Removal Torque of Miniscrews Used for Orthodontic Anchorage—A Preliminary Report

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Purpose: *Implant anchors such as miniscrews and miniplates have been loaded immediately for anchorage during orthodontic treatment. The purpose of this study was to measure the removal torque of immediately loaded miniscrews after clinical usage and to determine the possible factors associated with this value.* ***Materials and Methods:*** *From 29 patients with malocclusions, 46 miniscrews were removed, and removal torque was measured with a torque gauge. Removal torque values were subjected to statistical analysis for possible association of different clinical characteristics.* ***Results:*** *The mean removal torque value was 1.10 kg·cm, and removal torques for 50% of the implants were greater than 0.89 kg·cm (8.7 N·cm). Removal torque values were significantly higher in the mandible than in the maxilla. The removal torques of 15-mm and 17-mm miniscrews were significantly higher than those of 13-mm miniscrews. Therefore, the site of implantation and miniscrew length were important factors associated with removal torque. However, there was no significant correlation between the removal torque value and age, gender, healing time, or time in function.* ***Discussion:*** *When miniscrews are used as anchorage for uprighting tipped molars, excessive torque in a counterclockwise direction may loosen them. From the measurements obtained in this investigation, miniscrews can sufficiently sustain an uprighting moment.* ***Conclusion:*** *The removal torque values of the majority of miniscrews in this study population when loaded immediately as orthodontic anchorage were greater than 0.89 kg·cm, and this was sufficient for these implants to fulfill their purpose as anchors in 3-dimensional tooth movements.* INT J ORAL MAXILLOFAC IMPLANTS 2006;21:283–289

Key words: *dental implants, miniscrews, osseointegration, removal torque*

Recently, mini-implants have been widely adopted for anchorage control during orthodontic treatment.[1–7] With this skeletal anchorage, a wider range of tooth movements can be achieved without patient compliance, including intrusion, retraction, protraction, and uprighting.[6–11] Moreover, immediate loading of these mini-implants after initial wound healing can provide treatment efficiency without compromising the duration of their use as orthodontic anchorage. Therefore, especially in mutilated dentition where no anchoring teeth are available for orthodontic tooth movement, and in adult patients who cannot wear extraoral auxiliaries because of social demands or working schedules, mini-implants may provide a solid foundation for successful orthodontic treatment.

Development of the use of implants for orthodontic anchorage was initiated in 1945 by Gainsforth and Higley,[12] who attempted to use implants to move canines in dogs but failed. Later, the development of modern implants and the success of immediately loaded transitional endosseous implants led to their application as orthodontic anchorage.[13,14] Because of

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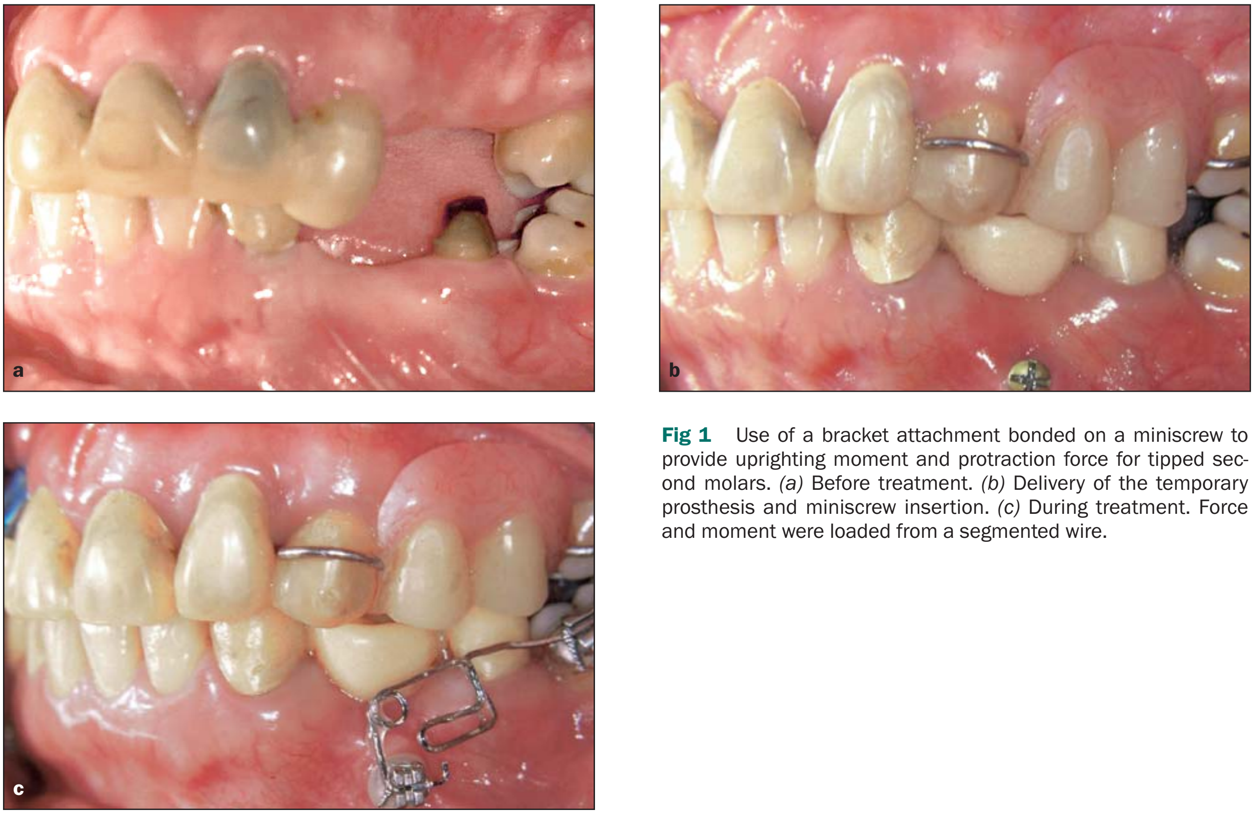

Fig 1 Use of a bracket attachment bonded on a miniscrew to provide uprighting moment and protraction force for tipped second molars. *(a)* Before treatment. *(b)* Delivery of the temporary prosthesis and miniscrew insertion. *(c)* During treatment. Force and moment were loaded from a segmented wire.

their versatility, ease of placement and removal, low cost compared to conventional dental implants, and ability to withstand immediate loading after wound healing, the use of mini-implants has become popular in modern clinical orthodontics.[14] Mini-implants tailored for orthodontic needs also have been developed. Costa and colleagues described a specially designed implant with an arch wire slot on the screw head for use with an arch wire connecting the implants for better control of tooth movement in all 3 dimensions.[3] Other designs with different attachments are also emerging on the market.[6,7,15]

Though an increasing number of reports have indicated that these immediately loaded implants can provide good anchorage control, removal torque, a reference for the magnitude of osseointegration of conventional implants, has never been studied for miniscrews used for orthodontic anchorage. However, removal torque has been frequently evaluated in animal models. Only a few reports on human subjects,[14,16,17] including Simon and Caputo's analysis of removal torques for transitional implants, are available.[14] The purpose of this study was to examine the removal torque of miniscrews used in orthodontic patients and to explore the correlation between removal torque and other clinical variables.

MATERIALS AND METHODS

The sample consisted of 46 miniscrews applied to 29 Chinese subjects, 25 women and 4 men, who had undergone the placement of miniscrews and orthodontic treatment in the authors' department from 2001 to 2003. Patient age ranged from 18 to 53 years, with a mean ± SD of 28.4 ± 9.2 years. There were 16 cases of class I malocclusion, 10 of class II, and 3 of class III. Five of the 29 patients had treatment with partial fixed appliances to achieve local orthodontic tooth movement. The other 24 patients had comprehensive full-mouth fixed appliances to correct the malocclusion.

The miniscrews were titanium bone screws designed for use for fixation of fractures in craniofacial regions from Mondeal (Tuttlingen, Germany) or Leibinger (Freiburg, Germany). They were 2 mm in diameter and 11, 13, 15, or 17 mm in length (and, in the case of 1 mandibular implant, 7 mm). They provided sufficient orthodontic anchorage to achieve various orthodontic treatment goals, including anterior teeth retraction, posterior teeth protraction, molar intrusion, and uprighting (Fig 1). The miniscrews were implanted buccally in the posterior alveolar crest. All 46 miniscrews remained stable without significant mobility

Fig 2a Instrument for measuring removal torque.

Fig 2b Miniscrew removal.

throughout the course of treatment. The average lag time from placement to loading (ie, the average healing time ± SD) was 9.46 ± 8.23 weeks. The mean period of implant function (± SD) as an anchorage unit in the mouth (defined as time in function) was 14.67 ± 7.53 months. When it was determined by senior instructors that the miniscrews were no longer needed for orthodontic anchorage, they were removed by 1 author with the torquing gauge. Under local anesthesia, the manual screwdriver was connected to a torque gauge manometer (Torque gauge model 6BTG; Tohnichi Tokyo, Japan) (Fig 2a) and the maximal torque required to loosen the miniscrew was registered (Fig 2b).

The removal torque values and other clinical variables were recorded in Microsoft Excel (Microsoft, Redmond, WA) and analyzed with the SPSS statistical package program for Windows (version 10.0; SPSS, Chicago, IL). The removal torque values were expressed as the means with standard deviation relevant to each clinical variable. To investigate the statistical significance of group difference, the data were subjected to Student *t* test or analysis of variance (ANOVA). Post-hoc comparisons of means were performed using the Scheffé test. *P* values less than .05 were considered significant.

RESULTS

A summary of the removal torque values and number of miniscrews relevant to various clinical variables is presented in Table 1. The mean removal torque for the 46 miniscrews was 1.10 kg·cm (range, 0.24 to 2.15 kg·cm) (Fig 3). No significant differences were found between the miniscrews with respect to gender or age groups if the grouping of age was cut off at 30 years. There were also no significant differences in removal torque among the miniscrews used for different types of tooth movements, including

Table 1 Removal Torque Values Means ± SDs and No. of Miniscrews

Variable/group	Removal torque (kg • cm)	No. of miniscrews
Total	1.10 ± 0.52	46
Gender		
Male	0.91 ± 0.40	7
Female	1.14 ± 0.53	39
Age		
> 30 y	1.25 ± 0.52	14
≤ 30 y	1.04 ± 0.51	32
Purpose of anchorage		
Retraction	1.10 ± 0.49	36
Intrusion	1.01 ±0.56	4
Uprighting	1.25 ± 0.49	2
Protraction	1.20 ± 0.35	2
Location of miniscrew		
Side		
Left	1.06 ± 0.56	25
Right	1.16 ± 0.47	21
Quadrant		
Maxillary right	1.03 ± 0.41	16
Maxillary left	0.88 ± 0.53 *	16
Mandibular left	1.45 ± 0.46 *	8
Mandibular right	1.46 ± 0.51	6
Jaw		
Maxilla	0.96 ± 0.47 **	32
Mandible	1.45 ± 0.47 **	14
Length of miniscrew (mm)		
11	1.41 ± 0.55	4
13	0.75 ± 0.44 *	12
15	1.23 ± 0.50 *	22
17	1.15 ± 0.46	8
≤ 13	0.91 ± 0.54	16
≥ 15	1.21 ± 0.49	30

**P* = .046 (post-hoc Sheffé test).
***P* = .002 (Student *t* test).

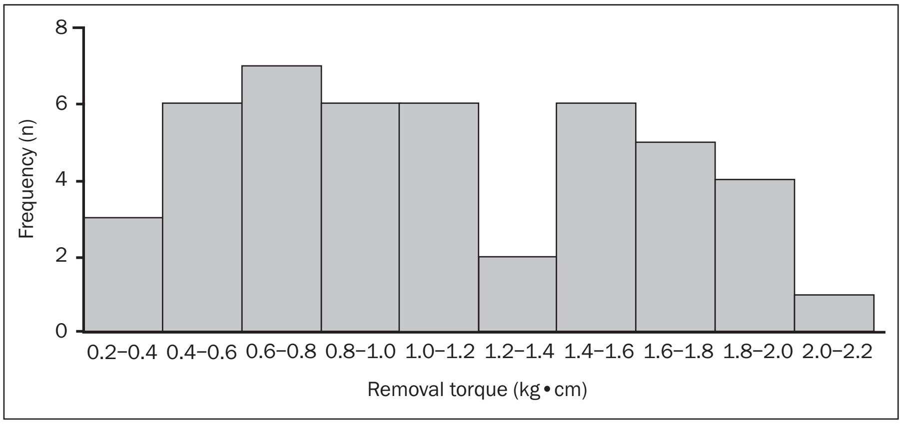

Fig 3 Distribution of removal torque values (n = 46).

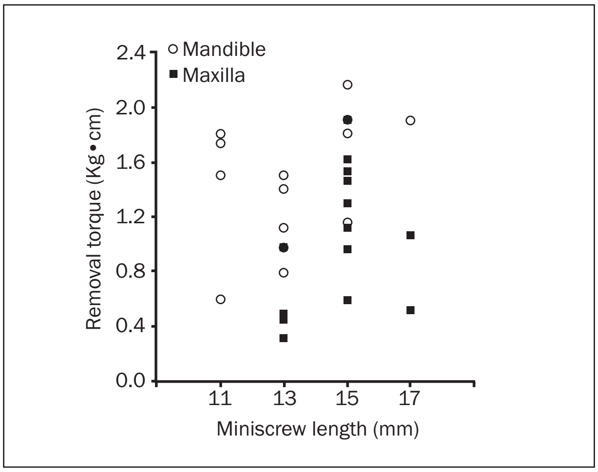

Fig 4 Scatter-plot of removal torque values of miniscrews in maxilla and mandible.

intrusion, uprighting, protraction, and retraction (the most common type of anchorage used in this study).

Implant location (side, quadrant, and jaw) was also considered and subjected to analysis. There was no significant difference between miniscrews placed on the left side and those on the right side. With respect to different quadrants for miniscrew placement, a significant difference between the maxillary left quadrant and the mandibular left quadrant was detected by 1-way ANOVA ($P = .018$) and post-hoc Scheffé test ($P = .046$).

The mean removal torque value of miniscrews in the maxilla (0.96 ± 0.47 kg·cm) was significantly lower compared to that in the mandible (1.45 ± 0.47 kg·cm) ($P = .002$). To investigate whether screw length affected their removal torque, the miniscrews were grouped according to length (11, 13, 15, or 17 mm). A significant group difference was detected by 1-way ANOVA ($P = .031$). The post-hoc Scheffé test revealed that the removal torque value for 13-mm miniscrews (0.75 ± 0.44) was significantly lower than that for 15-mm miniscrews (1.23 ± 0.50) ($P = .046$). The scatter-plot (Fig 4) demonstrated that the length of miniscrews placed in the maxilla was equal to or greater than 13 mm. Shorter miniscrews were used only in the mandible. Moreover, the tendency toward lower removal torque in the maxilla can be seen across various screw lengths in Fig 4.

Results of 2-way ANOVA also revealed that both miniscrew length and jaw of implantation were significant variables determining the removal torque value of miniscrews. However, the effect of interaction between these 2 variables did not reach the level of statistical significance. Figs 5a and 5b provide the mean and error-bar plots of removal torque values for miniscrews in the maxilla and mandible, respectively. In the maxilla, removal torque for 13-mm miniscrews (0.45 ± 0.24 kg·cm) was significantly lower than those of 15 mm (1.12 ± 0.45 kg·cm) ($P = .003$) and 17 mm (1.04 ± 0.37 kg·cm) ($P = .033$) (Fig 5a). As for the mandible, a 7-mm miniscrew was ignored because of limited sample size. Removal torque in the 13-mm group (1.15 ± 0.30 kg·cm) was lower than those of 11 mm (1.41 ± 0.55 kg·cm) and 15 mm (1.75 ± 0.43 kg·cm) (Fig 5b). However, no statistically significant difference was noted among these 3 groups (1-way ANOVA, $P = .093$). A wider range of removal torque values was observed in the mandible compared to the maxilla.

To discern whether osseointegration would be more complete if more healing time was provided before loading, leading to higher removal torque, the mean healing time (9.46 ± 8.23 weeks), mean time in function (14.67 ± 7.53 months), and their correlation with removal torque were analyzed and found to have no significance.

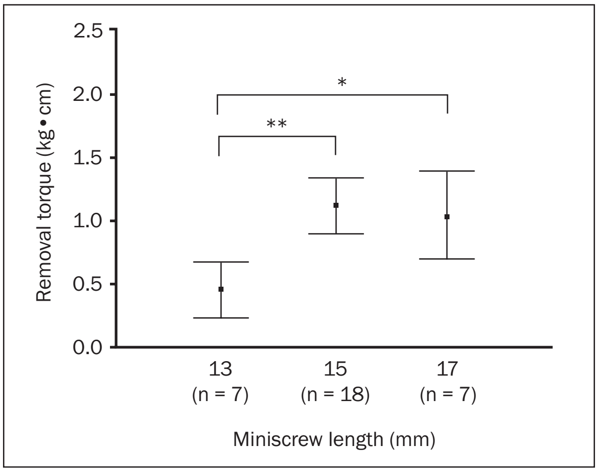

Fig 5a Error-bar plot of removal torque values of miniscrews in the maxilla (mean ± SD). *P = .033. **P = .003 (1-way ANOVA and Scheffé test).

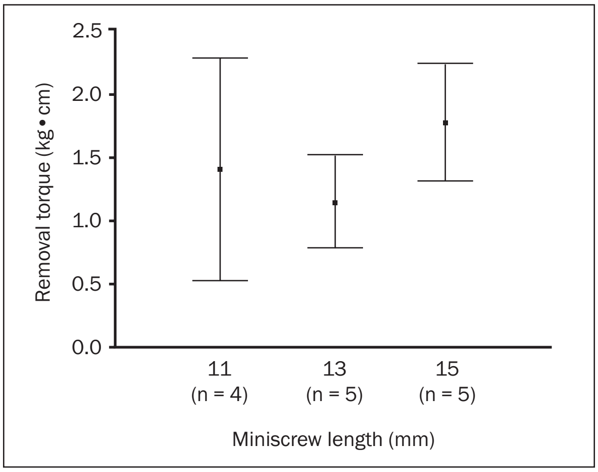

Fig 5b Error-bar plot of removal torque values of miniscrews in the mandible (mean ± SD).

DISCUSSION

The removal torque of miniscrews loaded immediately for orthodontic anchorage was successfully measured. The range of the values was 0.24 to 2.15 kg·cm, and the scatter-plot pattern indicated the variability of removal torque. Removal torque has been considered an indicator of the extent of osseointegration in implant research. Sullivan and associates[17] studied the removal torque of pure titanium screw-type implants and indicated that osseointegrated implants should have a removal torque greater than 20 N·cm. In Simon and Caputo's study, 55% of the implants demonstrated a removal torque greater than 20 N·cm; the minimum removal torque observed was 10.5 N·cm.[14] In the present study, 50% of the implants had a removal torque above 0.89 kg·cm (8.7 N·cm), which is below those values mentioned previously. Therefore, the degree of osseointegration of these immediately loaded miniscrews was relatively low, and the interaction of bone and mini-implant was likely to be mainly mechanical interlocking. The other reason why the removal torque was low in the present study may be the thinness of the dentoalveolar bone. A study by Niimi and coworkers[18] found that removal torque was significantly correlated with the thickness of cortical bone when implants were placed in fibula, iliac crest, or scapula in cadavers.[18] However, they also demonstrated that the value of removal torque did not correlate with the total thickness of the bone, but only with cortical bone thickness.[18]

There was no correlation found between removal torque and patient gender or age. However, the patients receiving miniscrews for orthodontic anchorage were predominantly young females in this clinical population. Therefore, a larger study population should be gathered and analyzed to clarify this issue.

Regarding the length of miniscrews, theoretically, longer implants should have a greater contact surface area with alveolar bone, resulting in higher removal torque. However, Simon and Caputo[14] did not find a correlation of the length of transitional implants and removal torque. In the present study, the miniscrews were separated into 4 groups by length (11, 13, 15, and 17 mm), and the analysis indicated that miniscrew length was a significant determinant of removal torque, especially in the maxilla.

As for the effect of arch and position of placed miniscrews, miniscrews in the mandible had significantly higher removal torque than those in the maxilla. This finding is consistent with the studies of Simon and Caputo[14] and Carr and coworkers.[19] In Simon's study, transitional implants placed in the mandible demonstrated higher removal torque than those placed in the maxilla, suggesting more effective osseointegration of implants placed in the mandible. Carr and associates also found greater torque failure levels for unloaded implants placed in the mandibles of baboons than for those placed in baboon maxillae. Moreover, in a report by Truhlar and colleagues[20] assessing 2,839 implants with radiographs and tactile sensation, type 2 bone dominated the mandible, and type 3 bone was more prevalent in the maxilla (based on Lekholm-Zarb classification system[21]). Therefore, with better bone quality and thicker cortical bone, implants placed in the mandible should have higher removal torque than those placed in the maxilla.

When samples were separated by quadrant (maxillary right, maxillary left, mandibular left, mandibular right), there were significant differences between the maxillary left and mandibular left quadrants. Clinically, it could be perceived that the moment from a cantilever applying intrusive force to molars on the maxillary right and the mandibular left quadrants in a counterclockwise direction had the potential to loosen the screws; in the maxillary left and the mandibular right quadrants, force was applied in a clockwise direction, which may have tightened the screws. However, those samples being loaded with moments were not selected and analyzed because of the limited number of samples loaded in this fashion.

Removal torque is associated with the extent of bone-implant contact. Johansson demonstrated that removal torque increased with time postplacement when implants were placed in the tibiae of rabbits.[22] Simon and Caputo also found that mean torque values increased with time in function.[14] From radiographic studies, it was assumed that continued osseointegration on the surface of implants persisted 2 years postplacement.[23] Based on these studies, premature loading should be avoided, since bone-implant contact could further develop with time. For mini-implants used for orthodontic anchorage, immediate loading was performed after initial wound healing. Therefore, it was not surprising that no correlation between removal torque and healing time or time in function was detected, since sufficient time for osseointegration was not allowed in any case. Other factors such as the smooth-surfaced implants used,[24] and loading in a direction lateral but not vertical to the long axis of the implant could also have affected the development of osseointegration. Therefore, the miniscrews in the present study may have been stabilized by way of "mechanical retention" rather than osseointegration.

It has been suggested that a waiting period for bone healing is unnecessary for miniscrews to sustain normal loads of orthodontic forces.[25,26] In a cephalometric study, Liou and colleagues[25] indicated that a miniscrew can be a stable anchor for orthodontic tooth movement despite the fact that it does not remain absolutely stationary. The miniscrews assessed in the present study were clinically stable throughout the treatment course and successfully fulfilled the treatment goals, which mostly involved the retraction of anterior teeth.

The load on miniscrews for tooth uprighting is theoretically greater than that used for retraction, which is often unidirectional and without torque. In clinical orthodontic research, Majourau and coworkers[27] demonstrated that a second molar could be uprighted efficiently with 50 gm of force on an uprighting spring of 30 mm length, ie, 1,500 gm·mm force moment.[27] The present results showed that 50% of the miniscrews reached removal torque of 0.89 kg·cm, ie, 8,900 gm·mm. Though variable levels of removal torque were found among these miniscrews in this study, the value of the removal torque should be sufficient to provide the moment needed for 3-dimensional control of tooth movement. Therefore, osseointegration may not be required for these mini-implants to function as orthodontic anchorage. With sufficient removal torque, the miniscrews could be loaded for posterior tooth uprighting by applying a cantilever spring from the posterior teeth to the miniscrew, on which a bracket is bonded for 3-dimensional control of tooth movement. However, whether long-term loading of these uprighting moments would predispose these miniscrews to fail awaits further investigation.

The stability of miniscrews for orthodontic anchorage has received more study with increased miniscrew usage. Miyawaki and coworkers[26] investigated the stability of titanium screws placed in buccal alveolar bone for orthodontic anchorage. They reported that inflammation of peri-implant tissue and high mandibular plane angle, which often exists with thin cortical bone, were risk factors for screw mobility. The risk factors associated with failure of mini-implants used for orthodontic anchorage in the authors' department have been previously reported.[28] The independent prognostic indicators identified were anatomic location and peri-implant soft tissue character. Moreover, two thirds of the failures occurred before orthodontic loading or within 1 month after loading. Failure of miniscrews in the posterior mandible was found to be associated with peri-implant inflammation. Miniscrews in the buccal alveolar region of the posterior mandible are susceptible to inflammation because of limited keratinized mucosa. Overheating is also likely to occur during miniscrew placement in the posterior mandible because of the higher bone density. The present study demonstrated higher removal torque of miniscrews placed in the posterior mandible than in the posterior maxilla. It is implied that bone density may be an important factor affecting removal torque of miniscrews as long as their survival is not compromised by peri-implant inflammation or tissue destruction caused by overheating.

CONCLUSION

These results indicated that the removal torque values for the majority of these miniscrews when loaded immediately as orthodontic anchorage and successfully used for 3-dimensional tooth movement were greater than 0.89 kg·cm (8.7 Ncm). The removal torque values were higher when the miniscrews were placed in the mandible compared to the maxilla. Miniscrew length was also a significant determinant in removal torque values, especially in the maxilla. The removal torque of 13-mm miniscrews was significantly lower than those of 15-mm and 17-mm miniscrews. However, there were no significant correlations between the removal torque of miniscrews and patient age, gender, healing time, or time in function. The stability of the implants measured in this study was sufficient for these implants to fulfill their purpose as anchors in 3-dimensional tooth movements.

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