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The effect of drill-free and drilling methods on the stability of mini-implants under early orthodontic loading in adolescent patients

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SUMMARY The aim of this study was to compare the stability of mini-implants using drill-free and drilling methods, both before and after early force loading. Sixty-two adolescent patients (24 males and 38 females, mean age 15.7 ± 4.2 years) were randomly assigned to three groups and 112 titanium mini-implants were placed between the upper first molars and second premolars to achieve molar distalization. Groups I (n = 22) and II (n = 20) received pilot drilling with diameters of 1.1 and 0.9 mm, respectively, while the drill-free method was used in group III (n = 20). Distalization forces of up to 200 g were applied with nickel-titanium (NiTi) open coil springs. The Z-test was used for statistical analyses to compare the success rates of the groups with each other.

The overall success rate was 77.7 per cent. There was no significant difference between groups I and II either before or after loading. Significant differences were found between groups I and III (P = 0.0002) and between groups II and III (P = 0.045) both before and after loading. Mini-implants using the drill-free method provided the highest success rate before orthodontic force application and also maintained their stability after early loading for 1 month during orthodontic treatment. Smaller drill diameters can contribute to clinical stability of mini-implants in the short-term, however long-term evaluations are needed to clarify the stability of temporary skeletal anchorage devices throughout orthodontic loading.

Introduction

Anchorage control is fundamental to successful orthodontic treatment. Headgear has been considered as an effective form of orthodontic anchorage but depends on patient cooperation (Higuchi and Slack, 1991; Cheng *et al.*, 2004; Gelgör *et al.*, 2004). The requirement for orthodontic treatment modalities that provide maximal anchorage control and minimal compliance, especially for adults, has led to the application of implant technology in the orthodontic field (Favero *et al.*, 2002). These are osseous anchorage units that are not dependent on patient compliance, but good quality and quantity bone are necessary for their placement (Favero *et al.*, 2002; Deguchi *et al.*, 2003).

Mini-implants were introduced as temporary anchorage devices (TADs) in orthodontics for various purposes, such as canine, anterior and *en masse* retraction, molar uprighting, distalization, and protraction (Costa *et al.*, 1998; Lin and Liou, 2003). Their small size, simple placement procedure, short or no waiting period for orthodontic force application, no need for laboratory work, easy removal after orthodontic treatment, and lower costs are several advantages of mini-implants when compared with other TADs (Lin and Liou, 2003; Wang and Liou, 2008). Two types of mini-implants have been introduced. The predrilled mini-implant requires a pilot hole drilled before placement, whereas the self-drilling mini-implant is directly driven into the placement site without a pilot hole. Both remain in the placement site primarily by mechanical retention instead of osseo-integration (Costa *et al.*, 1998; Melsen and Verna, 1999). It has been reported that self-drilling mini-implants have less mobility and more bone-to-implant contact than predrilled mini-implants (Kim *et al.*, 2005). The response to self-drilling and predrilled mini-implants during early orthodontic force application in humans still remains questionable. Therefore, the purpose of this study was to evaluate the early stability of mini-implants using drill-free and drilling methods both before and after orthodontic force application.

Subjects and methods

A total of 62 adolescent patients (24 males and 38 females; mean age 15.7 ± 4.2 years) with 112 titanium mini-implants (Absoanchor; Dentos, Daegu, Korea) with a diameter 1.4 mm and body length of 7 mm were included in this study. They were selected from orthodontic patients who required upper molar distalization but who had refused extraoral anchorage because of aesthetic reasons. The inclusion criteria were Angle Class II malocclusion, no history of trauma, no significant medical history, no congenital anomalies, and no previous orthodontic treatment. All subjects were drawn from the same population. The study was approved by Gazi University Institute of Health Sciences. Informed consent was obtained from all patients prior to the start of the treatment procedures.

The study material was sourced from an original cohort of 69 adolescent patients; however, seven subjects were excluded due to the incomplete records. The final sample consisted of 62 patients. Group I (10 males and 12 females, mean age 15.2 years) had a pilot hole drilled with a drill of diameter 1.1 mm and group II (7 males and 13 females, mean age 16.1 years) with a diameter of 0.9 mm. The pilot holes were prepared with 30–40 degrees of angulation to the long axis of the teeth under saline irrigation with a contra-angle handpiece (1:20 speed reduction) rotating at 500 rpm. In group III (7 males and 13 females, mean age 15.4 years), self-drilling (drill-free) insertion was performed using a manual screwdriver.

All mini-implants were placed by the same clinician (MSA) between the buccal side of the upper first molars and second premolars. The proximity of the mini-implants to the roots and lamina dura was controlled by periapical radiographs and the presence of an adequate distance to the roots was confirmed as recommended by Kuroda *et al.* (2007b). After insertion, the patients received non-steroidal anti-inflammatory drugs (Naproxen sodium) and used a mouth rinse, including benzydamine hydrochloride and clorhexidine gluconate twice a day for 10 days. Additionally, the mini-implants were observed for 2 weeks to determine any signs and symptoms of inflammation before loading.

Orthodontic forces were applied by nickel-titanium (Ni-Ti) open coil springs 2 weeks after implantation (Figure 1). The success rates were evaluated before force loading and 1 month after the application of distalization forces of up to 200 *g*. Mini-implant failure was recorded when there was significant mobility that could not sustain the orthodontic force. For proportional comparison between groups, the *Z*-test was used for statistical analyses to compare the success rates.

Figure 1 Distalization mechanics with a nickel titanium open coil spring.

Results

The overall success rate was 77.7 per cent, ranging from 65 (group I) to 94 (group III) per cent (Table 1). Comparison of the success rates before orthodontic force application revealed no significant difference in groups I and II ($P = 0.38$), while in group III, the success rate was 100 per cent (Tables 1 and 2).

When the success rates after orthodontic force application over a 1 month period were compared, no statistically significant difference was found between groups I and II ($P = 0.54$), groups I and III ($P = 0.16$), or groups II and III ($P = 0.41$; Table 2).

At the end of the follow-up period, groups I, II, and III had success rates of 65.12, 77.14, and 94.12 per cent, respectively. Significant differences were found between groups I and III ($P = 0.0002$) and groups II and III ($P = 0.045$) when compared with each other. Comparison of groups I and II revealed no significant difference ($P = 0.24$; Table 2).

Discussion

The stability of mini-implants is a major consideration in treatment results (Park *et al.*, 2005). The current study was designed to compare drilling versus drill-free mini-implants in adolescent patients. The success rate for mini-implants has been reported to range from 37 to 97 per cent (Kim and Choi, 2001; Moon, 2002; Miyawaki *et al.*, 2003; Cheng *et al.*,

Table 1 Success rates of mini-implants before and after orthodontic force application in group I (drill 1.1 mm), group II (drill 0.9 mm), and group III (drill-free).

	Group I ($n = 22$)	Group II ($n = 20$)	Group III ($n = 20$)
Total number of mini-implants	43	35	34
Failure before force loading (%)*	8 (81.4)	4 (88.57)	0 (100)
Failure after 1 month (%)*	7 (83.72)	4 (88.57)	2 (94.12)
Total failure (%)*	15 (65.12)	8 (77.14)	2 (94.12)

*Values in brackets represent percentage success rates.

Table 2 Comparison of the success rates between group I (drill 1.1 mm), group II (drill 0.9 mm), and group III (drill-free)

	Before force loading	After force loading	Total
Groups I–II	0.38	0.54	0.24
Groups I–III	0.0018**	0.16	0.0002***
Groups II–III	0.034*	0.41	0.045*

$*P < 0.05$, $**P < 0.01$, $***P < 0.001$.

2004; Motoyoshi *et al.*, 2007). Various parameters such as age, gender, craniofacial skeletal pattern, site of implantation, loading protocol, dimension and angulation of the mini-implants, quality and quantity of bone, peri-implant tissue inflammation, mobility of soft tissues, and root proximity have been shown to play role in the stability of mini-implants (Costa *et al.*, 1998; Deguchi *et al.*, 2003; Miyawaki *et al.*, 2003; Cheng *et al.*, 2004; Kim *et al.*, 2005; Cho, 2006; Park *et al.*, 2006; Wilmes *et al.*, 2006; Kuroda *et al.*, 2007a, b; Motoyoshi *et al.*, 2007, 2009). Only a limited number of studies have investigated the effect of drill-free and drilling on the stability of TADs under early orthodontic loading (Kim *et al.*, 2005).

Wilmes and Drescher (2009) stated that primary stability of mini-implants is dependent on the predrilling diameter, insertion torque, and insertion depth. Tseng *et al.* (2006) reported that the length of the implant is related to the success rate and stated that the depth of insertion is more important than its location or length, the recommended depth being at least 6 mm. Chen *et al.* (2006) also found a significant difference in the length of mini-implants in relation to success rates. Deguchi *et al.* (2006) concluded that the appropriate length of mini-implants for safe insertion is approximately 6–8 mm. Therefore, a 7 mm mini-implant was chosen for the present study. The results revealed that the overall success rate was 77.7 per cent. Groups I and III and groups II and III showed statistically significant differences when compared with each other. The success rates were highest in group III, followed by groups II and I.

The stability of mini-implants depends on mechanical (device design and dimensions) and biological (bone quality, quantity, and time before loading) factors (Saito *et al.*, 2000; Deguchi *et al.*, 2003; Miyawaki *et al.*, 2003). Considering that mini-implant stability might have been achieved by mechanical interdigitation rather than osseointegration during the early healing period, bone quantity appears to be the main factor in the stability of TADs (Costa *et al.*, 1998; Miyawaki *et al.*, 2003). The density of cortical and cancellous bone in adolescents is less than in adults and mini-implant failures during orthodontic treatment are often observed (Park *et al.*, 2005). This might be due to the higher bone metabolism in growing children and to the lower maturation of bone, including the maxillofacial bones (Motoyoshi *et al.*, 2007). A significantly greater risk was found for the stability of mini-implants placed in younger patients in previous studies (Miyawaki *et al.*, 2003; Park *et al.*, 2005; Chen *et al.*, 2007; Motoyoshi *et al.*, 2007). The present research was performed on adolescent patients where their growth potential might have contributed to the failure of mini-implants.

A 100 per cent success rate was observed in group III in the 2 weeks before loading, representing excellent initial contact with cortex and cancellous bone. However, in groups I and II, failure of mini-implants was observed prior to loading. During the drilling process, the soft tissues are traumatized by the rotating instruments. Although oral rinses were prescribed, this initial process might have caused inflammation in both groups. Therefore, resorption of the cortex might have occurred. In addition, the drilling procedure might have led to heat-induced bone tissue injury during dental implant site preparation (Eriksson and Albrektsson, 1983; Benington *et al.*, 2002). Excessive heat might have occurred on the cortex of the bone. This is the main basis for bone resorption around implants. Although all surgical procedures were carried out by the same researcher, excessive pressure might have been applied to the contra-angle driver resulting heat generation.

Irrigation during drilling prevents excessive heat on the cortex (Eriksson and Albrektsson, 1983; Benington *et al.*, 2002). In the present study, all drills were used with external cooling. Saline irrigation may also be applied with internal cooling passing through the pilot drill. Both internal and external cooling with saline irrigation is recommended. Furthermore, to avoid the side-effects related to the use of drills, a self-drilling technique is recommended for maximum success.

It has been reported that drill-free screws can result in high initial stability due to less bony damage compared with those that require drilling (Kim *et al.*, 2005). Increased levels of bone preservation and bone-implant contact are the advantages of drill-free screws that could reduce mobility of screws under early orthodontic loading. With regard to the high success rates observed in the drill-free group in the present study, the results are consistent with the findings of Kim *et al.* (2005). Drills with relatively large diameters might lead to microfracture of bone between the threads, thereby inducing bony necrosis (Kim *et al.*, 2005). In the present study, although no statistically significant difference was found between groups I and II before or after loading, the higher success rate in group II might indicate clinical benefits during treatment if a thinner drill causes less microfracture in bone.

Conclusions

Mini-implants inserted using the drill-free method provide the highest success rate before orthodontic force application and also maintain their stability during a period of 1 month after early force loading. Smaller drill diameters can contribute to clinical stability of mini-implants in the short-term, however evaluations are needed to clarify long term stability.

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