Insertion torque values and success rates for paramedian insertion of orthodontic mini-implants

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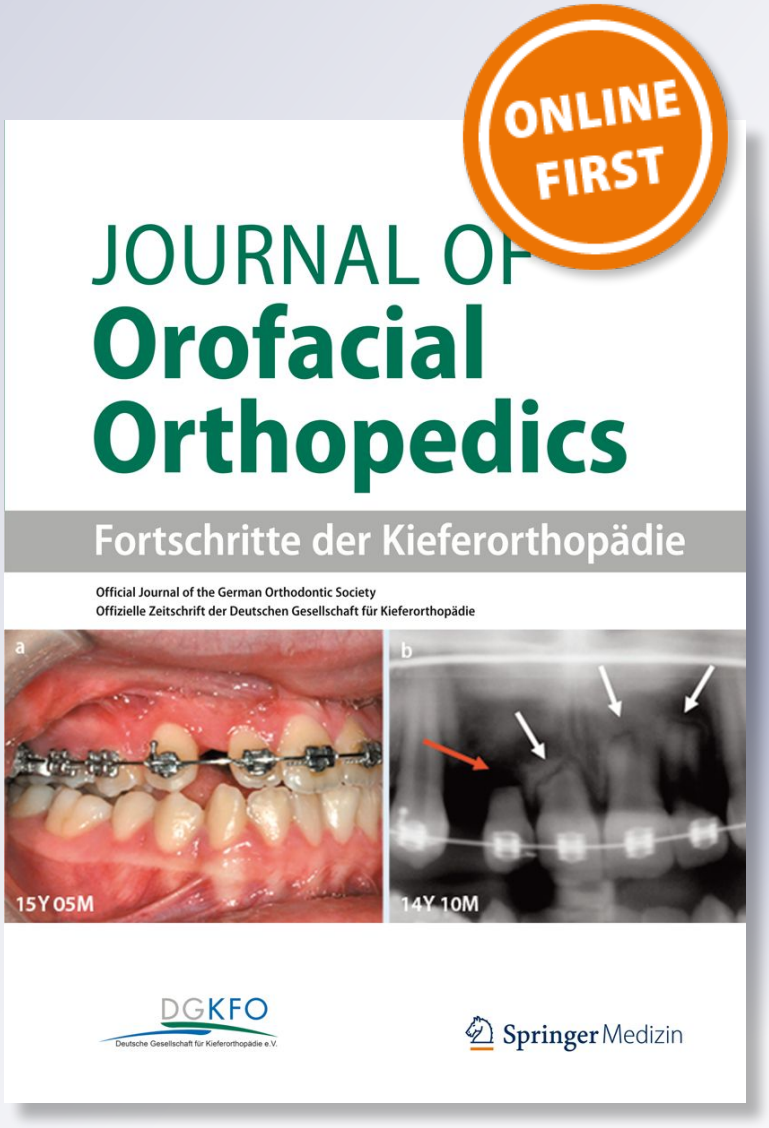

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ORIGINAL ARTICLE

Insertion torque values and success rates for paramedian insertion of orthodontic mini-implants

A retrospective study

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Abstract

Objectives Orthodontic mini-implants (OMIs) are a reliable method to provide temporary orthodontic anchorage. We hypothesized that there is an optimal insertion torque (<10 Ncm) that can be used to ensure the success of self-drilling OMIs in the paramedian region.

Patients and methods Included were 40 (26 females, 14 males) consecutive patients requiring palatal skeletal anchorage. Mean age was 17.3 years (range 11.0–44.6 years) for female patients and 15.7 years (range 10.6–36.9 years) for male patients. A total of 22 patients received a Beneslider according to Wilmes for the distalization of maxillary first molars, 10 patients received a Mesialslider for the mesialization of maxillary first molars, and 8 patients received a bone-borne rapid palatal expansion (RPE) appliance. Torque values of 10–15 Ncm were recorded in 46.3% of the OMIs and 15–20 Ncm in 35% of OMIs. OMIs that endured the orthodontic force applied for ≥6 months were considered as success.

Results The overall success rate was 98.8%. No significant differences were found between insertion torque values with respect to the right and left sides, Jarabak's ratio, facial axis, and Frankfort to mandibular plane angle. There were no significant differences in the OMIs insertion torques with regard to the different appliances. No association was found between insertion torque and vertical skeletal morphology.

Conclusion With an overall success rate of 98.8%, the study hypothesis that greater insertion torque (>10 Ncm) will decrease the success rate and increase palatal OMI failure was rejected.

Keywords Orthodontic mini-implants · Insertion torque · Success rate · Skeletal anchorage · Anterior palate

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Insertionsdrehmoment und Erfolgsrate paramedian inserierter kieferorthopädischer Mini-Implantate

Eine retrospektive Studie

Zusammenfassung

Zielsetzung Kieferorthopädische Mini-Implantate (OMIs) stellen eine verlässliche Methode dar, um eine temporäre kieferorthopädische Verankerung zu gewährleisten. Wir stellten die Hypothese auf, dass es für paramedian inserierte selbstbohrende OMIs ein optimales Insertionsdrehmoment (<10 Ncm) gibt.

Patienten und Methoden Vierzig (26 w, 14 m) konsekutive Patienten, bei denen eine skelettale Verankerung im Gaumen erforderlich war, wurden in die Studie aufgenommen. Das Durchschnittsalter lag bei 17,3 (11,0–44,6) Jahren für die weiblichen bzw. 15,7 (10,6–36,9) für die männlichen Patienten. Insgesamt 22 Patienten erhielten einen Beneslider nach Wilmes zur Distalisation der ersten Oberkiefermolaren, 10 erhielten einen Mesialslider zur Mesialisation der ersten Oberkiefermolaren und 8 eine knöchern verankerte Apparatur zur forcierten Gaumennahterweiterung (GNE). Bei 46,3% der OMIs wurden Drehmomente von 10–15 Ncm registriert und bei 35% Werte von 15–20 Ncm. Als Erfolg wurden die OMIs gewertet, die der für ≥6 Monate applizierten kieferorthopädischen Kraft standhielten.

Ergebnisse Insgesamt lag die Erfolgsquote bei 98,6%. Er ergaben sich keine statistisch signifikanten Unterschiede zwischen den Drehmomenten in Bezug auf den Jarabak-Index, den Gesichtsindex oder den FMPA (Winkel zwischen Frankfurter Horizontalen und Mandibularebene, FH-MP), auch nicht zwischen den beiden Seiten. Es ließen sich keine signifikanten Unterschiede zwischen OMI-Drehmoment-Werten im Hinblick auf die verschiedenen Apparaturen feststellen. Zwischen Insertionsdrehmoment und vertikaler skelettaler Morphologie fand sich ebenfalls kein Zusammenhang.

Schlussfolgerung Bei einer Erfolgsquote von insgesamt 98,8% wurde die Hypothese, dass höhere Drehmomente bei der Insertion(>10 Ncm) die Erfolgsrate verringern und die Versagensquote palatinaler OMIs erhöhen, verworfen.

Schlüsselwörter Orthodontische Mini-Implantate · Drehmoment · Erfolgsrate · Skelettale Verankerung · Vorderer Gaumen

Introduction

Orthodontic mini-implants (OMIs) have become a reliable method for providing temporary orthodontic anchorage [28]. Because of high success rates [1], palatal sites are increasingly used in clinical practice [44]. Areas bilateral to the median suture immediately posterior to the palatal rugae are suitable regions for the insertion of palatal OMIs due to the available bone [9–11, 37].

OMI-anchored appliances for upper molar distalization and mesialization have been described. Either median or paramedian insertion sites can be chosen for those purposes, whereas appliances for rapid palatal expansion (RPE) require paramedian insertion of OMIs [6, 38, 43]. Due to their mode of action, appliances for distalization and RPE exert intrusive forces on the OMIs, whereas appliances for mesialization exert extrusive forces.

Besides other factors, it is known that the OMI insertion torque can influence both success and failure rate [4, 33]. Suzuki et al. [33] reported a higher failure tendency with insertion torque figures greater than 10 Ncm. Motoyoshi et al. [21] recommended insertion torque between 5 and 10 Ncm, whereas Chaddad et al. [4] found higher success rates at torque values greater than 15 Ncm.

It was stated by Motoyoshi et al. that bone thickness correlated positively to the OMI's stability and success rate [22]. It was already described that cortical bone was thicker in hypodivergent patients than in hyperdivergent patients [7], especially with respect to buccal and lingual sites, and hence might affect insertion torque values. This suggests that the patient's craniofacial morphology ought to be considered clinically using pretreatment cephalograms.

In vitro studies [17, 34] evaluated OMI insertion torques utilizing sophisticated laboratory setups. In vivo data have been published about the insertion torque magnitude for palatal OMI placement [24, 26]. However, additional equipment which is not standard in a typical practice was employed in these studies. Furthermore, the clinician typically relies on a torque-controlled surgical drive where different insertion torque levels can be preselected.

We hypothesized that there is an optimal insertion torque that can be used to ensure the success of OMIs. Therefore, the aims of this study were (1) to analyze the insertion torque values for self-drilling OMIs in the paramedian region, (2) to reveal possible correlations between insertion torque and vertical skeletal morphology, and (3) to test the hypothesis that an insertion torque >10 Ncm will increase OMI failure.

Fig. 1 Beneslider used for distalization of upper first molars
Abb. 1 Beneslider zur Distalisation der oberen ersten Molaren

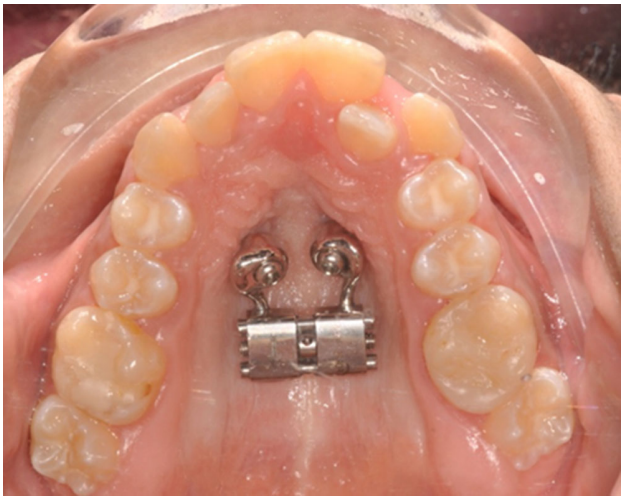

Fig. 3 Bone-borne appliance for rapid palatal expansion
Abb. 3 Knochengetragene Apparatur zur forcierten Gaumennahterweiterung

Patients and methods

Patient selection and inclusion criteria

Ethical approval for this retrospective study was granted by the institutional review board (Verbal no. 75, Date 12/12/2016, University of Trieste, Italy). In all, 40 (26 females, 14 males) consecutive patients treated in a private orthodontic practice with palatal skeletal anchorage were included. All OMIs were inserted between April 2015 and October 2016. Mean age was 17.31 years (range 11.01–44.63 years) for female patients and 15.65 years (range 10.57–36.86 years) for male patients. Inclusion criteria were the following: healthy, nonsmoking patients with no history of orthodontic treatment and with permanent dentition except for second and third molars. For all patients, full records including digital lateral headfilms (KODAK 9000C®, Carestream Health Inc., Rochester, NY, USA) were available.

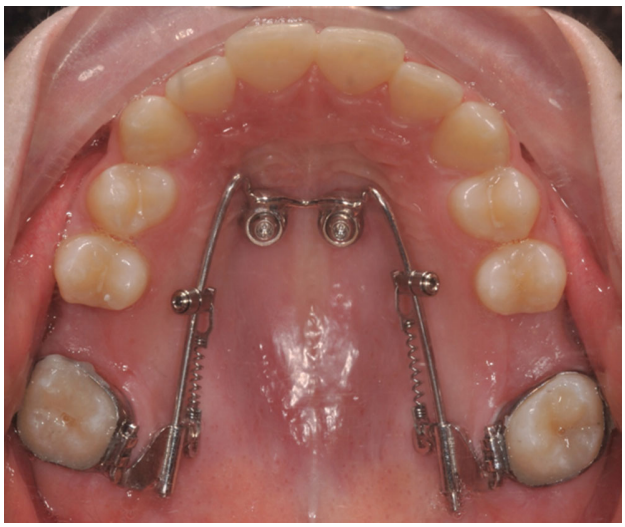

Fig. 2 Mesialslider used for mesialization of upper first molars
Abb. 2 Mesialslider zur Mesialisation der oberen ersten Molaren

A total of 22 patients received a Beneslider according to Wilmes ([41]; Fig. 1) for the distalization of maxillary first molars, 10 patients received a Mesialslider ([40]; Fig. 2) for the mesialization of maxillary first molars, and 8 patients received a bone-borne rapid palatal expansion (RPE) appliance ([6]; Fig. 3). The customized appliances were placed within one week after OMI placement. Forces exerted by calibrated nickel–titanium force modules were 2.35 N per side and OMI in Mesial- and Benesliders. For the RPE appliance, forces greater than 2 N were reported [31].

Insertion of OMIs

Two OMIs were always placed 3–5 mm from the median suture [2] immediately posterior to the palatal rugae [9, 10, 37] by the same orthodontist. Only one brand was used (OrthoEasy® Pal, Forestadent, Pforzheim, Germany). All OMIs had the same diameter (1.7 mm) and length (8 mm), and were placed under local anesthesia (Articain 1:100,000). All OMIs were self-drilling, and a surgical drive unit (Implantmed®, W&H Italia S.r.l., Brusaporto/Bergamo, Italy) was used, providing a 20:1 contra angle handpiece. The motor speed was set to 100 revolutions/min, and torque control was set to 5 Ncm, and could be increased by steps of 5 Ncm each if necessary. The surgical drive unit was designed to stop the screwing phase if the preset torque value was exceeded. The initial set up of the

motor was 5 Ncm. During OMI insertion, if necessary, the torque was progressively increased (steps of 5 Ncm). For each screw, the insertion torque was recorded and allocated to the following five ranges (Ncm): $0 < x \leq 5$, $5 < x \leq 10$, $10 < x \leq 15$, $15 < x \leq 20$, and $20 < x \leq 25$.

Cephalometric analysis

Vertical skeletal morphology was assessed by one blinded examiner on the pretreatment cephalograms that were part of mandatory initial diagnostics. A dedicated cephalometric software kit (Delta-Dent®, Outside Format, Spino D'Adda, Italy) was used for the tracings with an officially calibrated and certified image viewing system. To avoid bias, three common cephalometric parameters were assessed: Jarabak's ratio, facial axis, and Frankfort to mandibular plane angle (FMA). Consecutively, values were allocated to the different vertical skeletal patterns (horizontal = H; normal = N; vertical = V) according to the common norm values (ratio: 0.67–0.72; facial axis: 90° ± 3°; FMA: 22–29°).

Definition of success or failure

According to Motoyoshi et al. [21], success or failure of the OMI was decided 6 months or more after placement. If the OMI endured orthodontic force applied for 6 months or more, the OMI was recorded as a success. If the OMI loosened before 6 months, it was recorded as a failure.

Data collection and statistical analysis

Data were collated using Microsoft Excel® 2007, (Microsoft Corp., Redmond, WA, USA). The same blinded examiner remeasured the cephalometric parameters for vertical skeletal morphology after an interval of 3 months.

The method error (ME) was then calculated for the three parameters using the Dahlberg formula ($ME = \sqrt{\sum d^2/2n}$) [5] where d is the difference of the repeated measurement pairs and n the number of measurements. ME was 0.37 for Jarabak's ratio, 0.22 for the facial axis and 0.29 for the Frankfort to mandibular plane angle (FMA).

Normal distribution of the data was assessed with the Kolmogorov–Smirnov test. Homogeneity of variance was tested with Levene's tests. To assess the insertion torque related to the appliances used and vertical skeletal morphology, multiple group comparisons were performed with one way analysis of variance (ANOVA), whereas two groups were always compared using paired Student's t-tests. To reveal possible associations between insertion torque of both sides and vertical skeletal morphology, additional Pearson correlations were conducted. All statistical analyses were undertaken using SPSS® for Windows®, version 22.0 (IBM Corp., Armonk, NY, USA). Statistical significance was set at $p < 0.05$.

Results

The overall success rate was 98.75%. No screw registered an insertion torque value higher than 25 Ncm. Two OMIs had an insertion torque value lower than 5 Ncm (Table 1), and one of these two OMIs, providing anchorage for a Mesialslider, failed 3 weeks after orthodontic force application. The remaining OMIs were successful.

No statistically significant differences were found between insertion torque values in relation to Jarabak's ratio, facial axis or Frankfort to mandibular plane angle (FMA) and no significant difference ($p > 0.05$) was found between the right and left side (Table 2). Correlations between the insertion torque of the OMIs of both sides and the vertical skeletal morphology were only weak and insignificant (Table 3). The OMIs' insertion torques revealed no significant differences supporting the different appliances (Table 4).

Discussion

The overall success rate in our investigation was of 98.75%, thus, agreeing with similar studies reporting success rates ranging from 95.9% [13] to 98% [12] for palatal insertion.

Table 1 Distribution of patients according to different insertion torque ranges
Tab. 1 Verteilung der Patienten in Hinblick auf die verschiedenen Drehmomentbereiche

	Number of OMIs			
Insertion torque range (Ncm)	Males	Females	Total	%
0 to ≤5	0	2	2	2.50
>5 to ≤10	4	2	6	7.50
>10 to ≤15	7	30	37	46.25
>15 to ≤20	12	16	28	35.00
>20 to ≤25	5	2	7	8.75
Total	**28**	**52**	**80**	**100**

OMI orthodontic mini-implants

Table 2 Results of cephalometric analysis
Tab. 2 Ergebnisse der kephalometrischen Analyse

Parameter	OMIs right side		OMIs left side		Right vs. left side
Jarabak's ratio	Insertion torque (mean ± SD)	*p*-value[a]	Insertion torque (mean ± SD)	*p*-value[a]	*p*-value[b]
H: *n* = 15	H: 17.00 ± 3.68	0.349 NS	H: 17.33 ± 3.72	0.486 NS	H: 0.807 NS
N: *n* = 11	N: 18.18 ± 4.05		N: 17.33 ± 4.04		N: 1.000 NS
V: *n* = 14	V: 15.71 ± 4.75		V: 16.07 ± 5.25		V: 0.852 NS
Facial axis					
H: *n* = 9	H: 18.33 ± 3.54	0.468 NS	H: 18.33 ± 3.54	0.552 NS	H: 1.000 NS
N: *n* = 25	N: 16.60 ± 4.73		N: 17.33 ± 5.00		N: 0.773 NS
V: *n* = 6	V: 15.83 ± 2.04		V: 15.83 ± 2.04		V: 1.000 NS
Frankfort to mandibular plane angle					
H: *n* = 8	H: 16.25 ± 2.31	0.844 NS	H: 16.25 ± 2.31	0.701 NS	H: 1.000 NS
N: *n* = 24	N: 16.87 ± 4.85		N: 17.08 ± 4.87		N: 0.883 NS
V: *n* = 8	V: 17.50 ± 3.78		V: 18.12 ± 5.58		V: 0.770 NS

OMI orthodontic mini-implants, *SD* standard deviation; Vertical skeletal pattern: *H* horizontal, *N* normal, *V* vertical, *NS* not significant
[a]One way ANOVA
[b]Paired Student's t-test

Table 3 Results of the Pearson correlation
Tab. 3 Ergebnisse der Pearson-Korrelation

	Insertion torque			
	Right OMIs		Left OMIs	
Cephalometric parameter	r	*p*-value	r	*p*-value
Jarabak's ratio	0.12	0.455 NS	0.10	0.542 NS
Facial axis	0.24	0.141 NS	0.22	0.171 NS
FMA	0.07	0.662 NS	0.14	0.386 NS

NS not significant, *FMA* Frankfort to mandibular plane angle, *OMIs* orthodontic mini-implants
Correlation between insertion torque of OMIs (right and left side) and vertical skeletal morphology. Pearson correlation coefficient (r) and *p*-value displayed

Table 4 Insertion torque related to the appliances used
Tab. 4 Insertionsdrehmomentbei den untersuchten Apparaturen

		Right OMIs		Left OMIs		Right vs. left side
Appliance	*N*	Insertion torque (mean ± sd)	*p*-value [a]	Insertion torque (mean ± sd)	*p*-value [a]	*p*-value [b]
Beneslider	22	17.05 ± 3.33		17.05 ± 3.33		1.000 NS
Mesialslider	10	16.00 ± 5.16	0.732 NS	16.00 ± 5.16	0.422 NS	1.000 NS
Hybrid-RPE	8	17.50 ± 5.35		18.75 ± 5.83		0.170 NS

NS not significant, *SD* standard deviation, *RPE* rapid palatal expansion, *OMIs* orthodontic mini-implants
[a]One-way ANOVA
[b]Paired Student's t-test

Results from different investigations [14, 25, 29] suggest that joining two OMIs through the appliance might increase the success rate. This has to be considered when assessing our results. Remarkably, even a 100% success rate has been reported for OMIs inserted into the median suture when the implants were joined through the appliances [14].

Suzuki et al. [33] reported a higher failure tendency with insertion torque values greater than 10 Ncm. This was also supported by Wilmes et al. [39] who suggested that very high insertion torques may lead to higher failure rates, which was corroborated by Nguyen et al. [23]. Motoyoshi et al. [21] evaluated the insertion torque value using 1.6 × 8 mm OMIs suggested an optimal range of 7.2–13.5 Ncm, while a significantly higher torque value was observed in failed rather than in successful OMIs. These investigators recommended insertion torque values of 5–10 Ncm. However, ideal torque values might differ according to the type of OMI and the placement method used. An insertion torque significantly higher than 10 Ncm (average, 14.5 Ncm) was observed with self-drilling OMIs

compared to predrilling variants (average, 9.2 Ncm) by some investigators [32], while this observation was contradicted by others [3]. Another study [14] reported that the maximum insertion torque increases with increasing screw length and outer diameter.

In our investigation, the majority (46.25%) of OMIs were inserted with torque values ranging between 10 and 15 Ncm, and 35% were inserted with torque values ranging between 15 and 20 Ncm. The latter values are in agreement with the different recommendations for insertion torque found in the literature [21, 33]. On the other hand, a recent meta-analysis by Meursinge Reynders et al. [19] concluded that there is insufficient evidence to recommend specific insertion torque levels to obtain higher success rates for OMIs. A recent study [42], where large variations between insertion torques were found for OMIs of different manufactures, strongly supports the outcome of the aforementioned meta-analysis.

In our study, vertical skeletal morphology was assessed using three common cephalometric parameters. No association was found between insertion torque and vertical skeletal morphology. Horner et al. [7] found that cortical bone tends to be thicker in hypodivergent than in hyperdivergent subjects, potentially calling for higher insertion torques. However, these authors only measured interradicular sites. Moreover, only a single cephalometric parameter was used to assess vertical skeletal morphology which might have biased their results. Contrary to this, a very recent 10-year cross-sectional study [18] investigating a total of 1356 OMIs inserted in 570 patients revealed that the craniofacial pattern does not affect OMI success.

In our study, patients were treated with different bone-borne appliances that exhibited differences referring to forces they exert on the OMIs. Still, mechanical loosening remains a common complication leading to OMI failure [8]. Interestingly, only one OMI supporting a Mesialslider failed. It is known that OMIs do not remain stationary under orthodontic loads [15] and extrusive displacement ranging between 0.1 and 0.8 mm has been found under orthodontic force application [27]. Hence, extrusive load might have particularly contributed to OMI failure in one of our patients.

All customized appliances in our study were placed after within one week after OMI placement. A recent meta-analysis [30], however, demonstrated that no significant differences of the failure rates of OMIs were observed between immediate loading (up to 2 weeks) or late loading (later than 2 weeks). In a study by Manni et al. [16], OMIs were exposed to loads greater than 2 N. Moreover, they found that immediate loading with those forces led to even higher success rates compared to delayed loading.

On the other hand, some clinicians advocate a 2-week soft tissue healing period for OMIs placed before orthodontic loading [35, 45]. Taking this time before loading the OMIs could be favorable. The healed soft tissue might cover the gap between OMI and bone as a "biologic barrier," hence, preventing bacterial colonization and subsequent peri-implant inflammation [20].

The study hypothesis that greater insertion torque (>10 Ncm) will decrease the success rate and increase palatal OMI failure was rejected. However, numerous factors not assessed in our investigation contribute to the success rate of OMIs [30] and insertion torque is not the sole determinant. Because many questions remain unanswered [36], further research preferably with prospective designs and larger sample sizes is recommended.

Conclusion

The insertion torque of OMIs inserted in the paramedian region ranged between 10 and 20 Ncm. Despite the fact that a 10 Ncm threshold was postulated, no strict torque recommendation can be drawn from our results.

Compliance with ethical guidelines

Conflict of interest B. Di Leonardo, B. Ludwig, J.A. Lisson, L. Contardo, R. Mura and J. Hourfar declare that they have no competing interests.

Ethical standards Ethical approval for this retrospective study was obtained from the institutional review board. For this type of study formal consent is not required.

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