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Review Article

THE INSERTION OF OUR ORTHODONTIC MINISCREW IMPLANTS AND THE EFFECT OF THAT ORTHODONTICS TREATMENT ON THE ROOT RESORPTION: A LITERATURE REVIEW

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ABSTRACT

Recently, the use of miniscrews to achieve absolute anchorage has gained popularity in clinical orthodontics as rigid anchorage procedure. Miniscrew implants contributes many advantages when used as temporary anchorage devices like, providing absolute anchorage, convenient placement and removal, can be placed in different sites and requires less patient compliance. This makes them an indispensable treatment option in cases with critical anchorage that would have otherwise resulted in anchorage loss if treated with regular means of anchorage.

The aim of this broad review is to:1- focus on the progressive evolution, clinical applications, indications and complications of the miniscrew implants when used to achieve a temporary but absolute skeletal anchorage for orthodontic applications also the aim of this review was to systematically evaluate the failure rates of miniscrew implants in relation to their specific insertion sites and to explore the insertion site dependent risk factors contributing to their failure. 2- evaluate the relation between orthodontically induced root resorption (OIIRR) and different mechanics with fixed appliances.

Conclusion: The best insertion sites are found in the palate and the least successful location is in high up positions in the zygomatic buttress. Root contact is a major risk factor contributing to the failure of miniscrew implants placed between the first molars and second premolars. Results should be interpreted with caution due to the methodological drawbacks of some of the included studies and the small number of studies investigating some of the insertion sites. The application of heavy forces causes more RR in particular with certain mechanics (Buccal tipping, rotational movements, jiggling forces and intrusive forces) when compared to other mechanics (tip bends and extrusive forces), also the application of continuous forces show more amount of RR especially with one and three-week activation intervals. Results should be interpreted with caution owing to the compromised internal validity in the included individual studies.

Keywords: Anchorage, Temporary Anchorage Devices, Mini-Implant, Orthodontics

INTRODUCTION

1. Background of the insertion of orthodontic miniscrew implants:

There is no doubt that the introduction of implants into the field of orthodontics has revolutionized the entire scope of every orthodontic practice adding a new but yet a viable tool to the orthodontic arsenal. Their simplicity, ease of use, durability and excellent anchorage reinforcement capabilities are probably the reasons for their wide acceptance among the orthodontists and their patients. The introduction of dental implants into the orthodontic scope of practice in the 1990s was a lifelong process of some exceptional previous work that was carried out on this subject aiming to initiate and integrate the use of implants into the field of dentistry. There were actually some early attempts that were carried out to investigate the performance of implementing vitallium screws in the ramus of five dogs on the traction of teeth that showed that teeth could be effectively moved although the overall results didn't show a lot of success in the long term maintenance of the implanted screws and resulted in a wider destruction of the bone at the implantation site (Gainsforth and Higley, 1945). Branemark and his colleagues (1969) carried out an early animal experiment in order to potentially explore the factors associated with the healing process and long term stability of the implants they used in their study. These early attempts were aimed to establish these implants as a future prosthetic replacement to the teeth paving the way into further important research to be carried out into this area. At the same period, other research projects utilized these implants aiming to explore the mechanism of craniofacial growth. These studies provided a lot of information based on the utilized implants about the mandibular rotations and growth mechanism (Bjork, 1955; Bjork, 1969). However, it was not before 1983 when a case report was presented showing the effective use of an anterior screw that was used to treat a patient with an increased overbite (Creekmore and Eklund, 1983). Afterwards, a gradual introduction of different types of implants into the clinical orthodontic practice took place presenting the use of endosseous implants (Roberts et al., 1990), the use of palatal implants (Wehrbein et al., 1996) and finally the introduction of the most popular type which is the mini-implant or miniscrew (Kanomi, 1997). Thus, there are so many designs and variations resulting in different systems that provide skeletal anchorage in orthodontics.

1.1 Types of skeletal anchorage:

There have been different terms describing the utilization of different types of skeletal anchorage systems. Temporary anchorage devices (TADs) has been used widely as a term to reflect the actual idea of these different implant systems being used on a temporary basis to provide anchorage reinforcement capabilities during orthodontic and orthopedic movements. On the contrary, implants used in other dental fields rely on their long term stability and maintenance totally relying on the osseointegration process and acting as a potentially permanent solution for the restoration of missing teeth. The developmental process of different types of skeletal anchorage came from both the implants used as part of the restorative interface and those used as maxillofacial bone fixation systems (Gill and Naini, 2012). Thus, three distinct types were established, mainly the implant, which presents in a larger diameter and size than the orthodontic miniscrew implant (OMI), which presents with a smaller diameter and size and finally the mini-plate type (Figure 4).

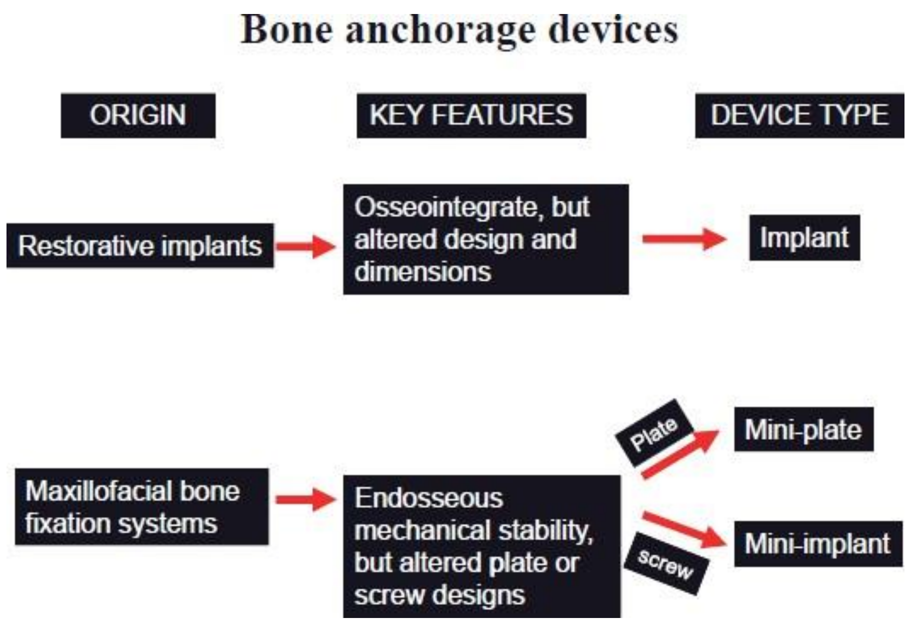

Figure 4: Different types of bone anchorage devices reproduced from (Gill and Naini, 2012)

Another classification categorizing the implants by their shape and size, bone contact and their clinical application was hypothesized (Labanauskaite et al.,2005).

According to the shape and size:

- Conical (cylindrical) implants.
- Miniscrew implants.
- Palatal implants.
- Prosthodontic implants.
- Miniplate implants.
- Disc implants (onplants).

According to the implant bone contact:

- Osseointegrated implants.
- Non-osseointegrated implants.

According to the mode of application:

- Used only for orthodontic purposes.
- Used for both prosthodontic and orthodontic purposes.

1.2 Miniscrew implants design:

One main aspect that distinguishes the commonly used OMIs from the conventional osseointegrated implants and mini-plates is the design. The OMI presents with a unique design that consists of the head, the neck and the body (Cousley, 2013). The head is frequently presented in a button-like appearance with different shapes that could be in the form of a sphere or a hexagonal. Alternatively, a bracket-like design is also used as it facilitates the purpose of using the OMI as an indirect anchorage source (Papadopolous and Tarawneh, 2007).

The neck connects the head with the main body crossing the mucosal barrier leaving the head as a clear visible part for traction. The main and critical part of the OMI is the thread body component which technically performs the insertion and mechanical retention of the OMI thus acting as a key factor for any planned successful outcomes concerning the OMI design. The thread component is usually utilized with a length ranging from 4 – 14 mm and a diameter ranging from 1.2 – 2 mm (Papadopolous and Tarawneh, 2007). Both of these smaller lengths and diameters constitute for the difference between the commercially popular OMIs and their larger osseointegrated prosthetic implants or palatal implants (Figure 5).

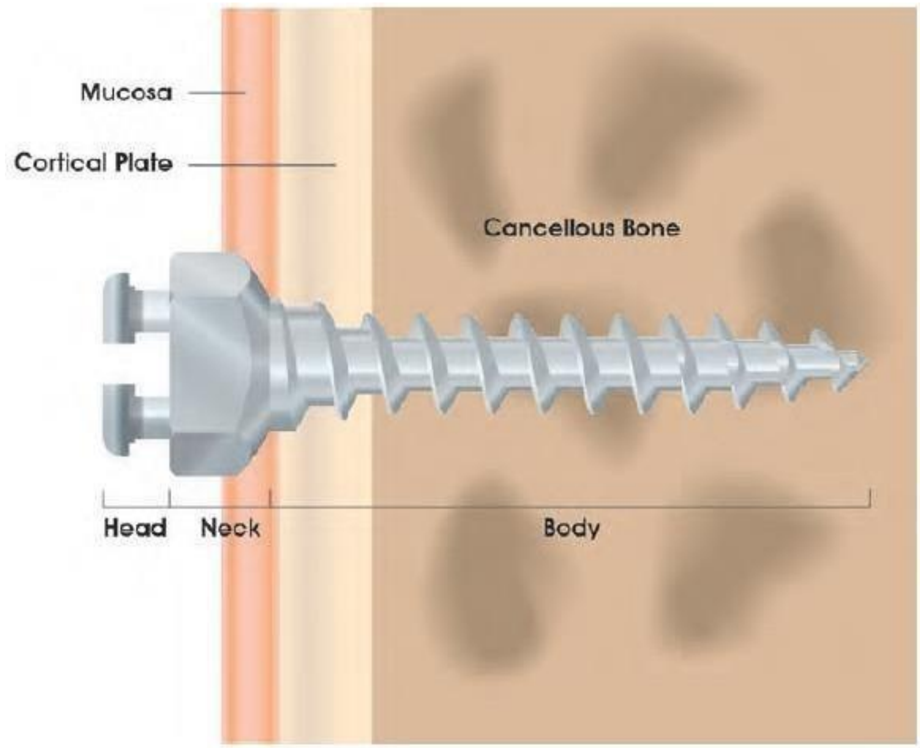

Figure 5: Design of orthodontic miniscrew implants reproduced from (Cousley, 2013)

1.3 Clinical handling of miniscrews:

OMI insertion is rather a simple procedure that usually requires a small local anesthetic injection before inserting the OMI into its specified insertion site within the oral cavity. OMIs can be inserted using a self-drilling or a self- tapping technique with both techniques demonstrating a statistically non-significant difference either in their success rates or the probabilities of both techniques causing OMIs to hit the dental roots according to a recent meta- analysis (Yi et al., 2016). Several in-vitro and animal studies have investigated the effect of the initial placement angulation on the OMI stability and concluded that a placement angulation of 50° to 70° offers the best laboratory outcomes regarding the OMI initial stability (Xu et al., 2012; Wilmes et al., 2008). Another aspect was the exploration of the optimal initial insertion torque required to provide stability for the inserted OMIs. In- vitro and animal studies were carried out simultaneously providing some information that a higher initial insertion torque associated with a higher length and diameter of OMIs results in better outcomes regarding OMI stability (Song et al., 2007; Cha et al., 2008; Lim et al., 2008; Florvaag et al., 2010). On the contrary to these previous findings, clinical studies demonstrated that a higher insertion torque significantly increases the chances of OMIs to fail and thus an initial insertion torque of 5-10 Ncm is recommended (Motoyoshi et al., 2006; Suzuki and Suzuki., 2011; Suzuki et al., 2013). However, a systematic review by Reynders and his colleagues (2012) presented the fact that there is insufficient evidence to reach any conclusions about this subject and that more high quality studies are needed. OMIs have a superior advantage having the ability of being inserted into the alveolar bone without a surgical flap elevation when compared with the traditional approach associated with the conventional implants used for prosthodontics restoration. This would allow for a less traumatic and invasive procedure subjecting the patients to a better experience. However, some studies have reported on the insertion of OMIs with surgical flap elevation and demonstrated rather a problematic success rates (Viwattanatipa et al., 2009; Topouzelis and Tsaousoglou., 2012). This might rather be explained by the additional probability of having an infection associated with the surgical incisional location and the fact that patients will probably lend themselves to ignoring meticulous oral hygiene measures at that location allowing more OMIs to experience failures.

1.4 Clinical applications:

One unique feature that renders the OMIs as a very popular solution nowadays among orthodontists is its versatility. OMIs present with a small diameter and length increasing their versatility to be used technically in more and more locations in the oral cavity. Early studies about the volumetric readings of the availability of alveolar bone for OMI insertion indicated that OMIs could theoretically be placed safely in the posterior interradicular regions up to the second molars and even more favorably in various palatal sites suggesting an optimal OMI length of 6-8 mm and a maximum diameter of 1.5 mm (Poggio et al., 2006; Deguchi et al., 2006). Ludwig and his colleagues (2011) suggested that the best anatomical site in the palate for OMI insertion lies within the anterior region alternatively suggesting using the posterior region at the lateral borders as another key location. OMIs could be effectively placed at the lateral borders of the palate posteriorly to intrude the posterior teeth allowing for improvements in openbite cases (Kravitz et al., 2007; Akay et al., 2009). This location could be also utilized for effective distalization of the maxillary molars with the help of incorporated trans-palatal arches (Miresmaeili et al., 2015). Another popular location in the palate for OMI insertion is the midpalatal area along with its paramedian region. These locations are heavily utilized for many purposes including the mesialization of the maxillary dentition, distalization of the maxillary molars, retraction of the incisors, transverse expansion of narrow palatal vaults and the effective intrusion of the posterior segments (Kinzinger et al., 2008; Kang et al., 2011; Lee et al., 2014; Nienkemper et al., 2015). OMIs are frequently placed in the mandible between the first molars and second premolars allowing effective retraction of the lower incisors (Manni et al., 2012; Suzuki et al., 2013). Some studies have reported utilizing OMIs even in more posterior areas in the mandible between the first molars and the second molars or at the retromolar area for effective retraction of the incisors or uprighting posterior teeth (Park et al., 2006; Sarul et al., 2014). OMIs were also inserted between the lower canines and premolars to hypothetically prevent the lower incisors from demonstrating excessive proclination whilst actively using fixed functional appliances (ElKordy et al., 2015). Other studies utilized these small OMIs for intruding the lower incisors in deep overbite cases by inserting the OMIs between the roots of the lower laterals and canines taking into consideration the small interradicular space available in this location (Aydogdu and Polat-Ozsoy., 2011). In the maxilla, OMIs could be used in the anterior region by either inserting two OMIs between the lateral incisors and canines one on each side; between the lateral incisors and centrals or by inserting a single OMI between the two maxillary centrals to actively intrude the upper incisors in deep bite cases (Deguchi et al., 2008; Polat-Ozsoy et al., 2009; Saxena et al., 2010; Nishimura et al., 2014). Other popular insertion sites in the maxilla are between the roots of the first molars and second premolars or between the canines and first premolars for effective retraction of the incisors or distalization purposes (Cousley., 2013) (Figure 6).

Figure 6: Different locations of OMIs; on the right: a combination of buccal and parapalatal OMIs for posterior segment intrusion, on the left: an interradicular OMI between the first molar and second premolar for en-masse retraction in a case of class II div I.

1.5 Efficacy of skeletal anchorage:

One important aspect concerning the effective manipulation of a newly introduced system is exploring its efficacy. The ability of OMIs to remain stable throughout treatment is an important factor that must be considered. Constantly utilizing something which continuously fails underpins its efficient use. Previous systematic reviews examined the general failure rates of OMIs and reported it to be in the range of 13.5% - 16.4 % (Schatzle et al., 2009; Papageorgiou et al., 2012). These failure rates were slightly less than that reported for other skeletal anchorage systems such as the palatal implants or the miniplates (Dalessandri et al., 2014). However, it should be taken into consideration that OMIs offer an advantage when compared with these systems which is their simplicity and less invasiveness. The other part concerning the efficacy of utilizing OMIs is their ability to provide an efficient yet a controllable action over the movement of the teeth. A recent Cochrane review concluded that that there is a moderate quality of evidence suggesting the effective usage of skeletal anchorage and that the results from the OMIs are showing a lot of promise (Jambi et al., 2014). It is also notable that OMIs do not only offer superior anchorage capabilities over extra-oral headgears or even the palatal arches, but also they have a wide patient acceptance (Sandler et al., 2014). Thus, these previous facts probably explain their increasingly wide popularity among orthodontists and their patients nowadays.

1.6 Risk factors:

There are many factors which could typically influence the success rates of inserted OMIs. Cousley (2013) classified those factors into patient related, OMI related and operator related factors.

1.6.1 Patient related factors:

These factors are related to the patient and could present as insertion site related factors including the cortical bone thickness, relation to vital structures within the maxilla and the mandible, availability of inter-proximal radicular bone and approximation to the dental roots (Cousley., 2013). Other factors within this subgroup include the patient's age. A recent meta-analysis concluded a statistically significant difference for OMI failures when OMIs were inserted in patients less than twenty years old (Hong et al., 2016). These results might be explained by the difference in the maturity of the bone between adult and young patients. Other factors include the effective maintenance of a good status of oral hygiene and the status of smoking patients as this was concluded to be a risk factor increasing the failure rates of OMI failures (Bayat., 2010). Differences in failure rates between males and females are seen to be negligible and thus gender seems to have little contribution to the subsequent failures of OMIs (Hong et al., 2016). Although many previous systematic review have reported on the better success rates reported in the maxilla when compared with the mandible (Papageorgiou et al., 2012; Dalessandri et al., 2014), none have reported an in- depth exploration of each individual insertion site separately.

1.6.2 Implant related factors:

These factors are typically related to the choice of diameter and length of the OMI. OMIs with greater diameter and length have the potential to have a greater success rates due to the increased amount of mechanical bone contact and increased torque values during the initial insertion (Cousley., 2013). This hypothesis has been supported by the results of a meta- analysis that OMIs with a diameter greater than 1.4 mm and length greater than 7 mm have better outcomes (Hong et al., 2016). Even though these results favor utilizing greater lengths and diameters for OMIs, the end results are unlikely to produce a clinically significant outcome.

1.6.3 Operator related factors:

These factors represent the choice of the drilling method, surgical placement method, the OMI loading and the operator's experience.

OMIs could be placed efficiently without an incisional flap elevation and that might be considered as a great advantage over mini-plates. On the contrary to the traditional delayed loading in prosthodontic conventional implants, OMIs are shown to demonstrate comparable success rates when either loaded in an early or a delayed fashion as shown by the results from a recent meta-analysis (Dalessandri et al., 2014). On the other hand, both self- tapping and self-drilling OMIs are shown to produce comparable outcomes with no significant differences between them (Yi et al., 2016). Operator's experience could play an important role as the more experience with handling OMIs, the more likely OMIs would survive (Kim et al., 2010).

1.7 Review question:

The aim of this review is to answer the question regarding the best possible insertion sites for miniscrew implants presenting the failure rates of any analyzable insertion sites and to additionally explore the insertion site dependent risk factors that could potentially influence the failure rates of the miniscrew implants

2. Background of root resorption due to orthodontics forces:

There is no doubt that orthodontically induced inflammatory root resorption (OIIRR) is one of the most common complications that occur during treatment with fixed braces. The exploration of root resorption started in the 18th century with some exceptional studies that were performed on animals to investigate and observe root resorption in the field of dentistry. The first reported tissue changes related to tooth movement were reported by Sandsted in (1904) when; he placed bands on dog' maxillary canines with a labial arch on the central incisors to perform a lingual movement for 3 weeks then he extracted the teeth and evaluated it histologically. He found that no root resorption (RR) happened. However, there was observed necrosis in pressure areas of the periodontal membrane. In (1911) Oppenheim did another study on deciduous teeth of monkeys to assess the center of rotation of different tooth movements. He observed a resorption crater on the pressure side and bone formation on the stress side with necrotic areas on the pressure side when heavy forces are achieved. This report has been used as a guide to orthodontic therapy for many years. In (1926) Ketcham started to report the relation between root resorption and orthodontic treatment on patients by doing a radiographic survey of three hundred and eighty-five treated orthodontic patients and he concluded that the amount of root resorption increases after orthodontic treatment and he recommend to do radiographs before, during and after every treatment (Stuteville, 1938). In (1933) Becks and his colleagues compared root resorption in orthodontic patients and controls observing that orthodontic treatment caused more root resorption. After those influential inputs scientists began to focus on the aetiologies, forces and types of movements related to root resorption and the improvement of technology helped the researchers to have more detailed investigation. (Figure 7 and 8)

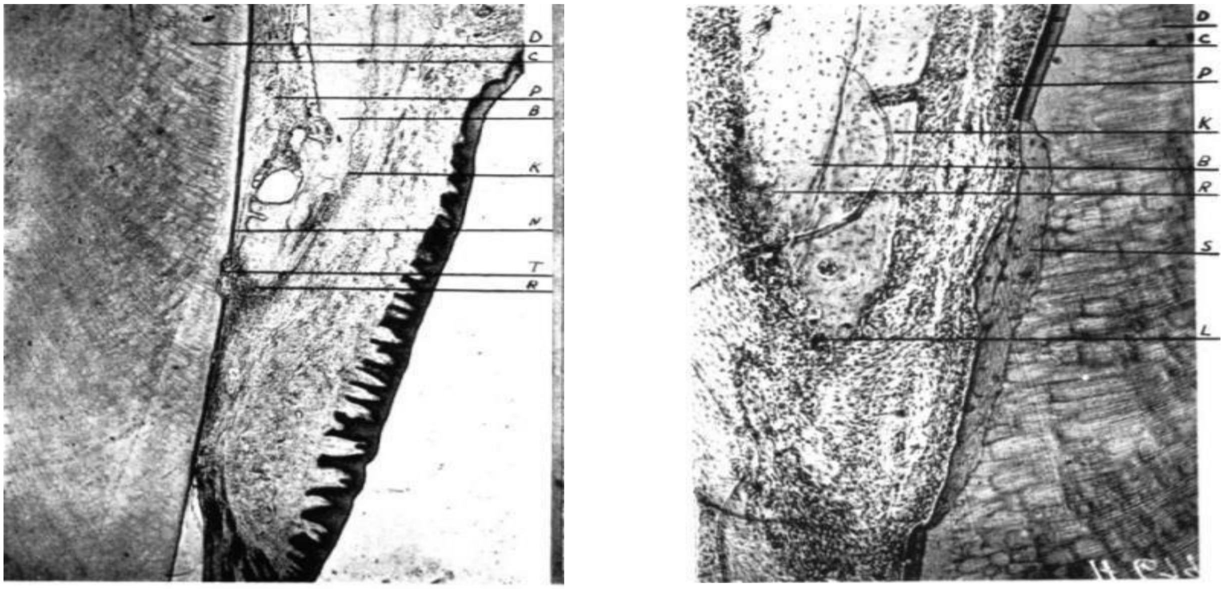

Figure 7: Showing microphotographs of tooth sections illustrating areas of resorption affecting tooth (T) and bone (R). (Stuteville, 1938)

2.1 Methods of detection and prevalence:

Different radiographs have been used to diagnose root resorption through history up to the use of micro computed tomography (Figure 1.3). Dental panoramic tomographs (DPT) have been used to assess overall resorption of teeth however it has narrow focal trough which result in unclear orientation of teeth (Leach et al., 2001). Periapical radiograph with a film holder or bisecting angle technique is used instead because of its easiness to adjust and more accuracy (Leach et al., 2001). Assessment of periapical films was either by caliber on film or digital x-ray and scanning. An interesting research compared the accuracy of scanned film and digital periapical radiographs to assess root resorption. They evaluated 24 scanned film and digital radiograph for 6 extracted teeth before and after 1mm of apical trimming using Image-J-Link 1.4 software and they found that there is an agreement between true tooth length and the experimented scanned films and digital radiographs with no difference between these two methods (El-Angabawi et al., 2012). Sameshima and Asgarifar in (2001) found that root resorption was less accurate by 20% with DPT compared to a periapical radiograph. Now, the use of CBCT is increasing as it has the ability to assess root resorption in three dimension. A lot of studies therefore now using the CBCT, however its use should be limited because of its high exposure and high cost (Isaacson and Allan 2015).

Prevalence of root resorption varies according to the type of investigation used. Brezniak & Wasserstein (2002) found that root resorption happens from 30% to 70% by 2D (periapical radiograph), Makedonas and his colleagues (2012) stated that root resorption is detected by 97% by CBCT. Histologically root resorption happen to almost 100% of orthodontic patients (Han et al., 2010).

There are specific teeth which are more susceptible to resorption than others A) Maxillary lateral incisors, B) Maxillary central incisors, C) Mandibular incisors, D) Mandibular second premolar and E) Maxillary second premolar. Lupi et al., (1996) found that root resorption occurs to 15% of the population before orthodontic treatment and occur in 73% after treatment. The extent of root resorption is usually minimal in most of the patients. Linge and Linge in (1991) used intra oral radiograph to assess extent of resorption in 485 treated patients and they found that root resorption of more than 4mm happend in about 2.3% of patients. Levander and Malmgren (1988) found that root resorption of more than half the length of original root occurred in only 1% of patients. (Figure 9).

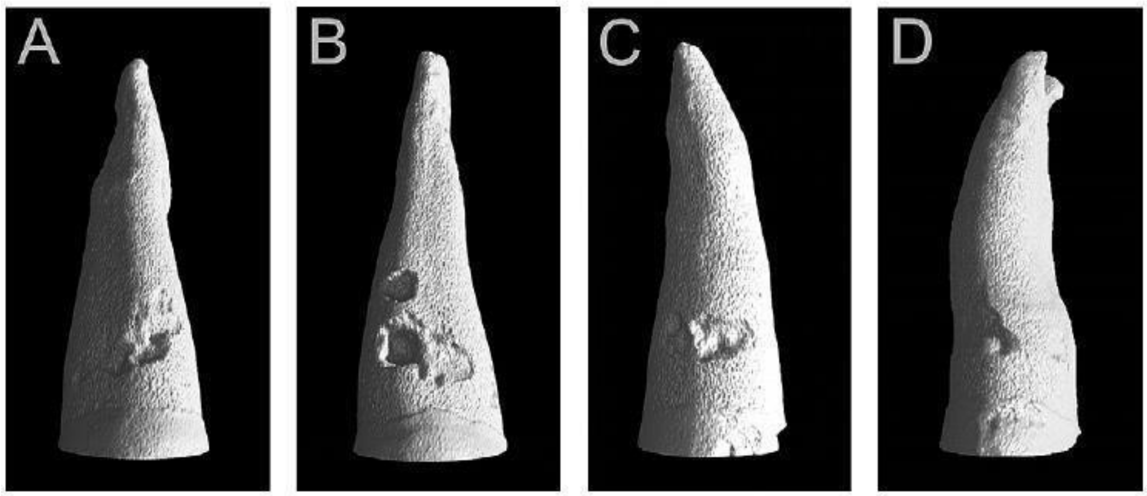

Figure 8: Showing Root resorption using Micro computed tomography (Aras et al., 2011)

Figure 9: Periapical radiograph of upper incisors taken after de-bonding showing severe root resorption of more than half of root length. (This radiograph is taken at private practice)

2.2 Factors affecting root resorption:

Harris et al., (2006) stated that root resorption is an inevitable pathological outcome of orthodontic tooth movement. Brudvik and Rygh (1994) studied the cellular process in mice and reported that when over compression of periodontal ligaments happen, it causes necrotic tissue area and during removal of these tissues by macrophage-like cells at the periphery of the hyalinized zone which contain the blood vessels of periodontal ligaments, resorption of the outer layer of root occurs. Resorption continues untill the hyalinized surface is totally removed which takes on average about 10 days (Kvam, 1971). Resorption lacunae expand the surface area of the root which results indirectly in decreasing compression areas and starting of cementum repair. Extent of root resorption increases when the reactivation of forces happens at the presence of osteoclast which happen at the 4th day.

2.2.1 Biological Factors:

Biological factors vary from one person to another and are related to the metabolic rate and hormonal changes altering the relation between the osteoclast and osteoblast.

Historically, it was thought that resorption was related to genetic factors only and a Sib Pair test was used to assess its effect. An interesting study by Ngan et al. (2004) who retrospectively compared pre and post records of 16 monozygomatic and 10 dizygomatic twins. They found that 49.2% of monozygomatics twins had resorption and for dizygomatic twins a 28.3% was only noted concluding that there is a genetic component (genotype). Sameshima and Sinclair (2001) also reported that root resorption prevalence is more in White and Hespanic ethnicities than in the Asian population which gives good indication that it is related to genetics. However, it is not clear if root resorption is related only to genetics or a combination of genetic and environmental factors. Age is also an important factor in root resorption, the older the patients, the more the susceptibility to resorption because of the denser bone, decreased turnover and increased thickness of cementum (Mirabella and Artun, 1995). Linge and Linge (1991) reported that if the orthodontic treatment started before the closure of apex (before 11 years of age) it will decrease the root resorption. However, it is not always possible to start at this age for all patients. Gender may also affect the incidence of root resorption. Some research shows that males are more prone to resorption, however, other researches have shown that results were non-significant (Harris et al., 1997). Root shape was historically thought to increase risk of root resorption, however Brin et al., (2003) have concluded that there is no significant difference between root resorption and root morphology. Alveolar bone width and the proximity of the root to the cortical plate were discussed by Wehrbein et al., (1995) to be a relative factor to increase resorption but there was also no evidence to support this. Small or peg-shaped laterals have same incidence of resorption as normal teeth.

2.2.2 Environmental factors:

Root resorption can be associated with medical conditions of asthma and allergy which according to Nishioka et al., (2006) OIIRR could be related to the administration of corticosteroids which is taken by these patients. In-vitro studies have shown that root resorption increased with patients with hypothyroidism and also with patients that had deficiency in vitamin D and calcium. In contrary, NSAIDS, aspirin and bisphosphonates have shown lower incidence of root resorption, however, these need further investigation. Habits like finger sucking, nail biting and tongue thrust have shown an increase in root resorption and also closing open bites related to these habits (Harris and butler., 1992). Trauma to teeth increase root resorption as Linge and Linge (1983) showed that there was 1.07 mm root resorption when compared to non-traumatized teeth (0.64 Mm) Malmgren and his colleagues suggested to wait 1 year after trauma before continuing orthodontic treatment. Endontically treated teeth have shown same incidence of resorption as non-treated teeth (Spurrier et al., 1990). Foo et al. (2007) have evaluated the effect of systemic fluoride on rats found that it decreased the craters of resorption, however, it's not significant. Also in 2013, Karadeniz et al., classified 48 patients who required orthodontic treatment into high fluoride (more than 2 ppm) and low fluoride (0.05 ppm) groups and he applied heavy and light forces on each group for 28 days and concluded that fluoride doesn't have any beneficial effect on root resorption. Recently, in-vitro studies have shown that systematic administration of casein phosphopeptides might help in decreasing root resorption (Crowther et al., 2017).

2.2.3 Mechanical factors:

Mechanical factors are related to the treatment factors which are demonstrated in the direction, duration and magnitude of force. Tooth movements can be divided as follows:

2.2.3.1 Tipping movement: forces are at apical part and margins of tooth.

2.2.3.2 Bodily movement: forces are at one side of tooth.

2.2.3.3 Intrusion: forces are concentrated at apical part.

E) Extrusion: no areas of pressure concentration unless there are areas of undercut. Tooth movement is always a combination of these movements, so operators must always be cautious about the forces applied and the duration of treatment. In 2017 an interesting prospective study compared the root resorption between the ascending (25 to 225 g.) and descending (225 to 25 g.) forces using magnetics for 8 weeks and they found that there is no significant difference between them in root resorption which indicated that the application of heavy forces happening either at the start or end of treatment will result in same amount of resorption and the biological effect on cells is the same (Huang et al., 2017).

2.3 Assessment of root resorption:

A lot of indices have been used to evaluate root resorption through history and amongst the most used ones is that developed by Malmgren's (1982) indexwhichclassifiedtheseverityof apical root resorption into 5 groups; grade 0: no signs of resorption, grade 1: mild resorption with normal root length, grade 2: moderate resorption with small area of root loss, grade 3: accentuated resorption almost 1/3 of root is lost, and grade 4: extreme resorption of morethan 1/3 of root length. (Figure 10)

Comparative assessment: This method involves taking intra-oral radiographs before treatment (T1) and another radiograph after de-bonding or at a certain period of treatment (T2) using bisecting angle technique or periapical with holder (Figure 11) on the same tooth and then compare the results using different methods such as digitizer technique (Levander et al., 1994). CBCT or DPT or lateral cephalometric radiographs could be used instead of intra-oral radiographs (Jiang et al., 2015) (Xu et al., 2010).

Analysis can be done on extracted teeth using the micro computed tomography x-ray system with customized software. Micro tomography allows the imaging of the internal micro structure with high resolution and the software reconstructs the complete internal micro structure of the root with 3D data This helps to decrease the need to take multiple radiographs with more precise and accurate results (Alamadi et al., 2017).

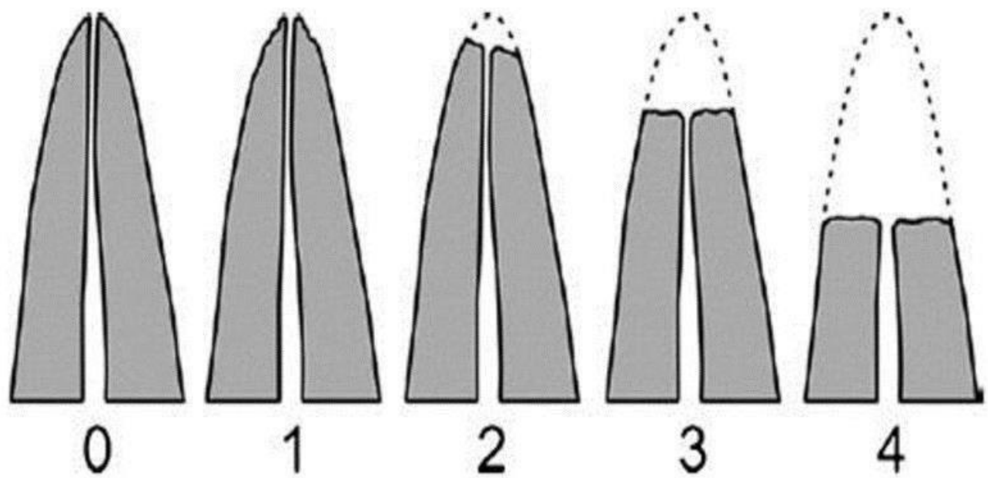

Figure 10: Index for assessment of root resorption showing five categories of root resorption (Malmgren et al.,1982)

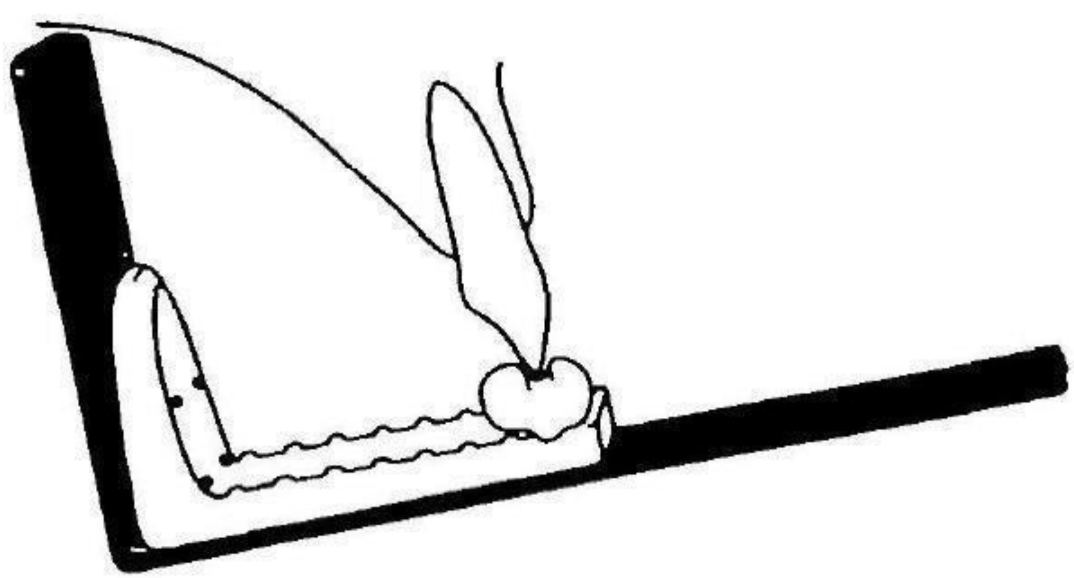

Figure 11: Periapical radiograph with film holder to have accurate and repeatable results (Levander et al., 1994).

2.4 Management of resorption:

Prediction of OIIRR is always difficult because it has multi factorial aetiologies; however, a recent retrospective study has shown that markers in blood and saliva can predict the susceptibility to root resorption because the salivary cytokines increase in moderate and severe root resorption cases (Yashin et al., 2017). These results seem to be promising but more investigations are needed. Before treatment patients must be informed about the possibility of root resorption. Levander and Malmgren (1988) recommended to take an x-ray on upper incisors every 6 to 9 months. Levander (1994) recommended that if root resorption is detected, treatment should be stopped for a 3-month pause and that modifications should be implemented to finish treatment as soon as possible. Periods of repair of cementum and bone have been observed after treatment. A specific cementum attached protein (CAP) has been reported to bind to mineralized root surface with the role of cementogenesis and cementoblast recruitment, but if the underlying mineralized dense cementum is resorbed, repair will not extend to these layers (Brezniak and Wasserstein., 2002). Owman-Moll and Kurol in 1998 compared the reparative cementum in resorptive craters between 2-3 weeks and 6-7 weeks and they observed that the longer the duration of retention the more the reparative process. At 2 and 3 weeks it showed 38% and 44% but at 6th week it showed 82% repair. Another study by Cheng in 2007 using micro computed tomography compared the reparative process after heavy and light forces for 4 and 8 weeks revealed that 1) Reparative process differs from one person to another, 2) The amount of applied forces also affect the reparative process as it only happens until the 4th week in light force in contrary to heavy forces which show reparative process after the 4th week.

We should consider that this study was done for only 4 weeks of force application which is not the case in clinical practice.

DISCUSSION

It is clear that the choice of OMI insertion site presents as a challenge due to the different possibilities encountered and the wide variety of possible locations. An appropriate selection would actually reflect a high standard quality of healthcare delivery to the patients presenting with different needs for anchorage reinforcement within their treatment planning scopes. A problematic location would hinder the effectiveness of orthodontic treatment through repeated failures. This would lead to a delay in treatment delivery process, might force a change to another method of anchorage reinforcement or even cause an associated complication. It is crucial to understand the anatomical limitations posed by the variety of possible locations for OMIs insertion taking into account the clinician's personal experience and the available evidence regarding this topic. This review attempted to provide a clinical guide to the selection of the best possible OMI insertion sites and an insight into those specific insertion site risk factors that might contribute to the failures of OMIs. A diagrammatic representation of the explored insertion sites in this review which is based on the quantitative pooling of the results is summarized (Figure 12).

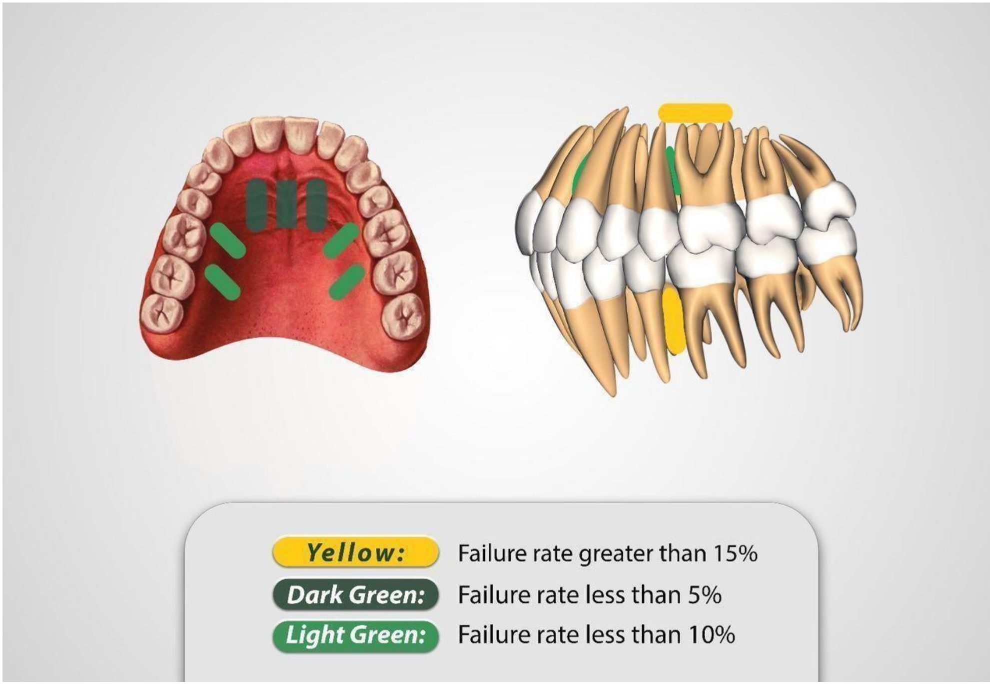

Figure 12: Diagrammatic representations of the explored insertion sites based on the results quantitative synthesis Classification according to origin and insertion: The classification of extra-dental intra-oral anchorage according to the origin incorporates firstly the systems that were developed from dental implants. These include palatal implants and retro- molar implants.8,9 Pre-drilling and a healing period for osteointegration are prerequisites of these systems before loading is achieved. The last entity in the category that is developed from dental implants is the on-plant, which was presented by Block and Hoffman.10

The second tributary in the classification includes the mini-plates,11-13 mini-implants14 and Aarhus mini-implants.15 These were developed from surgical screws, have smooth surfaces and are loaded immediately.

There are two methods of inserting mini-implants firstly self drilling and secondly self tapping. Self drilling mini-implant systems have cutting tips that make the pilot hole. On the other hand self tapping mini-implant systems need a pilot hole because they have a non-cutting tip. Self tapping systems are thought to be more advantageous than self drilling systems because in the self drilling type, a high pressure can be called for and this can cause compression of the bone which can further provoke bone resorption and sub-sequential failure.16,17

Uses of Mini-Implants: Since mini-implants have only gained international popularity in the last 15 years, their indications are not well registered. Most publications are case reports that portray new devices as alternatives to anchorage methods. E.g. Melson et al used patients with missing molars and performed retraction and intrusion of anterior teeth. The usage of mini-implants instead of headgear in extraction cases has also been reported18,19 and it is mentionable that for posterior tooth movement mini-implants have replaced other types of fixed appliances.20-22

Patients who can genuinely benefit from the usage of mini-implants are the ones in which traditional anchorage is impossible to obtain POJ 2010:2(2) 76-81 78 because of insufficient teeth. Also, in patients where the forces to the reactive unit would induce radical consequences, mini-implants are the chief aid for anchorage. If asymmetric tooth movement in all planes of space is needed in a patient TADs are utilized. Plus it is reported that borderline cases of orthognathic surgery can be avoided by their use. In some cases, a mini-implant can be used to develop bone through tooth movements, so that a prosthetic replacement can be provided.23

Contributing Factors to Mini-Implant Failure: It is documented that approximately 10% of all orthodontic mini-implants fail. This is a greater percentage than that of prosthetic dental implants because osteointegration is not achieved. The various factors that contribute to the failure include implant related factors, operator dependent factors and patient related factors.24–26

Implant related factors: The length of a mini-implant system is an important feature of its design. Previously it was proposed that the length of mini-implants should be at least 6mm but recently smaller ones have produced higher success rates.27

An appropriate diameter is also an integral part for the success of a mini-implant system. A diameter of 1mm or less resulted in failure of the mini-implants according to Miyawaki et al.28 It was put forward that a mini-implant of diameter 1.2mm-1.3mm was appropriate for insertion in the safe zones of the maxilla and the mandible. If the device is 2mm in diameter, it ought not to be determined secure for the placement in the posterior inter-radicular spaces of the maxilla, with the exemption of spaces between the first molar and the second pre-molar on the palatal side and between the canine and the first pre-molar.29 Mini-implants with a diameter of less than 1.5 mm were destined for tooth bearing areas, in particular the inter-radicular area.

Another prerequisite for the success of a mini-implant is that it should possess a smooth surface. If this is not the case, infection around the mini-implant could occur and lead to its failure.23

If the neck area of a mini-implant is not strong enough or if the mini-implant itself is too narrow there are chances that it might fracture when stress is applied on it. Hence a conical mini-implant with a strong neck and an appropriate diameter in relation to the quality of the bone is necessary if failure is to be avoided.30

Operator related factors: It is said that there is no match for experience. If the orthodontist exerts excessive pressure at the commencement of the insertion of mini-implants, it can lead to the fracture of the cutting tip. Therefore it should be kept in mind that the screw driver should not be ―wiggled‖ while extracting it from the mini-implant head. Intense heat generation in the pre-insertion drilling phase can account for local necrosis of bone and consequentially lead to failure of the mini-implant.30

When the mini-implant head has a bracket like slot, putting a ligature around it will render it hopeless for the patient to keep the mini-implant area free of inflammation. It is also noted that flap surgery causes a greater risk of infection whereas a flapless surgery is relatively more acceptable to the patient. A self drilling mini-implant system should be desired in a flapless procedure.23,28

Considering that mini-implants are used for absolute anchorage, it is worth mentioning the amount of forces that can be applied to them. The maximum force that can be withstood by a mini-implant system is 50N-450N. Delayed mobility may breed failure of a mini-implant system if overloading beyond 450N is performed.31 During placement, high torsional stress may cause implant bending or fracture or yield small cracks in the peri-implant bone. This can greatly influence mini-implant stability.32,33

In the factors that lead to the failure of mini-implant systems, the placement protocol is of fundamental concern for the orthodontist. Mini-implants should be placed in an area POJ 2010:2(2) 76-81 79 where the damage to related structures is unlikely and the anatomy is amicable for its long term success. It should not touch the dental roots as osteosclerosis, dentoalveolar ankylosis and even tooth vitality can be at stake because of injury to the roots.34,35 If only the periphery of the dental root is injured without the pulp being involved, the tooth's prognosis is not hindered.36

During placement in the maxillary posterior dento-alveolar, maxillary incisal and zygomatic regions, perforation of the nasal and maxillary sinuses can occur. If the maxilla is atrophic posteriorly there are greater chances of sinus perforation.37 Major veins and arteries should be avoided during placement of the mini-implant as well.

Long term stability of mini-implants consists of sufficient primary and secondary stability. Adequate primary stability is dependent upon appropriate cortical bone thickness. Therefore according to various authors mini-implants should not be placed in less than 0.5 mm to 1 mm of cortical bone thickness.38

It is noted by various authors that in orthodontic loading anchorage failure maybe 11% to 30%.39-42 Anchorage is related to bone density.43-45 If there is low bone density because of inapt cortical thickness, failure occurs.36 According to Hounsfield units (HU), bone density is divided into four groups, D1, D2, D3 and D4.46 It was stated by Sevimay et al47 that self drilling screws are ideal for D1 to D3 bone. Greater anchorage is achieved when mini-implants are inserted in D1 and D2 bone. Placing mini-implants into D4 bone is contraindicated due to a higher rate of failure.48,49 The chances of anchorage failure are higher in the maxilla due to greater trabeculae and lesser bone density44,50,51,53 (Figure 1).

If the cortical bone is not fully engaged during mini-implant placement, it can slide under the mucosal tissue along the periosteum bringing about mini-implant slippage. When an angle of 30o from the occlusal plane is used and immense forces are applied there are greater chances of mini-implant slippage.53

Figure 1: Bone Density Diagram (Courtesy Nel D. Kravitz and Budi Kusnoto)

If misplacement of the mini-implant in the retro-molar region, maxillary palatal slope or mandibular buccal dento- alveolus slope occurs, it can lead to nerve involvement or injury. However in cases where there is minor nerve damage, full recovery takes place in approximately six months.54

When air infiltrates the skin or the sub mucosa causing soft tissue distention, air subcutaneous emphysema occurs.55 If the clinician does not manage this properly and the treatment is not discontinued it could lead to mini-implant failure.

Patient related factors: The patient should be informed and educated of the advantages and disadvantages of the treatment and consent should be sought.

There are numerous factors that effect the insertion of mini-implants like poor oral hygiene, gingivitis, thick mucosa, application of force, post extraction healing etc.23,30

The contraindications of mini-implants include factors such as tobacco smoking, uncontrolled diabetes, arthritis, medication (immunosuppressants), gingivitis, periodontitis, reduced mouth opening, bone quality, and radiotherapy.3 POJ 2010:2(2) 76-81 80

About the root resorption, it is clear in the literature that RR occurs nearly in all orthodontic patients. Its exact cause in relation to different mechanics is still unclear. A precise understanding of this phenomenon is essential if we ever intend to provide high quality of care to our patients. This literature review included only RCTs in an attempt to eliminate any low quality evidence as RCTs are considered to be the gold standard of good quality research, however the majority of the studies evaluating RR for a fraction of the overall duration of the treatment will not reflect a realistic clinical setting. Certain mechanics may affect the final root length which in turn might result in loss of vitality or mobility of the tooth which will complicate the orthodontic treatment. It is crucial to understand the effect of every type of orthodontic movement and its related biological effects taking into account the available evidence regarding this topic and the clinician's experience. This literature review attempted to improve clinical practice and provide a clinical guide for the selection of the least problematic mechanics. Previous systematic reviews illustrated causes of RR in relation to different types of mechanics, however this review was strictly designed to include only RCTs. Moreover, this review did not only provide a qualitative analysis but a quantitative analysis was panned and undertaken detailing different orthodontic mechanics and types of forces utilized daily in every orthodontic practice.

Review identification:

This review investigated RR related to different mechanics used alongside fixed appliances. A systematic and a meticulous identification of the potentially relevant literature is a very important step as it paves the way for well-constructed review. The search strategy was customized for each search engine using individual keywords and MeSH terms and keywords from previous systematic reviews (Appendix 3.1). This strategy increased the chances of finding relevant articles. During the process of searching a large amount of literature was identified (2035) because the topic has an intensive research base due to its great importance in the field of orthodontics. After the removal of duplicates only (1688) remained and this can be expected as of the search was undertaken on four different databases which would guarantee detecting the same articles multiple times. The initial exclusion of large numbers of studies was due to the large number of animal studies, lab studies and case reports exploring this subject as they are easier and more convenient both ethically and detection of results. These studies were excluded as they were not compatible with the inclusion criteria. The search was performed only in English language with no search of the grey literature. There was no restriction on neither the publication date nor the study design.

Recommendations for clinical practice:

Results from this review could provide a guide for the proposed mechanics and expectations of the amount of RR during treatment. According to the available evidence within this review, high forces should be avoided during treatment. The highest amount of resorption was reported in jiggling, rotational, buccal tipping and intrusive movements respectively. On the other hand, extrusive and tip bends cause also RR but in lesser extent. Continuous forces cause more RR especially when activated every three weeks and one week in compare to intermittent forces which show a decrease in resorption however it increases treatment duration.

Also qualitative results had shown that arch wires, brackets, space closure mechanics (En-masse versus two step and tipping versus bodily movement), different mechanics of intrusion, previously traumatized teeth and fluoride. Had no difference in the amount of RR. On the other hand, traumatic occlusal forces and using one step of fixed appliances rather than two step of functional or head gear, resulted in more RR. It is orthodontist's responsibility to choose the best applied forces based on the results of this review. It also our responsibility to inform the patient about the risk factors associated with our choices.

CONCLUSIONS

1. Root resorption happen to all orthodontic patients with different extent due to biological response.
2. Heavy forces cause more OIIRR than light forces in particular with buccal tipping, rotational, jiggling forces, and intrusive movements.
3. Low quality evidence suggest that continuous forces may cause more OIIRR than interrupted forces.
4. Further high-quality studies are needed in this area.
5. OMIs present with different failure rates that vary accordingly with the specific location in which they are inserted.
6. The best insertion site for OMIs is in the midpalatal area and the least successful insertion site is in high up positions in the zygomatic buttress.
7. Root contact is a major risk factor that significantly contributes to the failure of OMIs inserted between the first molars and second premolars.
8. Future high quality research investigating this crucial area and reporting on various insertion sites altogether with a comprehensive reporting on the possible risk factors is needed.

Sites for orthodontics implants insertion

Palatal insertion sites:

All of the palatal insertion sites have demonstrated a lot of promise from the results of the synthesized data in this review. The nature of the palate itself makes it a simple but yet an effective choice for OMI insertion. The quality of the palatal bone altogether with the fact that it is away from tooth roots makes it a perfect choice for any clinician for an easy OMI insertion (Alsamak et al., 2014). The midpalatal insertion site demonstrated the lowest failure rates (1.3%) in this review. These results are logical taking into account the previously mentioned facts and that the midpalatal area offers a direct access for OMI insertion. On the other side, midpalatal OMIs could be criticized for their placement in younger individuals with immature midpalatal suture (Karagkiolidou et al., 2013). However the evidence within this subject only relies on animal studies and further studies are needed to clarify for this important aspect (Asscherickx et al., 2005). The paramedian insertion site fell behind the midpalatal region with a 4.8% failure rate rendering it to be effectively utilized as an alternative for the midpalatal region. This difference in the failure rates might be attributed to the anatomical differences between both of the midpalatal and paramedian region and the differences in the thickness of the soft tissues between both sites. Karagkiolidou and her colleagues (2013) reported a slightly lower failure rate than what was found in this review in their retrospective cohort study. The last palatal insertion site was the parapalatal area found at the lateral borders of the palate. This area could be effectively utilized for posterior segment intrusion especially with the low failure rates 5.2% found within this review (Yao et al., 2005). This area most notably had the highest failure rates within all explored palatal sites probably because of the proximity of the OMIs to the roots of the molars and premolars.

Maxillary buccal insertion sites:

Three buccal insertion sites were investigated in this review. The most popular insertion site lies in the interradicular space between the maxillary first molars and second premolars with more than thirty studies reporting on this insertion sites. This might be attributed to the simple and direct mechanics that could be utilized for incisor retraction when OMIs are inserted in this site making it the most popular insertion site amongst the included studies. The failure rate was noted to be 9.2% which is still regarded as an acceptable rate. The OMIs inserted between the maxillary canines and lateral incisors had an overall 9.7% which is highly comparable with the other interradicular insertion site previously mentioned. This higher failure rate from the palatal insertion sites would be attributed to the additional existence of dental roots. Other popular insertion sites for incisor intrusion are the interradicular spaces between the two maxillary central incisors. Only small sample sized studies reported on this insertion site and thus they were not included in this review (Al-Falahi et al., 2012; nayak et al., 2012). The least successful insertion site within this review was found for the zygomatic buttress. The zygomatic buttress could be defined as the pillar of cortical bone along the zygomatic process in the maxilla (Liou et al., 2004). This region suffered a failure rate which is greater than 16% and this might be attributed to the nature of soft tissues in this area and the harder accessibility to this region. The pooled results also manifested in a substantial heterogeneity which might be attributed to the placement of the OMIs between a surgical and a non-surgical placement method within the included studies (Liou et al., 2004; Viwatanatipa et al., 2009; Ge et al., 2012; Dawlatly et al., 2014).

Mandibular buccal insertion sites:

Only a single insertion site had sufficient studies to be pooled into a quantitative synthesis. The failure rate for the mandibular OMIs placed between the roots of the first molars and second premolars was 15.1%. This popular mandibular location utilized for incisor retraction in the lower arch suffered high failure which is consistent with previous reports indicating that the mandible suffers greater failures than the maxilla (Papageorgiou et al., 2012; Dalessandri et al., 2014).

Sarul and his colleagues (2015) reported an approximately 26% failure rates for OMIs inserted between the mandibular first and second molars. One study investigated the utilization of OMIs for lower incisor intrusion and inserted OMIs between the mandibular canines and lateral incisors (Aydogdu and Polat-Ozsoy., 2011). The author acknowledged the limited space within this area and utilized small length and diameter OMIs ending with approximately 8% failure. It is obvious that higher failure rates are consistent in the mandible when compared with the maxilla and this could be attributed to the nature of the cortical bone thicknesses between both jaws.

Risk factors:

There is a whole range of possible risk factors either related to the implant itself, the operator or the host (Chen et al., 2009; Cousley., 2013; Yi et al., 2016). Factors related to the insertion site present themselves as anatomical limitations or restrictions hindering the OMI placement into this specific region or place. The cortical bone density, proximity to the roots, proximity to vital structures (nerves, vessels, maxillary sinus) or the side of insertion could present themselves as potential risk factors affecting the success and failure of OMIs. Root contact was found to have an odds ratio of 13 of causing more failure to OMIs placed between the first molars and second premolars. This result presents not only as a statistically significant result but also with a huge clinical significance explaining the results obtained about the variability between the failure rates between the palate and other interradicular insertion sites. The influence of maxillary sinus perforation did not manifest itself to have a statistically significant value as only two small studies were pooled. OMIs on the right side demonstrated a higher failure rates than OMIs placed in the left side and this could be possibly explained that right handed operators might find it mechanically more comfortable to place OMIs in the left side. The other aspect might be that right handed patients themselves might be more comfortable brushing in the left side of the mouth thus better oral hygiene status would be prevalent in this side. However the results were not statistically significant and does not manifest as a clinically influential aspect. The results obtained for the data discussing the cortical bone thickness could not be pooled into a statistical quantitative synthesis due to the large existing heterogeneous methods and locations between the explored studies.

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