CLINICAL ORAL IMPLANTS RESEARCH

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Accuracy of mechanical torque-limiting gauges for mini-screw placement

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Abstract

Aim: The purpose of this investigation was to determine and compare the accuracy of four available mechanical torque-limiting gauges (MTLGs) for mini-screw placement.

Materials and methods: The torque outputs of six randomly obtained MTLGs, either of the screwdriver or torque ratchet type of four mini-screw manufacturers were obtained. Mounted on a joint, a universal testing machine applied perpendicular force to a lever arm with a crosshead speed of 1 mm/min. For each device, 10 repetitions of the corresponding target torque level were recorded after initial sterilisation (1) and after 5, 10, 20, 50 and 100 times to evaluate its potential influence on MTLGs. The breakpoints (N cm) were calculated for comparison of the groups.

Descriptive statistics and mean breakpoints values for each MTLG computed and compared with the reference values indicated on the respective torque gauges provided by the producer.

Results: The mean torque values for the AbsoAnchor® MTLG devices were significantly below torque levels, but provide consistent torque values. All but one obtained values for the Spider Screw, MTLG of the screw driver type, were within the indicated moment range during the first 50-times of sterilization process. But after 100-times of steam sterilization all mean breakpoint values were relevantly higher than the indicated torque range values.

Each individual MTLG produced independently constant breakpoint torque values, but differed significantly from each other. For all but the Spider Screw® MTLG, the sterilisation process had a statistically significant different influence at the various breakpoint torque levels.

Conclusion: After application of the manufacturers' preset torque levels, significant variations were observed between individual devices. The torque output of each individual device deviated in varying degrees from target torque values and was influenced by various degrees by the sterilisation process over time.

Adequate anchorage control is one of the most important and occasionally limiting factors in orthodontics. Its control is essential for successful orthodontic treatment outcomes. Traditionally, orthodontists have used teeth, intraoral and/or extraoral appliances to control anchorage – minimising the movement of certain teeth, while completing the desired movement of other teeth. In the past decades, the orthodontic literature has published numerous case reports and scientific papers documenting the possibility of using several different types of temporarily placed anchorage devices (TAD) (Creekmore & Eklund 1983; Roberts et al. 1990; Triaca et al. 1992; Bousquet et al. 1996; Kanomi 1997; Umemori et al. 1999; De Clerck et al. 2002). The anchorage by means of a TAD permits an independency of patient compliance (Creekmore & Eklund 1983).

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As regular orthodontic patients do not display edentulous alveolar bony ridges for the insertion of an implant, in the late 1990s specially designed mini titanium screws have been introduced (Kanomi 1997).

But in some cases, there is an early failure of mini-screws shortly after installation and orthodontic loading. This loss may be caused by the lack of sufficient primary stability, which causes an inappropriate healing and a possible premature loss of the implant (Friberg et al. 1991; Lioubavina-Hack et al. 2006). The insertion torque or resistance to insertion influences the retention of the screw; however, this does not directly relate to the rate of loss (Motoyoshi et al. 2006). But, if the initial stability may not be obtained, corresponding to the small insertion torque, then later stability supported by osseointegration may not be acquired. Hoop stresses, which are generated around the dental implant threads during insertion, may be beneficial in enhancing the primary stability of the implant but if the resistance is too high, the mini-screw placement torque may generate a level of stress resulting in the degeneration of the bone at the implant–tissue interface (Meredith 1998), and then the bone regeneration surrounding the implant thread may be aggravated.

Assessing the success rate of mini-implants, implant placement torque (IPT) was identified as a risk factor for early screw loss (Motoyoshi et al. 2006; Chaddad et al. 2008). IPT values below or above a certain threshold were associated with upto 12 times higher risk for early failure.

To overcome this problem, several mini-screws companies offer limiting torque wrenches to control placement torque during mini-screw installation. But up to now, there exists no study documenting the accuracy of these devices. Therefore, the purpose of this investigation was to determine and compare the accuracy of four available mechanical torque-limiting gauges (MTLGs) for mini-screw placement.

Material and methods

Six randomly obtained MTLGs of four mini-screw manufacturers were obtained to determine their accuracy relative to their target torque values (Table 1, Fig. 1a–d). All MTLGs were new and either of the screwdriver or torque ratchet type. All the gauges were mounted on a joint and were aligned in the testing apparatus to ensure consistency for the point of force application and of the force for all devices tested. With a universal testing machine (Z010, Zwick, Ulm, Germany), a perpendicular force was applied to a lever arm, 3 cm away of the centre of rotation (Fig. 2a and b) with a crosshead speed 1 mm/min. Target torque values were set at 10, 20 and 30 N cm for the tomas® pin torque ratchet (Dentaurum, Ispringen, Germany), at 10, 20 and 30 cN m for the LOMAS Orthodontic mini Anchor System torque ratchet, Mondeal, Mühlheim a. d. D., Germany, at 1 and 2 kgf for the AbsoAnchor® torque screwdriver (Dentos Inc., Daegu, South Korea) and at green (5–10 N cm), yellow (11–15 N cm) and red (16–20 N cm) level for the Spider Screw® torque screwdriver type (H.D.C. SRL, Sarcedo, Italy), respectively. The force was applied to the MTLG until the friction released at the corresponding limits. The peaks forces were captured in Newtons by means of a specific software (testXpert V.11.02, Zwick/Roell). The breakpoint was calculated using the formula $M =$ peak force (N) $\times$ lever arm (cm). The lever arm for each MTLG of each group was 3 cm.

For each device, 10 repetitions of the corresponding target torque level were recorded after initial sterilisation (1) and after 5, 10, 20, 50 and 100 times (Unsteri 3-3-6 1 ED, MMM Sterilisatoren AG, Rudolfstetten, Switzerland) to evaluate its potential influence on MTLGs. All measurements were performed by the same operator (D.G.).

The Statistical Package for the Social Sciences version 15 (SPSS Inc, Chicago, IL, USA) was used in order to calculate descriptive statistics for the data. Mean breakpoints values for each MTLG at each condition were computed and box-plots were given. Moreover, 95% confidence intervals (95% CI) for means – at the corresponding breakpoints – in all groups at each level of number of sterilisation were computed. These results were then compared with the reference values indicated on the respective torque gauges provided by the producer.

In order to investigate the variances between breakpoints of torques gauges and the dispersion of 10 repeated measurements' at the specific breakpoints, one-way ANOVA with random effects together with variance components (σ^2_{Torque}, σ^2_{Error}) were computed. Moreover, intraclass correlation coefficient (ICC) was calculated following the formula:

$$\text{ICC} = \frac{\sigma^2_{\text{Torque}}}{\sigma^2_{\text{Torque}} + \sigma^2_{\text{Error}}}$$

A large value of ICC (close to 1) indicates that σ^2_{Error} is very small (the mean breakpoint of one particular torque can be estimated with high precision). The spread between the mean breakpoints of different torques is substantial (σ^2_{Torque} has an overwhelming influence).

In order to compare the estimated variance of torque σ^2_{Torque} between different conditions, we applied a test given by Sachs (1997) together with Satterthwaite procedure for the estimation of degrees of freedom. It is enough to compare a quotient of two different variances with a level equal to 9.3 obtained from $F_{3,3}$ distribution. The quotient of variances bigger than 9.3 is considered to be different at α-level $= 5\%$.

Additionally, linear mixed models with random intercept were computed. Akaike Information Criterion (AIC) together with Bayes Information Criterion (BIC) were used for the model choice.

Results of the statistic analyses with p-value $< 5\%$ were interpreted as significant.

Results

The mean moment values of each torque-limiting gauge (MTLGs), incl. 95% CI,

Table 1. **Mechanical torque-limiting gauges tested**

Manufacturers	Lot number	Target torque value
Screwdriver type		
AbsoAnchor®	DT70402T	1, 2 kgf
Spider Screw®	TD0908	Green (5–10 N cm)
		Yellow (11–15 N cm)
		Red (16–20 N cm)
Torque ratchet type		
tomas® pin	398,970	10, 20, 30 N cm
LOMAS Orthodontic mini Anchor System	486,375	10, 20, 30 cN m

applied at corresponding target torque breakpoints of 4 mini-screw manufacturers tested are depicted in Table 2 and Fig. 3a–d. The indicated breakpoints on the MTLGs were converted to the corresponding uniform N cm-units.

One MTLG (Mondeal) was malfunctioning and could not produce measurable moments at a target torque of 10 cN m after five times of sterilisation, 20 cN m after 20 times of sterilisation and failed to produce any results after 100 times of sterilisation. The missing values were not considered for evaluation.

For the AbsoAnchor® MTLG, all mean torque values assessed were at all times statistically significantly below the target breakpoints of 1 kgf (= 9.81 N cm), range from 3.8–6.6 N cm, and 2 kgf (= 19.62 N cm), range 8.9–11.9 N cm, respectively (Table 2a and Fig. 3a). The measured values were approximately 50% below the indicated torque levels.

All but one values obtained for the Spider Screw®, MTLG of the screwdriver type, were within the indicated moment range during the first 50 times of the sterilisation process (Table 2b and Fig. 3b). After 100 times of steam sterilisation, however, the mean breakpoint values were relevantly higher than the indicated torque range values; 19 N cm for the green coloured, 22.9 N cm for the yellow coloured and 28.2 N cm for the red coloured breakpoint range respectively. This corresponded to a 50% (yellow and red) and an almost 100% (green) outreach of the upper breakpoint limit. But, the 95% CI contained the appropriate breakpoint ranges and were therefore not statistically significant, perhaps due to the large standard deviation (Table 2b). With cumulative sterilisation processes, the variance of the assessed moments at the intended breakpoint values increased (Table 3b).

Table 3b:		
red level	159.44/8.075	>9.3

The ratchet type of MTLGs (tomas® pin and LOMAS Orthodontic mini Anchor System) yielded statistically significant higher mean breakpoint torque values of 23–30.2 and 38.9–49 N cm at the indicated 20 and 30 N cm level for all sterilisation cycles, respectively (Table 2 and Fig. 3c and d). Except after the five times of sterilisation, the tomas® pin ratchet reached values within the intended torque range. For the lowest torque level (10 N cm), the LOMAS Orthodontics mini Anchor System ratchets did not differ from the breakpoint torque, whereas for the tomas® pin MTLGs statistically significant lower values after 5, 10 and 20 sterilisation cycles were assessed. The ratchet type of MTLGs did not statistically significantly ($P = 0.052$) differ from each other (tomas® pin vs. LOMAS Orthodontic mini Anchor System) asprovided by the linear mixed models (Table 4).

One-way ANOVA with random effects revealed that there were significant differences between mean breakpoints values of six different MTLGs at each condition (manufacturer, indicated torque level and sterilisation [$p < 0.001$]).

The mean variances of the six MTLG (σ_{Torque}) of the four different manufacturers tested and the mean measurement error (σ_{Error}) are depicted in Table 3. For the AbsoAnchor® (Table 3a), the measurement error was <1 N cm during the entire experimental testing. The estimated standard deviation (σ_{Torque}) of all MTLGs was

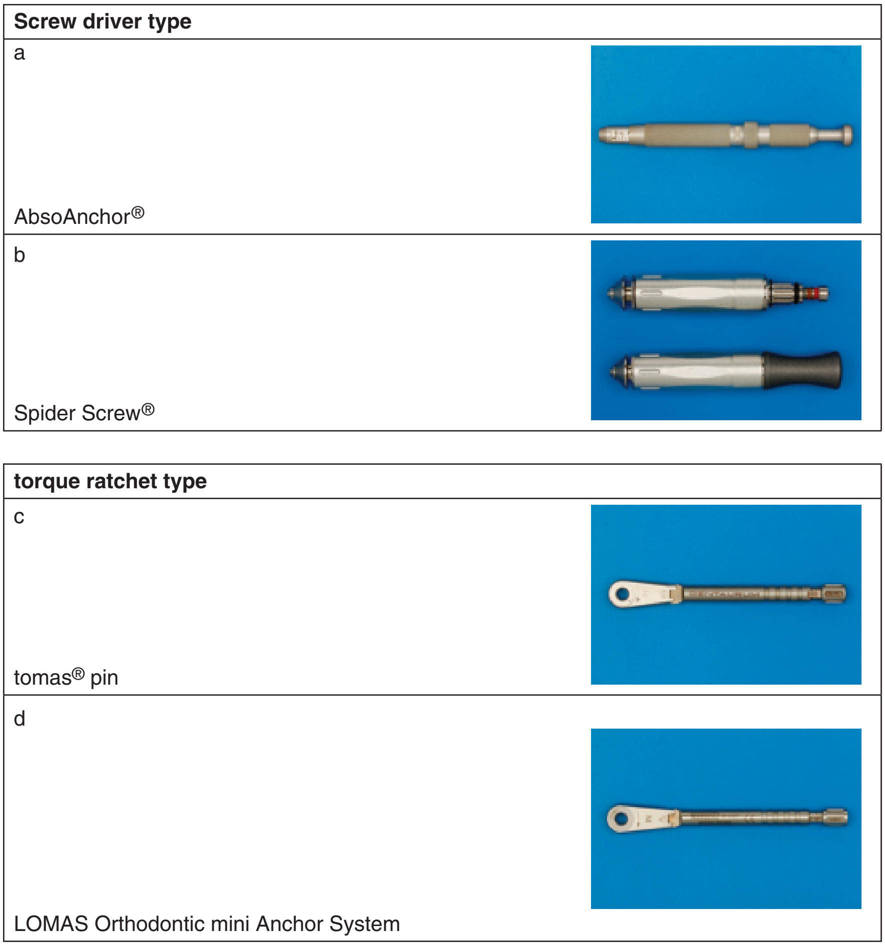

Fig. 1. Mechanical limiting torque gauges tested (a–d).

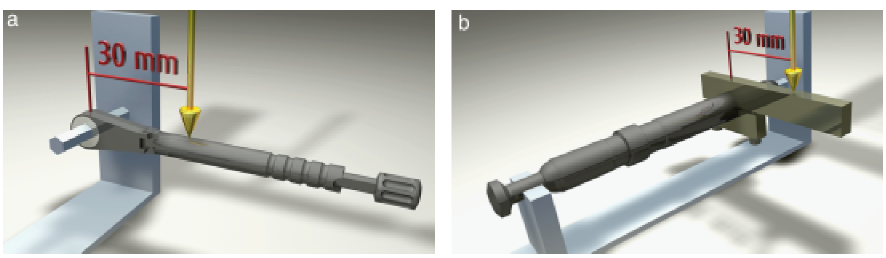

Fig. 2. (a, b) Illustration of perpendicular force application to a lever arm 3 cm away from the centre of rotation for the ratchet and screw type of mechanical torque-limiting gauges.

Table 2. **a–d: 95% confidence intervals for mean breakpoint values applied for the all mechanical torque-limiting gauges tested**

Time of sterilisation	Torque screw level: mean (95% CI)	
	1 kgf = 9.81 N cm	2 kgf = 19.62 N cm
(a)AbsoAnchor®		
1	6.6 (5, 7.6) N cm*	10.4 (9, 11.9) N cm*
5	3.8 (3.6, 4.8) N cm*	8.9 (7.6, 10.3) N cm*
10	4.2 (3.6, 4.8) N cm*	9.4 (8.2, 10.7) N cm*
20	4.2 (3.7, 4.6) N cm*	10.2 (7.6, 12.7) N cm*
50	4.6 (4.1, 5) N cm*	9.2 (8.3, 10.1) N cm*
100	4.7 (3.1, 6.6) N cm*	11.9 (7.9, 15.8) N cm*

Time of sterilisation	Mean (95% CI)		
	Green (5–10 N cm)	Yellow (11–15 N cm)	Red (16–20 N cm)
(b) Spider Screw®			
1	7.2 (4.8, 9.6) N cm	10.6 (7.7, 13.4) N cm	14.3 (12.6, 15.9) N cm*
5	7.7 (5.1, 10.4) N cm	11.1 (9.3, 12.9) N cm	15.7 (13.9, 17.4) N cm
10	7.6 (3.5, 11.6) N cm	10.3 (9, 11.5) N cm	14.9 (13.5, 16.3) N cm
20	9.7 (5.7, 13.6) N cm	13.7 (11.1, 16.3) N cm	17.7 (15.3, 20) N cm
50	10 (6.1, 14) N cm	15.1 (12.6, 17.5) N cm	21.1 (18.3, 23.8) N cm
100	19 (8.4, 29.5) N cm	22.9 (14.4, 31.7) N cm	28.2 (17.5, 38.6) N cm

Time of sterilisation	Mean (95% CI)		
	10 N cm	20 N cm	30 N cm
(c) tomas® pin			
1	9.3 (8.2, 10.4) N cm	26.6 (25.6, 27.6) N cm*	43.7 (41.8, 45.6) N cm*
5	8.2 (6.5, 9.6) N cm*	22.7 (19.9, 25.6) N cm	38.9 (36.9, 40.9) N cm*
10	7.8 (6, 9.6) N cm*	23 (21, 24.9) N cm*	39 (35.8, 42.2) N cm*
20	6.7 (5.5, 7.8) N cm*	23.1 (20.8, 25.3) N cm*	37.9 (36.8, 38.9) N cm*
50	9.1 (7.5, 10.6) N cm	26.4 (23.9, 28.9) N cm*	45.9 (43.6, 48.3) N cm*
100	8 (5, 10.8) N cm	27.5 (25.2, 29.7) N cm*	46.4 (42.6, 50.1) N cm*

Time of sterilisation	Mean (95% CI)		
	10 cN m = 10 N cm	20 cNm = 20 N cm	30 cN m = 30 N cm
(d) LOMAS Orthodontics mini Anchor System			
1	10 (8.4, 11.5) N cm	27.3 (24.3, 30.2) N cm*	42.8 (39.8, 45.8) N cm*
5	10 (7.6, 12.3) N cm	26.5 (23.4, 29.6) N cm*	42.8 (39.1, 46.5) N cm*
10	8.9 (6.6, 11.1) N cm	24.2 (21.5, 27) N cm*	39.6 (35.7, 43.5) N cm*
20	11.4 (7.6, 15.2) N cm	27.8 (24, 31.5) N cm*	44.2 (39.2, 49.2) N cm*
50	11.6 (7.8, 15.5) N cm	30.2 (25.7, 34.7) N cm*	49 (43.4, 54.4) N cm*
100	10.7 (9.3, 12) N cm	28.5 (25.2, 31.7) N cm*	47.3 (43.5, 51.1) N cm*

*Significant difference from company indicated target breakpoint.

within 0.4–1.5 N cm for the 1 kgf (= 9.81 N cm) torque level and 0.8–3.7 N cm for the 2 kgf (= 19.62 N cm), respectively, pointing to ICCs of 0.53–0.98.

For the other screwdriver type MTLG (Spider Screw®), σ_{Error} as well as σ_{Torque} started to increase significantly after the 50th sterilisation cycle (Table 3b). The ICC was always above the level of 0.81, pointing to the fact the method error was minimal. (The estimation of the mean breakpoint is very precise for a particular torque.) Each individual MTLG produced independently constant breakpoint torque values, but differed significantly from each other (Table 3b, σ_{Torque}, σ_{Error}).

Table 3b:		
red level	161.1/3.8	>9.3
yellow level	103.5/3.8	>9.3
green level	159.4/8.1	>9.3

The measurement errors (σ_{Error}) of the ratchet type of MTLGs (tomas® pin and LOMAS) was < 1 N cm. The variance of all MTLG of the tomas® pin type (σ_{Torque}) was within 1–2.7 for the indicated 10 N cm level, 0.9–2.8 N cm for the 20 N cm level and 1–3.5 N cm for the 30 N cm level, respectively, resulting in an ICC of more than 0.93. Exceptions were found for the tomas® pin after the fifth (ICC = 0.73) and 20th (ICC = 0.711) cycle of sterilisation at the 10 N cm torque level, respectively. For the LOMAS Orthodontic mini Anchor System MTLGs, the variance ranged from 1.4 to 5.5 N cm at the indicated 10 cN m breakpoint, 2.6–12.8 N cm for the 20 cN m level and 2.8 and 19.5 N cm for the 30 cN m level, respectively. The measurement error for the wrench type for MTLGs is minute (Table 3c and d).

Linear mixed models with random intercept are depicted in Table 4. For all but the Spider Screw® MTLG, the sterilisation process had a statistically significantly different influence at the various breakpoint torque levels.

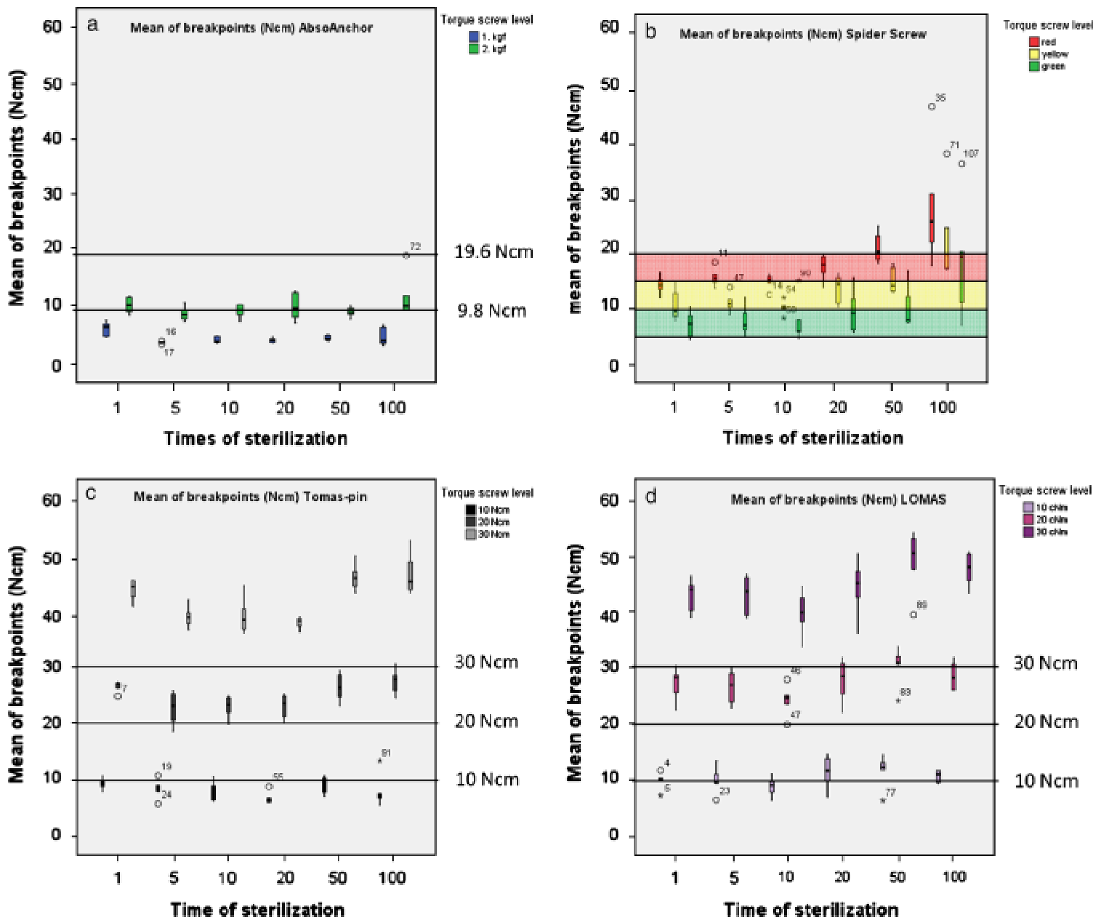

Fig. 3. Boxplots with mean breakpoints values for each mechanical torque-limiting gauges at each condition. (a) AbsoAnchor®. (b) Spider Screw®. (c) tomas® pin. (d) LOMAS Orthodontic mini Anchor System.

All dependent variables included in the models described in Table 4 were significant ($p < 0.001$).

AbsoAnchor®: The model for AbsoAnchor® is the most difficult to describe. Mean breakpoint value for the baseline group 2 kgf is equal to 9.8 N cm. The mean breakpoint value for the 1 kgf group is 4.7 N cm smaller than that of 2 kgf group. Actually, it is equal to 9.8–4.7 = 5.1 N cm. There is the time of sterilisation effect both linear and quadratic. The linear decrease of the mean breakpoint value is equal to 0.03 N cm in the 2 kgf group and is stronger in the 1 kgf group (−0.03 to 0.02 = −0.05).

Spider Screw®: The mean breakpoint value typical for the red (baseline) group is equal to 18.5 N cm. There is a decrease for the yellow group as compared with the red one by 5.9 N cm. There is also a decrease for the green group as compared with the red one by 10.6 N cm. There is a linear increase of the mean breakpoint value with the time of sterilisation for all groups equal to 0.15 N cm. It corresponds to an increase by 15 N cm after 100 sterilisations.

tomas® pin and LOMAS: The optimal models for tomas® pin and LOMAS are similar. No differences between tomas® pin and LOMAS were found ($P = 0.052$). In Table 4, two separate models for tomas® pin and LOMAS are reported.

Here, we interpret the model for tomas® pin. The mean breakpoint value for the target torque value group 30 N cm (baseline) is = 39.8 N cm. There is a decrease for group 20 and 10 N cm by 16.1 and 33.6 N cm, respectively. There is a positive influence of 0.07 of the time of sterilisation on the mean breakpoint value for the baseline group 30 N cm, which corresponds to an increase of 7 N cm after 100 sterilisations. For the group 20 N cm, there is a slighter increase with the time of sterilisation (0.07–0.03 = 0.04 corresponding to an increase of 4 N cm after 100 sterilisations) and practically no increase with the time of sterilisation for the group 10 N cm.

Discussion

Anchorage is one of the limiting factors in orthodontics and its control is essential for successful orthodontic treatment. According to the intended treatment goals, desired tooth movements should, therefore, be maximised, and undesirable effects minimised. Traditionally, orthodontic therapy used teeth, extraoral and/or intermaxillary appliances for anchorage. As the patient's cooperation is not always optimal, and therefore absolute anchorage is not provided (Nanda & Kierl 1992) and TAD (Daskalogiannakis 2000) have been introduced.

The dynamics of TAD loss (loss over time) is an important factor for choosing the appropriate anchorage device and for decision making in orthodontic treatment

Table 3. **Variance components with intraclass correlation coefficient for all mechanical torque-limiting gauges tested**

Torque screw level	Time of sterilisation	σ^2_{Toruqe} (N cm^2)	σ_{Toruqe} (N cm)	σ^2_{Error} (N cm^2)	σ_{Error} (N cm)	ICC
(a) AbsoAnchor®						
1 kgf = 9.81 N cm	1	1.449	1.2	0.101	0.32	0.935
	5	0.036	0.19	0.032	0.18	0.529
	10	0.314	0.56	0.028	0.17	0.918
	20	0.15	0.39	0.018	0.13	0.893
	50	0.174	0.42	0.1	0.32	0.635
	100	2.301	1.52	0.332	0.58	0.874
2 kgf = 19.62 N cm	1	1.763	1.33	0.539	0.73	0.766
	5	1.551	1.25	0.652	0.81	0.704
	10	1.369	1.17	0.211	0.46	0.866
	20	5.637	2.37	0.128	0.36	0.978
	50	0.691	0.83	0.106	0.33	0.867
	100	13.93	3.73	0.564	0.75	0.961
(b) Spider Screw®						
Red	1	3.82	1.95	0.235	0.48	0.942
Red	5	4.248	2.06	0.167	0.41	0.962
Red	10	2.579	1.61	0.618	0.79	0.807
Red	20	7.518	2.74	0.679	0.82	0.917
Red	50	10.757	3.28	1.069	1.03	0.91
Red	100	161.075	12.69	18.478	4.3	0.897
Yellow	1	11.237	3.35	0.143	0.38	0.987
Yellow	5	4.535	2.13	0.126	0.35	0.973
Yellow	10	2.152	1.47	0.032	0.18	0.985
Yellow	20	9.811	3.13	0.372	0.61	0.963
Yellow	50	8.147	2.85	0.586	0.77	0.933
Yellow	100	103.517	10.17	12.377	3.52	0.893
Green	1	8.075	2.84	0.052	0.23	0.994
Green	5	9.909	3.15	0.1	0.32	0.99
Green	10	23.332	4.83	0.077	0.28	0.997
Green	20	21.695	4.66	0.616	0.78	0.972
Green	50	22.246	4.72	1.623	1.27	0.932
Green	100	159.44	12.63	6.493	2.55	0.961
(c) tomas® pin						
10 N cm	1	1.041	1.02	0.008	0.09	0.992
10 N cm	5	2.566	1.6	0.956	0.98	0.729
10 N cm	10	2.756	1.66	0.022	0.15	0.992
10 N cm	20	1.122	1.06	0.457	0.68	0.711
10 N cm	50	2.02	1.42	0.03	0.18	0.983
10 N cm	100	7.51	2.74	0.04	0.21	0.994
20 N cm	1	0.87	0.93	0.059	0.24	0.936
20 N cm	5	7.536	2.75	0.039	0.2	0.995
20 N cm	10	3.268	1.81	0.017	0.13	0.995
20 N cm	20	4.374	2.09	0.053	0.23	0.988
20 N cm	50	5.63	2.37	0.07	0.26	0.988
20 N cm	100	4.5	2.12	0.09	0.3	0.981
30 N cm	1	3.135	1.77	0.107	0.33	0.967
30 N cm	5	3.497	1.87	0.029	0.17	0.992
30 N cm	10	9.235	3.04	0.056	0.24	0.994
30 N cm	20	0.982	0.99	0.055	0.23	0.947
30 N cm	50	4.96	2.23	0.14	0.38	0.972
30 N cm	100	12.4	3.52	0.18	0.42	0.986
(d) LOMAS Orthodontic mini Anchor System						
10 cN m	1	2.08	1.44	0.007	0.08	0.997
10cN m	5	4.959	2.23	0.115	0.34	0.977
10cN m	10	15.637	3.95	0.036	0.19	0.998
10cN m	20	29.042	5.39	0.049	0.22	0.998
10cN m	50	30.11	5.49	0.12	0.35	0.996
10cN m	100	19.96	4.47	0.02	0.12	0.999
20cN m	1	7.832	2.8	0.06	0.24	0.992
20cN m	5	8.449	2.91	0.061	0.25	0.993
20cN m	10	6.72	2.59	0.051	0.23	0.992
20cN m	20	12.658	3.56	0.692	0.83	0.948
20cN m	50	162.72	12.76	0.37	0.61	0.998
20cN m	100	140.53	11.85	0.26	0.5	0.998
30cN m	1	8.023	2.83	0.59	0.77	0.931
30cN m	5	12.191	3.49	0.036	0.19	0.997
30cN m	10	13.744	3.71	0.159	0.4	0.989

***Table 3.* (Continued).**

Torque screw level	Time of sterilisation	σ^2_{Toruqe} (N cm^2)	σ_{Toruqe} (N cm)	σ^2_{Error} (N cm^2)	σ_{Error} (N cm)	ICC
30cN m	20	22.606	4.75	0.58	0.76	0.975
30cN m	50	27.33	5.23	0.37	0.61	0.987
30cN m	100	380.55	19.51	0.51	0.71	0.999

ICC, intraclass correlation coefficient.

***Table 4.* Mixed models for all mechanical torque-limiting gauges tested ($p<0.001$)**

Predictors	AbsoAnchor® (N cm)	Spider Screw® (N cm)	tomas® pin (N cm)	LOMAS Orthodontic mini Anchor System (N cm)
Constant	9.8	18.5	39.8	33.9
Torque screw level 1	−4.7	−10.6	−33.6	−25.5
Torque screw level 2	0	−5.9	−16.1	−12
Torque screw level 3	–	0	0	0
Time of sterilisation	−0.03	0.15	0.07	0.07
Time of sterilisation × time of sterilisation	0.0004	–	–	–
Torque screw level 1 × time of sterilisation	−0.02	–	−0.07	−0.06
Torque screw level 2 × time of sterilisation	0	–	−0.03	−0.04
Torque screw level 3 × time of sterilisation	–	–	0	0

planning like the extraction of permanent teeth or the decision of an orthodontic approach only vs. a combined orthodontic–surgical procedure, Failures during orthodontic treatment may make a change of the treatment plan difficult or impossible.

Early failure of mini-screws shortly after installation and orthodontic loading may be caused by the lack of sufficient primary stability, which causes an inappropriate healing and a possible premature loss of the implant (Friberg et al. 1991; Lioubavina-Hack et al. 2006). Hoop stresses, however, which are generated around the dental implant threads during insertion, may be beneficial in enhancing the primary stability of the implant (Meredith 1998). But, it might be warned that such stresses can be excessive, resulting in necrosis and local ischaemia of the bone or strong tensional forces develop within the screw leading to screw fracture (Park et al. 2006; Wilmes et al. 2006). To overcome this problem, several mini-screw companies offer limiting torque wrenches to control placement torque during mini-screw installation. The purpose of this investigation was to determine and compare the accuracy of four available MTLGs for mini-screw placement and the possible influence of multiple sterilisation process.

Mean errors are not as important in the analysis of these data as the extreme variations recorded in the full range of torque output for the study. The extremes are the torque values that will be most likely to cause problems leading to screw fractures (Park et al. 2006; Wilmes et al. 2006) or impairment of the adjacent bone (Motoyoshi et al. 2006) (Table 2).

The AbsoAnchor® devices tested in this study were seen to demonstrate fairly constant variations from the set target values, but underestimated the corresponding breakpoints up to 50%. But from a clinical point of view, this in turn would rather mean to bear the danger of overestimating primary stability than of bone impairment and screw fracture. The Spider Screw® MTLG, in contrast, was the only device not indicating a precise breakpoint value rather than a breakpoint range (Table 2b). By having a critical range and not only a target breakpoint, the 95% CI contained the respective values, in the first 50 times of infection control procedures. After performing 100 times of infection control procedures, the extreme variations recorded in the full range of torque output yielded variations of up to more than 100% (Table 3b).

An interesting finding for the rachtet MTLGs (tomas® pin, LOMAS Orthodontic mini Anchor System) was that at lower levels, documenting primary stability for appropriate healing (Friberg et al. 1991; Lioubavina-Hack et al. 2006), the measured moment was rather underestimated, whereas at higher levels the measured mean torque values were up 50% higher than indicated. This is in contrast to another *in vitro* study on friction-style MTLGs, used for abutment connection in implant dentistry (Vallee et al. 2008) documenting consistent lower torque values than indicated.

As different target torque values had been tested ranging from 9.81 to 30 N cm, the results are reported as absolute difference deviation between the measured torque value and the targeted torque value must be put into relation of the indicated breakpoint. For the AbsoAnchor® MTLGs and the tomas® pin the variance ranged most of the time within 5–10% deviation corresponding to a failure of 1–3 N cm (Table 3c and d), respectively.

Over time, for ratchet-type MTLGs and the AbsoAnchor® MTLG, sterilisation had a significant influence on the accuracy of the target breakpoints. The impact of sterilisation was additionally influenced by the level of applied force (Table 4). Similar results were found for friction-style MTLGs, used for abutment connection in implant dentistry, showing to deliver a substantial error after clinical use due to corrosion through autoclaving (Gutierrez et al. 1997).

Failure of orthodontic mini-implants may be related to the bone quality and/or quantity found in the insertion site, to the diameter and/or length as well as the thread design of the implant, possible root contact during insertion of the implant or orthodontic treatment, surgical technique and the magnitude and direction of the applied orthodontic force (Büchter et al. 2005; Motoyoshi et al. 2006; Chen et al. 2008).

As there is a wide variation in the ability of clinicians to insert mini-screws (e.g. screwdriver, ratchet), calibrated torque devices are necessary to ensure consistency in tightening implant components. MTLGs are available to eliminate operator variability due to clinical experience while delivering a specific target torque value.

Manufacturers of MTLGs tested should improve their torque delivery system to reach the respective target value. To reduce any potential for inaccurate torque application, clinicians should use an MTLD that is recalibrated (Jaarda et al. 1993; Gutierrez et al. 1997; Tan & Nicholls 2002). At the same time, guidelines for the recalibration of MTLGs should be developed by the manufacturer and provided to the clinician to avoid the possibility of excessive torque delivery and the subsequent screw fracture or early failure.

Conclusions

It appears to be clear that the failure rate is influenced by multiple factors. In such a multi-factorial setting, it is still unknown as to what degree of predictive accuracy can be attributed to the insertion torque. If clinicians were able to predict the probability of mini-implant failure based on the insertion torque, then a modification of treatment strategies after insertion might become feasible.

To use the potentials and limits of the insertion torque used as a predictive factor on the failure of orthodontic mini-implants, which have to be evaluated and determined, the manufacturers of MTLGs tested should improve their torque delivery system to reach the respective target value indicated. Significant variations were observed between individual devices at all times. The torque output of each individual device deviated in varying degrees from target torque values and was influenced to a various degree by the sterilisation process over time.

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