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RESEARCH ARTICLE

FACTORS DETERMINING CLINICAL OUTCOME OF TEMPORARY ANCHORAGE DEVICES (TADS)

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ABSTRACT

The last two decades have been an era of emergence of temporary anchorage devices (TADs) because of their absolute intra-oral anchorage, easy-to place, easy to remove and their lower cost. This article is an attempt to provide a comprehensive literature review to quantify the success rate with the use of intra-oral temporary anchorage device for intra-oral anchorage along with the interpretation of clinical factors determining the success rate of TADs. A Literature search was performed using the MEDLINE database (PubMed using URL www.ncbi.nlm.nih.gov), Cochrane Central Register of Controlled Trials, Scopus, Google-Scholar from the year 2006 to 2023.

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INTRODUCTION

TADs can be defined as an intraoral device that is temporarily fixed to intra-alveolar and extra-alveolar bone for the purpose of absolute anchorage either by indirect anchorage (supporting the reactive unit) or direct anchorage which are removed after its use[1]. TADs constitute a wide array of intra-alveolar and extra-alveolar screws used for better anchorage control than conventional mean of anchorage control[55]. At present, the most commonly used TADs are intra-radicular mini-screws, Extra-radicular bone screws (Infrazygomatic crest screws, Buccal self screws and ramus screws) and Skeletal Anchorage System (Mini-plates).

Evolution of TADs: Gainsforth-and Higley[2] used vitallium screws and stainless steel wires in ramus of the mandible and it was believed to be the first published use of orthodontic implants for anchorage. Tooth movement in all six dogs was achieved with the use of these vitallium screws, but they were failed in 16 to 31 days, thereby only limited tooth movement was achieved. Branemark *et al*[3] demonstrated the stability of Titanium implants over a period of 5 years using light microscopic view showing bone-to-implant contact. Linkow[4] used mandibular blade-vent implants for Class II elastics.

Kokich *et al*[5] introduced a novel source of absolute anchorage when they deliberately induced ankylosis of a deciduous tooth which was then used to protract the maxilla in a patient with severe maxillary retrusion. Creekmore and Eklund[6] (1983) used a vitallium bone screw to treat deep overbite and this was the first reported clinical case in the literature which was treated with TADs. The screw was inserted in the anterior nasal spine to intrude the upper incisors and intrusive force was applied on the upper incisors using an elastic from the screw to the incisors. Many orthodontist encouraged the successful osseointegration of implants, as reported By Branemark, for anchorage reinforcement but it required surgical procedures for placement and removal and delayed implant loading because of the waiting period necessary for osseointegration, limited to only edentulous or retro-molar areas of the maxilla and mandible, increased risk of damage to adjacent root of the tooth or adjacent vital structures because of their larger dimensions and rrelatively higher cost. To overcome these above mentioned issues, TADs have been introduced as an alternative method for absolute anchorage.

Extra-Alveolar Anchorage[60]

- Infrazygomatic crest (IZC)
- Buccal Self Screws
- Ramal Screws

Skeletal Anchoage Systems (SAS):

- Onplant (Block & Hofmann[7])
- Skeletal anchorage system (Umemori & Sugawara[8])
- Arhus anchorgae system (Melsen *et al*[9])
- Spider screw anchorage system (Maino *et al*[10])
- Straumann system (Wehrbein and Merz[11])
- Graz implant supported system (Byloff *et al*[12])
- Zygomatiic plates for anchorage (Erverdi *et al*[13])
- Miniscrews (Kanomi[14])
- C-implant (Chung *et al*[15])

Success rates of micro/ mini implants as studied by various authors:

Author & year	Sample size	Success rate
Freudenthaler[16] (2001)	15	75%
Miyawaki *et al*[17] (2003)	Studied 3 type of implant system	84% (100% with miniplates)
Fritz *et al*[18] (2004)	16 (Implants)	70%
Cheng *et al*[19] (2004)	92 miniscrews	89%
Park *et al*[20] (2006)	227 mini+microscrews	91.6%
Tseng *et al*[21] (2006)	45 miniscrews	91%
Motoyoshi *et al*[22] (2006)	124	86.2%
Motoyoshi *et al*[23] (2007)	169	86.5%
Schatzle *et al*[24] (2009) (Systematic review)	2374 miniimplants 29 onplants	16.4% (failure rate) 17.5% for onplantss
Moon *et al*[25] (2010)	778 microimplants	79.0%
Kim & Yang[26] (2010)	210 miniscrews	88.20%
Tsui *et al* [27] (2012) (Systematic review)	-	91.4-100% (miniplates) 74.0-93.3% (palatal implants) 61-100% (miniscrews)
Papageorgiou *et al*[28] (2012) (Meta analysis)	4987 miniscrews in 1987 patients	13.5% (failure rate)
Lai TT *et al*[29] (2014)	266 TADs in 129 patients	97%
Jaramillo - Bedoya *et al*[30] (2022) (scoping review)	-	> 90% (overall) Miniplate (95+3 %) Mini implant (87+7%)
Chang C *et al*[61]	1680 buccal self screws	93%

Most of the studies reported greater than 90% success rates of TADs[30,56,57].

Factors determine the success of TADs are

Patient related	Implant related	Surgery related
• Age	• Implant type	• Placement site
• Sex	• Screw diameter	• Jaw
• Smoking	• Screw length	• Placement angle
• Malocclusion	• Thread design	• Flap/flapless
• FMA	• Thread surface	• Placement side
		• Cortical bone thickness
		• Root proximity
		• Insertion torque
		• Microflora

Effect of age & sex on the success rate

Author	Age	Sex
Miyawaki *et al*[17] (2003)	NS	NS
Cheng *et al*[19] (2004)	NS	NS
Liou *et al*[31] (2004)	NS	NS
Fritz *et al*[18] (2004)	NS	NS
Park *et al*[32] (2005)	NS	NS
Park el al[33] (2006)	NS	NS
Motoyoshi *et al*[22] (2006)	NS	NS
Kuroda *et al*[34] (2007)	NS	NS
Chen *et al*[35] (2007)	>30 years more success than younger age	NS
Moon *et al*[36] (2008)	NS	NS
Antoszewska *et al*[37] (2009)	NS	NS
Lim *et al*[38] (2009)	Adults>>children	
Moon *et al*[25] (2010)	NS	NS
Kim & Yang[26] (2010)	NS	NS
Lai *et al*[29] (2014)	NS	NS

NS- Non significant, SS- Statistically Significant

Most of the studies reported effect of the age and sex on success rate of TADs are statistically not significant except for Manni *et al*[39] who reported higher success rate in male (88.1%) than females (76.4%) patient ($p<0.05$). Their result was in contrast with the information available in the literature[17,19-20] and possible explanation could be the large number of mini-screws examined in their sample, different types of screws used, as well as difference in anatomical position (e.g cortical bone thickness) and hormonal differences.

Effect of mandibular plane angle

Author	Effect of mandibular plane angle
Miyawaki *et al*[17] (2003)	Patients with normodivergent & hypodivergent growth pattern (low mandibular palne angle) had statistically significantly higher success rates than patients with hyperdivergent growth pattern (high mandibular plane angle).
Kuroda *et al*[34] (2007)	No relation
Baek *et al*[40] (2008)	Lower success in patients with hyperdivergent growth pattern (high mandibular plane angle).
Antoszweska *et al*[37] (2009)	Patients with open-bite or normal bite had lower success rate than patients with deep-bite
Moon *et al*[25] (2010) Kim & Yang[26] (2010)	No relation

Most of the studies in the literature concluded that patients with normodivergent and hypodivergent growth pattern (average & low mandibular plane angle) had statistically significantly higher success rates than patients with hyperdivergent growth pattern (high mandibular plane angle). Kohakhura *et al*[41] & Tunori *et al*[42] stated that patients with brachycephalic head, (reduced gonial angles and reduced mandibular plane angles) have thicker cortical bone than dolichocephaly head. Brettin *et al*[43] concluded that bi-cortical miniscrew provides better anchorage resistance, lesser cortical bone stress, and increased stability as compared to mono-cortical miniscrews.

Effect of Implant Diameter and Length

Author	Diameter	Length
Park *et al*[33] (2006)	NS (1.2/1.5/2 mm)	NS (6,8,10,12 mm)
Miyawaki *et al*[17] (2003)	SS (1.5/2.3>>1 mm)	-
Wiechmann *et al*[44] (2007)	SS (1.6 mm >> 1.1 mm)	-
Chen *et al*[35](2006)	-	SS (8 mm>> 6 mm)
Kim & Yang[26] (2010)	NS	-
Lai TT *et al*[29] (2014)	NS (1.6mm /2 mm)	NS (8mm /10 mm)

Chen *et al*[35] reported increase in success rate from 72-90% with the use of long miniscrews (8 mm) as compared to 6 mm long miniscrews while Morarend *et al*[45] reported that small diameter (1.5mm) bi-cortical screws provides equal or even greater anchorage resistance than larger diameter (2.5 mm) mono-cortical screws.

Effect of Jaw and Insertion side

Author	Maxilla/Mandible	Right/Left
Park *et al*[33] (2006)	Maxilla>> Mandible	Left>> Right
Moon *et al*[36] (2008)	NS	NS
Lim *et al*[38] (2009)	Maxilla>> Mandible	-
Moon *et al*[25] (2010)	NS	NS
Papageorgiou *et al*[28] (2012)	Mandible more failure rate than maxilla (19.3% v/s 12%)	-
Lai TT *et al*[29] (2014)	Maxilla>> Mandible	NS

NS- Non significant, SS- Statistically Significant

Most of the studies considered significantly higher success rates in maxilla as compared to mandible. According to Chen *et al*[46] thicker cortical bone needed greater torque for insertion which is possibly harmful for survival of implant. Cortical bone thickness of 1mm or more was associated with lesser failures[47-48] while implants with use of torque values greater than 10 N/cm during implant insertion were associated with more mini-implant failure[22-23].

Park *et al*[33] found higher success rates for implants which were inserted on left side of the mouth but this result could be related to better oral hygiene on left side of the mouth in right-handed patients. Antozsweska *et al*[37] studied the effect of type of malocclusion on success rate of implants and they found 100% success rate in Class III malocclusion patients, 94.0% in Class II and 90.43% in Class I which was statistically non-significant. Similar statistically non significant results were also reported by Lai *et al*[29].

Effect of soft tissue type

Author & year	Results
Cheng *et al*[19] (2004)	Non-keratinized mucosa is a risk factor for implant failure
Park *et al*[33] (2006)	Palatal mucosa >> oral mucosa
Antoszweska *et al*[37] (2009)	Attached gingiva had the highest success rate
Lai *et al*[29] (2014)	Keratinised mucosa had the highest success rate
Chang *et al*[61] (2015)	No significant difference between placement in Mobile Mucosa or Attached Gingiva.

Most of the studies found higher success rates in the mini-implants which were inserted into the keratinized mucosa/gingiva.

Effect of root proximity: Kuroda *et al*[34] (2007) reported miniscrews with a minimal length of 8 mm and minimal diameter of 1.2 mm had sufficiently better implant stability with minimal risk to radicular injury.

Effect of placement position

Author	Placement position
Miyawaki *et al*[17] (2003)	No effect of the placement site
Kuroda *et al*[34] (2007)	1st & 2nd premolar >> 1st & 2nd molars
Moon *et al*[36] (2008)	Most stable position- maxillary 1st and 2nd premolar Least stable position- mandibular 1st & 2nd molar
Moon *et al*[25] (2010)	1st & 2nd premolars >> 1st and 2nd molars
Kim & Yang[26] (2010)	Midpalatal area >> Parapalatal area

Most of the studies found most stable position for TADS is maxillary 1st and 2nd premolar and least stable position is mandibular 1st & 2nd molar.

Effect of placement angle: Deguchi *et al*[49] recommended that placement of mini-implants at the angle of approximately 30˚ will increase the contact with the cortical bone by 1.5 times than placing the mini-implants at perpendicular to the long axis of the tooth while Lim *et al*[38] found that mini-implants inserted at at 45 ˚ to the long axis of tooth will increase the contact area with cortical bone.

Self drilling v/s Self tapping: Heidemann *et al*[50] reported superior contact between the screw and the bone using self-drilling screws as compared to self-tapping screws. Similar results were also reported by Kim *et al*[51].

Microorganism: Zhao *et al*[59] reported that various microorganism like Eikenella corrodens, Neisseria elongate, Prevotella intermedia, , Parvimonas spp., and Catonella morbid were found in increase quantity in failed TADs on Metagenomic sequencing. They concluded that one of the important factors which determine the success of TADs is control of bacterial adhesion on their surface[58].

Recommendations

- Liou *et al*[52] recommended that mini-screws implants should be inserted such that they must be 2 mm away from the roots of the adjacent teeth, nerves or other vital structure, when the TADs are inserted in inter-dental areas.
- Crismani *et al*[53] recommended that mini-Implant can be loaded with upto 203.94 gms force within a day after their placement.
- Miyawaki *et al*[17] recommended placement of miniscrews in firm attached gingiva rather than movable mucosa for superior results. They recommended flapless method for insertion as it causes lesser discomfort and pain to the patients and required lesser time for insertion.
- Beltrami *et al*[54] recommended that the mini-screws with lesser than 1.2 mm in diameter and lesser than 8 mm in length and miniscrews with greater than 10 mm in length has not been recommended.

CONCLUSION

The present review highlighted the usage of Temporary Anchorage Devices and factors determining their success rate. The overall success rate of the Temporary Anchorage Devices was greated than 90%[57]. The main factors that determine the success rate of the TADS are growth pattern of the patients, miniscrew diameter and length, site of placement, type of soft tissue, quality and quantity of the bone, adjoining vital structures, placement angle, method of placement and surgical technique used for miniscrews placement and control of microorganism adhesion on the surface of TADs. These factors should be taken into consideration while placement of the Temporary Anchorage Devices for orthodontic skeletal anchorage.

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