral appliances rely on patient compliance for success, and any lapse in their use can result in anchorage loss.

Mini screws were introduced into the field to provide a technique that can maintain absolute anchorage without requiring patient cooperation. The success of this technique has been demonstrated by its increasing prevalence in clinical application.

Mini screws allow practitioners to have control over anchorage in situations where traditional methods of maintaining anchorage are impossible, unattainable or impractical.[2] They are increasingly being used due to their affordability, ease of placement and removal, ability to provide absolute anchorage, and placement versatility, allowing them to be placed in many locations including the area between roots of teeth due to their small size.

In orthodontic practise, anchorage control has typically been a difficult and unpredictable challenge. To overcome this challenge, there have been numerous attempts to obtain bone tissue support for successful anchorage control.

Implant Stability

Achieving mini screw implant stability initially and maintaining Stability throughout the course of treatment is critical to its success. Evidence from dental implantology demonstrates that an implant's primary Stability is the most significant determining factor of its survival rate and reliability.

There are two phases of Stability- **Initial/primary** and **secondary/long term** stability, determined by time and the healing response of bone. Initial Stability is defined as the Stability of miniscrew from placement to orthodontic force application. Mechanical interlocking and miniscrew insertion technique are most critical for achieving proper initial or primary Stability. The bone's ability to heal and remodel as time progresses is more significant for secondary Stability. Initial Stability is critical because it directly influences the bone development necessary for secondary Stability and ultimate miniscrew success. Stability is necessary for the Miniscrews to act as a successful anchor and be able to resist orthodontic forces. The reported Stability of miniscrews varies from 83 to 91 %, which is lower than osseointegrated implants.

Miniscrew Failures

Mini screws offer many advantages in orthodontic treatment. However, the failure of mini screw stability limits their usefulness. Miniscrews in orthodontics is relatively new, and many reasons for their failures have been suggested and studied. Failures could be due to the host, the surgical technique or the management of the miniscrew during treatment. Host factors can be many, including osteoporosis, uncontrolled diabetes, smoking and parafunctional habits.[4] Surgical factors include overheating during placement, excessive trauma to the adjacent bone, and the failure to acquire proper Stability of the miniscrew.

MATERIALS AND METHODS

The data consists of 50 miniscrew implants which will be placed in Department of Orthodontics & Dentofacial Orthopedics, People's College of Dental Sciences & Research Centre, Bhopal, with age ranging from 14 to 26 years of age. All of these patients have to go for fixed orthodontic treatment with mini-screws placed as orthodontic anchorage. Micro implants of 1.5 X 9 mm Titanium mini-screws (S.K. Surgicals) will be inserted at the time of retraction by standard techniques according to manufacturers' instructions. All screws will be placed under local anaesthesia. The miniscrew will be placed with a hand screwdriver. All screws will be placed with normal saline solution irrigation. All screws will be examined for the initial Stability- after the insertion, before force application and for long term stability – minimum three months after force application. The examination of Stability will be done by manual examination for mobility. Each response variable was dichotomous; the value will be recorded as of 0 if miniscrew loosened (failed) and the value of 1 if it did not loosen. All the data will be recorded on an excel sheet and will be subjected to statistical analysis.

Data will be analyzed for overall initial and long term stability. To investigate the influence of various factors, the data will be divided according to age, sex, jaw involved (maxilla or mandible), site of placement and operator variable. This data will be

again subject to statistical analysis, and results will be drawn at the end of the study.

Inclusion Criteria:

Patient who:

a) Have had no orthodontic treatment previously
b) Requiring intrusion/ extrusion of teeth
c) retraction & realignment of anterior teeth with no posterior support
d) re-establishment of proper transverse & anteroposterior position of isolated molar abutment
e) require the closing of edentulous spaces of first molar extraction sites
f) orthopaedic traction

Exclusion Criteria:

a) Patients with known medical illness, e.g. Subacute bacterial endocarditis, Diabetes, Valvular disease, Anemia etc.
b) Patient with poor periodontal condition.
c) Patient with severe periodontal bone loss

RESULTS

The success rate %s of primary Stability & factors affecting the long term stability were observed with respect to these potential confounding factors: age, sex, jaw, placement site, tissue type, and a number of previous operations.

Table 1: Success rate % & distribution of mini-screws according to selected variables.

		STABILITY AT THE TIME OF INSERTION (T0)		STABILITY BEFORE FORCE APPLICATION (T1)		STABILITY AFTER 1 MONTH (T2)	
		Mini Screw Loosened (Failed)	Mini Screw Stable (Success)	Mini Screw Loosened (Failed)	Mini Screw Stable (Success)	Mini Screw Loosened (Failed)	Mini Screw Stable (Success)
Age	14-16 Years	0(0%)	8(100%)	0(0%)	8(100%)	0(0%)	8(100%)
	17-19 Years	0(0%)	5(100%)	0(0%)	5(100%)	0(0%)	5(100%)
	20-22 Years	0(0%)	4(100%)	0(0%)	4(100%)	0(0%)	4(100%)
	23-25 Years	0(0%)	27(100%)	4(14.8%)	23(85.2%)	4(14.8%)	23(85.2%)
	26 Years & Above	0(0%)	6(100%)	2(33.3%)	4(66.7%)	2(33.3%)	4(66.7%)
Gender	Female	0(0%)	32(100%)	6(18.8%)	26(81.2%)	6(18.8%)	26(81.2%)
	Male	0(0%)	18(100%)	0(0%)	18(100%)	0(0%)	18(100%)
JAW INVOLVED	Mandible	0(0%)	14(100%)	4(28.6%)	10(71.4%)	4(28.6%)	10(71.4%)
	Maxilla	0(0%)	36(100%)	2(5.6%)	34(94.4%)	2(5.6%)	34(94.4%)
SITE OF PLACEMENT	Incisal	0(0%)	1(100%)	0(0%)	1(100%)	0(0%)	1(100%)
	mand buccal	0(0%)	14(100%)	4(28.6%)	10(71.4%)	4(28.6%)	10(71.4%)
	max (midpalatal)	0(0%)	3(100%)	0(0%)	3(100%)	0(0%)	2(100%)
	max buccal	0(0%)	32(100%)	2(6.2%)	30(93.8%)	2(6.2%)	30(93.8%)
OPERATOR VARIABLE	Less than 40 Mini screw Implants	0(0%)	19(100%)	2(10.5%)	17(89.5%)	2(10.5%)	17(89.5%)
	More than 40 Mini screw Implants	0(0%)	31(100%)	4(12.9%)	27(87.1%)	4(12.9%)	27(87.1%)
Tissue Type	Movable Tissue	0(0%)	4(100%)	4(100%)	0(0%)	4(100%)	0(0%)
	Firm Tissue	0(0%)	46(100%)	2(4.3%)	44(95.7%)	2(4.3%)	44(95.7%)

Table: 2 Distribution of Stability before force application (T1) according to age.

Age	STABILITY BEFORE FORCE APPLICATION (T1)		Total	Chi Sq	p value	Success rate %
	Mini Screw Loosened (Failed)	Mini Screw Stable (Success)				
14-16 Years	0	8	8			(100%)
17-19 Years	0	5	5			(100%)
20-22 Years	0	4	4	5.107	0.277	(100%)
23-25 Years	4	23	27			(85.2%)
26 Years & Above	2	4	6			(66.7%)
	6	44	50			

Table 3: Distribution of Stability after 1 month (T2) according to age.

Age	STABILITY AFTER 1 MONTH (T2)		Total	Chi Sq	p value	Success rate %
	Mini Screw Loosened (Failed)	Mini Screw Stable (Success)				
14-16 Years	0	8	8			(100%)
17-19 Years	0	5	5			(100%)
20-22 Years	0	4	4	5.107	0.277	(100%)
23-25 Years	4	23	27			(85.2%)
26 Years & Above	2	4	6			(66.7%)
	6	44	50			

Table 4: Distribution of Stability before force application (T1) according to Gender.

Gender	STABILITY BEFORE FORCE APPLICATION (T1)		Total	Chi Sq	p value	Success rate %
	Mini Screw Loosened (Failed)	Mini Screw Stable (Success)				
Female	6	26	32	3.835	0.0501	(81.2%)
Male	0	18	18			(100%)
	6	44	50			

Table 5: Distribution of Stability after 1 month (T2) according to Gender.

		STABILITY AFTER 1 MONTH (T2)		Total	Chi Sq	p value	Success rate %
		Mini Screw Loosened (Failed)	Mini Screw Stable (Success)				
Gender	Female	6	26	32	3.835	0.0501	(81.2%)
	Male	0	18	18			(100%)
Total		6	44	50			

Table 6: Distribution of Stability at the time of insertion (T0) according to jaw involved.

		STABILITY AT THE TIME OF INSERTION (T0)	Total	Success rate %
		Mini Screw Stable (Success)		
JAW INVOLVED	Mandible	14	14	(100%)
	Maxilla	36	36	(100%)
Total		50	50	

Table 7: Distribution of Stability before force application (T1) and after 1 month(T2)according to jaw involved.

JAW INVOLVED	STABILITY BEFORE FORCE APPLICATION (T1)		Total	Chi Sq	p value	Success rate %
	Mini Screw Loosened (Failed)	Mini Screw Stable (Success)				
Mandible	4	10	14	5.057	0.025	(71.4%)
Maxilla	2	34	36			(94.4%)
	6	44	50			

Distribution of Stability after 1 month (T2) according to jaw involved

JAW INVOLVED	STABILITY BEFORE FORCE APPLICATION (T1)		Total	Chi Sq	p value	Success rate %
	Miniscrew loosened(Failed)	Mini Screw Stable (Success)				
Mandible	4	10	14	5.057	0.025	(71.4%)
Maxilla	2	34	36			(94.4%)
	6	44	50			

Table 8: Distribution of Stability at the time of insertion (T0) according to Tissue Type.

		STABILITY AT THE TIME OF INSERTION (T0)	Total	Success rate %
		Mini Screw Stable (Success)		
Tissue Type	Movable Tissue	4	4	(100%)
	Firm Tissue	46	46	(100%)
Total		50	50	

Table 9: Distribution of Stability before force application (T1) according to Tissue Type.

Tissue Type	STABILITY BEFORE FORCE APPLICATION (T1)		Total	Chi Sq	p value	Success rate %
	Mini Screw Loosened (Failed)	Mini Screw Stable (Success)				
Movable Tissue	4	0	4	31.88	<0.0001	(0%)
Firm Tissue	2	44	46			(95.7%)
	6	44	50			
Distribution of Stability after 1 month (T2) according to Tissue Type						
	STABILITY AFTER 1 MONTH (T2)		Total	Chi Sq	p value	Success rate % %
	Mini Screw Loosened (Failed)	Mini Screw Stable (Success)				
Movable Tissue	4	0	4	31.88	<0.0001	(0%)
Firm Tissue	2	44	46			(95.7%)
	6	44	50			

DISCUSSION

Mini screws in recent times have been adopted as the mainstay for anchorage control. Mini screws have the advantages of low cost, simple surgical placement, and ease of removal. They are small enough to be placed in any space in the alveolar bone, even interdental areas. Although mini-screws should remain stable throughout the required duration of the treatment, they can loosen during treatment. Achieving mini screw implant stability initially and maintaining Stability throughout the course of treatment is critical to its success. Stability of mini-screws is achieved through proper bone-to-implant contact and simple mechanical retention. Without proper bone-to-implant contact, mini screw movement may occur.

There are two phases of Stability- Initial or primary and secondary or long term stability, determined by time and the healing response of bone. Initial Stability is defined as the Stability of mini screw from placement (T0) to orthodontic force application (T1). Mechanical interlocking and mini screw insertion technique are most critical for achieving proper initial or primary Stability.[4] The bone's ability to heal and remodel as time progresses is more significant for secondary Stability. Initial Stability is critical because it directly influences the bone development necessary for secondary Stability and ultimate mini screw success. Stability is necessary for the mini-screws to act as a successful anchor and be able to resist orthodontic forces. The reported Stability of mini-screws varies from 83 to 91 %, which is lower than osseointegrated implants.

The present study was done to determine the clinical success rate of orthodontic mini screw implants by investigating the initial (from insertion till force application) & long term stability and to evaluate the various factors associated with Stability of mini screw implants. In the present study variables - age, sex, jaw involved, placement site, tissue type & operator experience were used & the overall success rate of the present study is **88%**.

According to Hoi-Jeong Lim et al. unlike the standard dental implants used as orthodontic anchorage after Osseointegration, mini screws can be loaded immediately because Stability is supported by the mechanical retention between the implant and the bone tissue. However, since magnitude, direction, and pattern of orthodontic

force could influence the Stability, it is necessary to assess Stability after stratifying the before and after orthodontic force applications to identify any associated factors. For example, if mini-screws loosen after orthodontic force application, patient factors would be more responsible than doctor factors. Conversely, if they loosen before orthodontic force application, doctor factors could be more responsible. For this reason, much more attention has been paid to initial mini screw stability— before orthodontic force application (T0 to T1) than late Stability—after orthodontic force application (T2) and the present study has successfully determined the clinical success rate of orthodontic mini screw implants by investigating the initial (from insertion till force application) T0 to T1 & long term stability (T2). The present study also evaluated the potential confounding factors affecting the initial (T0 to T1) as well as long term stability of mini-screws (T2) used for orthodontic anchorage, i.e. age, sex, jaw, placement site, tissue type & the number of previous operations.

In the present study as the patient's age increased, the success rate decreased which is contradictory to the study by Hoi-Jeong Lim where they found that children have a high possibility of loosening, and it would be better not to use mini-screws as the first choice of anchorage for them, but variations of bone quality must be expected in older subjects. But studies done by Lamberg-Allardt CJ, Outila TA et al. and Lin JT, Lane JM. is in agreement with a present study which can be explained on the basis of decreased calcium metabolism with age, especially in women. But this difference was statistically insignificant. (Table 2,3)

In the present study male subjects had a higher success rate than did the female subjects which are in agreement with the studies by *Hoi-Jeong Lim & Motoyoshi et al.* where male subjects had a higher success rate than did the females in a non-statistical trend, although a potential reason might be the bone mineral density of males is more as compared to females, and cortical bone is thinner in females than in males. Although *Cheng et al. and Miyawaki et al* found no differences between male and female subjects; either in relation to (T0) to (T1) & (T2).(Table 4, 5)

The maxilla had a higher success rate than the mandible in the present study; however, the mandible was expected to have a higher success rate because it has thicker and denser cortical bone than the maxilla. Based on these findings, it is likely that more compaction occurs in the mandible during placement of the mini screw, and this might result in bone necrosis that can cause mini-screws to loosen. Moreover, the mandible can be more susceptible to infection because its attached gingiva is narrow, and mini-screws can be implanted into the mucosal area. A study by Joorok *Park et al.* also agrees that in the alveolar process, 1 mm or more cortical bone thickness can be expected in the posterior dentition area. *Paola Maria Poggio* provided an anatomical map to assist the clinician in mini screw placement in a safe location between dental roots according to which second premolar and first molar in the maxillary buccal alveolar bone, between the molars in the maxillary palatal alveolar bone, and inter-radicular spaces from the first premolar to the second molar in the mandibular buccal alveolar bone are most suitable areas for mini screw implant placement. (Table 6,7)

In this study, the success rate of the mini screw implant was compared for different locations in the oral cavity. Maxillary buccal areas & mid--palatal area had a higher success rate than other sides for the primary as well as late Stability. The mid-palatal area is an excellent location for micro-implant placement with respect to (T0) to (T1) which has been followed in the present study. One reason for the highest success rate of mini-screws in the mid-palatal area might be that this is a keratinized mucosa area. *Sungmin Kang et al.* is in agreement with the fact that midpalatal area within 1 mm of the midsagittal suture had the thickest bone available in the whole palate. The thickness tended to decrease laterally and posteriorly. They concluded that when a mini-implant could deviate from the midpalatal area by more than 1 mm, recommending placing it not far posteriorly or using a shorter mini-implant leading to more success rate.

In the present study, firm tissue type had a higher success rate as compared to the movable tissues, which resulted in the failure of miniscrew implants. A study by *Hee-Jin Kim et al.* is in agreement with the fact that to obtain sufficient Stability of implants (T0) to (T2), the thickness of the soft tissue and the cortical bone in the placement site must be considered.(Table8,9)

In the present study out of 50 mini screw implants placed six mini-screws failed in the first week or before the force application which is in agreement with the study by *Cheol-Hyun Moon* where dislodgement of the OMI occurred most frequently in the first week before the force application, and more than 90% of the failures occurred within the first four months. Sex, age, jaw, soft tissue management, and placement site did not show any statistically significant difference in the success rate. Placement site, however, showed a significant difference in the mandible of adult patients. There was no difference in the success rate in the maxilla.

A number of problems remain to be explored since there is no perfect world. Since mini-screws should remain clinically stable after the orthodontic force is applied, the success rates of both pre- and post-orthodontic force application are important. Mini screws could loosen after orthodontic force application, though they are initially stable. Limitations of this study include the following: overall small sample size, particularly in specific areas. To reach a fuller understanding of these problems, randomized clinical trials with larger sample size is advocated.

CONCLUSION

The aim of this study was to determine the clinical success rate of orthodontic miniscrew implants by investigating the initial Stability (from insertion till force application) (T0 to T1) & (T2) also to evaluate the potential confounding factors affecting the late Stability of mini-screws (T2) used for orthodontic anchorage (age, sex, jaw, placement site, tissue type & a number of previous operations). Fifty minis-crews were placed in 21 patients during fixed orthodontic treatment and examined for any loosening. By the statistical analysis, these following conclusions were drawn.

- The overall success rate was 88 %
- The success rate was higher in younger individuals but decreased as age advanced; males had a higher success rate as compared to females; maxilla had a higher success rate as compared to mandible; midpalate & maxillary buccal area had a higher success rate than other sites; firm tissue had a higher success rate than movable tissue type. Although this difference was statistically insignificant except for the jaw involved and tissue type.
- The Stability of the miniscrew implants cannot be guaranteed or predicted. For this reason, any treatment plan should consider the possibility of failures.

CONFLICTS OF INTEREST

The authors declare they have no potential conflict of interests regarding this article.

REFERENCES

1. Hoi-Jeong Lim, Chun-Sun Eun, Jin-Hyoung Cho, Ki-Heon Lee and Hyeon-Shik Hwang Gwangju. Factors associated with initial Stability of miniscrews for orthodontic treatment. Am J Orthod Dentofacial Orthop 2009;136: 236-42
2. Kanomy R : Mini implant for orthodontic anchorage. J clin orthod 31: 763-67 , 1997
3. Costa A, Raffainl M, Melson B: Miniscrews as orthodontic anchorage, a preliminary report, Int J Adult Orthod Orthognathic Surg 13: 201-209, 1998.
4. Wilmes B, Rademacher C, Olthoff G, Drescher D. Parameters affecting primary Stability of orthodontic mini implants. Journal of Orofacial Orthopedics 2006; 67:162-174.
5. Costa A, Raffainl M, Melsen B. Miniscrews as orthodontic anchorage: a preliminary report. Int J Adult Orthod Orthognath Surg 1998; 13: 201-9.
6. Miyawaki S, Koyama I, Inoue M, Mishima K, Sugahara T, Takano-Yamamoto T. Factors associated with the Stability of titanium screws placed in the posterior region for orthodontic anchorage. Am J Orthod Dentofacial Orthop 2003; 124: 373-8.
7. Freudenthaler JW, Haas R, Bantleon HP. Bicortical titanium screws for critical orthodontic anchorage in the mandible: a preliminary report on clinical applications. Clin Oral Implants Res 2001; 12: 358-63.
8. L. Rasmusson, N. Meredith, L.H.Cho, L. Sennerby. The influence of simultaneous v/s

delayed placement on the Stability of titanium implants in onlay bone grafts. A histologic and biomechanic study in the rabbit. Int. J Oral Maxillofac. Surg. 1999; 28: 224-231.

9. Masami Ohmae, Shigeru Saito, Tomio Morohashi, Kenji Seki, Hong Qu, Ryuzo Kanomi, Ken-ichi Yamasaki, Tomohiro Okano. A clinical and histological evaluation of titanium mini-implants as anchors for orthodontic intrusion in the beagle dog. Am J Orthod Dentofacial Orthop 2001; 119: 489-97.

10. Shouichi Miyawaki, Isao Koyama, Masahide Inoue, Katsuaki Mishima, Toshio Sugahara and Teruko Takano-Yamamoto. Factors associated with the Stability of titanium screws placed in the posterior region for orthodontic anchorage. Am J Orthod Dentofacial Orthop 2003;124:373-8

11. Eric J. W. Liou, Betty C. J. Pai and James C. Y. Lin. Do miniscrews remain stationary under orthodontic forces? Am J Orthod Dentofacial Orthop 2004;126:42-7

12. Cheng SJ, Tseng IY, Lee JJ, Kok SH. A prospective study of the risk factors associated with failure of mini-implants used for orthodontic anchorage. Int J Oral Maxillofac Implants 2004; 19: 100-6.

13. Lin JT, Lane JM. Osteoporosis: a review. Clin Orthop Relat Res 2004; 425: 126-34.

14. Rodrigo Oyonarte, Robert M. Pilliar, Douglas Deporter and Donald G. Woodside. Peri-implant bone response to orthodontic loading: Part 1. A histomorphometric study of the effects of implant surface design. Am J Orthod Dentofacial Orthop 2005;128:173-81

15. Rodrigo Oyonarte, Robert M. Pilliar, Douglas Deporter and Donald G. Woodside. Peri-implant bone response to orthodontic loading: Part 2. Implant surface geometry and its effect on regional bone remodeling. Am J Orthod Dentofacial Orthop 2005; 128:182-9.