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Change in cranio-cervical angulation following orthognathic surgery

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SUMMARY Changes in natural head posture (NHP) were investigated in 33 patients (10 males, 23 females) with an age range of 16–40 years (median 21 years) following orthognathic surgery to change vertical face height. The reproducibility of the radiographer's technique of taking radiographs in NHP was investigated using a photographic method and found to be acceptable. The patients were divided into two groups: group 1, patients who had more than 3 mm of vertical change in anterior total face height (ATFH) and group 2, those who had less than 3 mm vertical change.

For group 1 there was a significant relationship between ATFH change and cranio-cervical angulation (NSL/OPT) change ($r = 0.532$, $P = 0.023$), compared with group 2 ($r = -0.247$, $P = 0.376$). A similar relationship was revealed between lower anterior face height (LAFH)/ATFH ratio and NSL/OPT, where the correlation was also higher in group 1 ($r = -0.635$, $P = 0.005$) compared with group 2 ($r = -0.182$, $P = 0.515$). The correlation between cranio-vertical angulation (NSL/VER) and ATFH was not significant for group 1 ($r = 0.406$) or group 2 ($r = 0.239$) patients . Additionally, NSL/VER and LAFH/ATFH correlation for the two groups was not significant ($r = -0.392$ and -0.338, respectively).

There appears to be a relationship between the reduction in vertical face height following orthognathic surgery and neck posture (as indicated by NSL/OPT). As no significant relationship was found between the reduction in face height and head posture (as indicated by NSL/VER) this suggests that neck posture, rather than head posture, had changed.

Introduction

The relationship between natural head posture (NHP) and craniofacial morphology has been examined in many studies. Subjects with an increased lower anterior face height (LAFH) and an increased inclination of the mandibular to the palatal and anterior cranial base planes have been found to have extended head posture and increased cranio-cervical angles (Solow and Tallgren, 1976; Solow *et al.*, 1984; Hellsing *et al.*, 1987). Previous work has shown that the degree of extension of the head and/or neck differs in patients with long, as opposed to short, faces (Solow *et al.*, 1984). Additionally, improving the airway by tonsillectomy or adenoidectomy brings about a reduction in cranio-cervical angle through head flexion (Linder-Aronson, 1970; Behlfelt *et al.*, 1990).

Although intra-cranial reference lines are widely used in cephalometric analysis, they have been shown to be inherently unreliable (Downs, 1956; Moorrees, 1995). In contrast, the long-term reproducibility of NHP has usually been shown to be good (Cooke and Wei, 1988b), with variance of NHP significantly less than the variance of intra-cranial reference planes (e.g. the Frankfort or sella–nasion plane) to the vertical over a 15 year period (Peng and Cooke, 1999). Indeed, a cephalometric analysis for skeletal pattern assessment involving the use of NHP was once proposed (Cooke and Wei, 1988a). However, it has recently been shown that the reproducibility assessment of NHP by means of the 'root mean square' formula (Dahlberg, 1940), so widely used by orthodontists, can prove misleading, as outliers are not readily identified (Bister *et al.*, 2002). Thus, NHP may not provide a totally reliable basis for individual diagnosis and treatment planning, but its use in the cephalometric assessment of groups of patients would still seem legitimate, permitting comparisons before and after treatment. This would also apply to the assessment of head and neck posture in different patient groups.

There are only a few studies that have investigated the possible relationship between orthognathic surgery and NHP. Of these, most have investigated the effect of mandibular surgery on head posture (Wenzel *et al.*, 1989; Achilleos *et al.*, 2000; Gu *et al.*, 2000). It has been shown that surgical setback of the mandible reduces nasopharyngeal airway size and increases head extension (Achilleos *et al.*, 2000). A study by Phillips *et al.* (1991) showed that a combination of maxillary impaction with mandibular advancement led to significant head flexion, 1 year after surgery. However, any relationship to a reduction in face height was not investigated. Schellhase (1984) found significant head flexion immediately after maxillary intrusion in a sample of 32 patients. Phillips *et al.* (1991) also reported that there were no significant changes in neck posture following five different orthognathic procedures. It should be noted that 'extension' could be due to a change in either head posture or neck posture, or a combination of the two.

In view of past evidence, it would seem possible that alteration of vertical face height by orthognathic surgery might well have an impact on head or neck posture. Following surgery to alter vertical face height, the cranio-cervical angle might be expected to change. Accordingly, the purpose of this study was to determine whether there was a relationship between the change in face height following orthognathic surgery and cranio-cervical angulation.

Subjects and methods

All patients included in this study were adults who had completed their growth. The records of 33 patients who had previously undergone orthognathic surgery at the Maxillofacial Unit, Queen Mary's Hospital, Roehampton, London, UK were retrospectively selected on the basis of the following criteria:

1. Availability of pre-surgery and a minimum of 6 months post-surgery lateral cephalograms taken in NHP between 1997 and 2002, with all cephalograms to include the second cervical vertebrae. A 6 month minimum time interval between surgery and the last cephalogram was required in order to minimize any effects from post-operative swelling.
2. Only those patients who had received routine orthognathic treatment for a skeletal base relationship anomaly were included; syndromic patients or those with cleft palate were excluded.
3. All subjects had undergone both a Le Fort I maxillary osteotomy and a mandibular bilateral sagittal split osteotomy, 15 had a mandibular advancement and 18 a mandibular setback. Patients who had received genioplasties were not included in the study, due to any resultant effect on vertical face height.

The age range of the patients was 16–40 years (median 21 years). There were 10 males and 23 females. The heights of the younger patients had been checked to ensure growth had ceased.

Protocol for head posture

A slightly modified protocol to that recommended by Solow (1994) was followed: the patients were asked to stand in the cephalostat and then to walk on the spot and tilt their head forwards and backwards with decreasing amplitude until a natural head balance was reached and to look straight into their eyes in a mirror mounted straight ahead. The head holder was then adjusted until the ear rods could be positioned into the ears without moving the patient. The radiograph was then taken. The above procedure was repeated if the patient's position changed during the adjustment of the ear rods. No occipital support was used.

Radiography

A Proline 2002 CC (Planmeca, Helsinki, Finland) was used to take all the lateral cephalograms. The film distance to the X-ray tube was fixed at 160 cm and the film distance to the mid-sagittal plane of the patient's head at 18 cm. The resulting magnification was 10 per cent. The films were exposed at 68–70 kV, 12 mAs and a filter of 2.5 mm aluminium equivalent was used. For definition of the true vertical, a 0.5 mm lead wire suspending a weight was used, and ear rods for identification of the transverse plane.

Lateral cephalograms

The cephalograms were traced and the landmarks identified by one operator (DS). From each cephalogram, the anterior total face height (ATFH = sum of the distance nasion to maxillary plane plus menton to maxillary plane), the ratio of LAFH/ATFH, the cranio-cervical angle (NSL/OPT) and cranio-vertical angle (NSL/VER) were measured (Figure 1). Using mean values for vertical dimension from Bhatia and Leighton's (1993) growth study material, the patients were grouped by the amount of change in vertical face height. In group 1 were those with a change greater than 0.5 standard deviation (SD 3 mm) and in group 2 those with less than 0.5 SD (3 mm) of change. Eighteen of these patients had more than 3 mm (0.5 SD) of vertical change in ATFH following surgery and the remainder (15) had less than 3 mm of change. All but one subject in group 1 had a reduction in ATFH, ranging from 3 to 10 mm. Nine of the patients in group 2 had a reduction in ATFH, two had no change and four had an increase in ATFH. Of the patients in group 1, eight had a mandibular advancement and 10 a mandibular setback, and in group 2 the numbers were seven and eight, respectively.

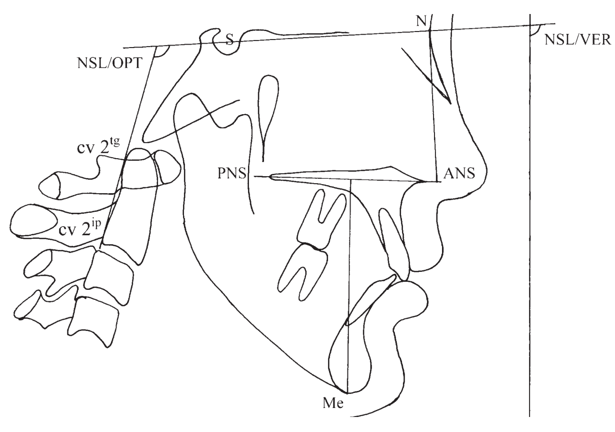

Figure 1 The cephalometric points traced. ATFH, anterior total face height: sum of the distance nasion (N) to maxillary plane plus menton (Me) to maxillary plane; ANS, anterior nasal spine; PNS, posterior nasal spine; LAFH/ATFH, ratio of lower anterior face height and ATFH; NSL/OPT, cranio-cervical angle; NSL/VER, cranio-vertical angle; OPT, tangent to the odontoid process in the upper cervical column based on: cv 2^{tg}, tangent point of OPT on the odontoid process; cv 2^{ip}, most inferior/posterior point on the second cervical vertebra corpus.

Reproducibility of NHP

The lateral cephalograms used in this investigation were taken in NHP, by two radiographers. The repeatability of the first radiographer's approach has previously been reported (Bister *et al.*, 2002). Using a photographic technique, it was found that repeatability coefficients for the facial plane and the E-plane were 4.00 and 4.15, respectively. A similar method was used in this study to assess the repeatability of the second radiographer's technique.

Statistical methods

Tests for association between the change in vertical face height (both ATFH and the LAFH/ATFH ratio) and the change in both cranio-cervical (NSL/OPT) and cranio-vertical posture (NSL/VER) were performed using Pearson's correlation coefficient. Assessment of the repeatability of the photographs (NHP), as well as of the tracings of the lateral cephalograms, was undertaken using coefficients of repeatability and the limits of agreement approach of Bland and Altman (1986). Statistical tests were performed using Excel (Microsoft Corporation, Seattle, Washington, USA) and Minitab (Minitab Inc., State College, Pennsylvania, USA).

Results

Table 1 shows the results for the 18 patients who had a minimum of 3 mm of vertical change following surgery (group 1) as well as those for the 15 patients who had less than 3 mm of vertical change (group 2).

Comparison of the two groups (Table 2) reveals that for group 1 there was a significant relationship between ATFH change and NSL/OPT angle change (r = 0.532, P = 0.023). This is in contrast to group 2 (r = –0.247, P = 0.376).

A similar relationship was revealed between the change in the LAFH/ATFH ratio and in NSL/OPT angle, where the

Table 1 The relationship of change in face height to cranio-cervical and cranio-vertical angulation.

	ATFH (mm)			LAFH/ATFH			NSL/OPT (°)			NSL/VER		
	Pre-surgery	Post-surgery	Change	Pre-surgery	Post-surgery	Change	Pre-surgery	Post-surgery	Change	Pre-surgery	Post-surgery	Change
Group 1												
1	127.0	123.0	–4.0	0.567	0.593	0.026	95.5	87.0	–8.5	104.0	101.0	–3.0
2	148.0	142.0	–6.0	0.588	0.620	0.032	94.5	91.0	–3.5	99.0	96.0	–3.0
3	135.5	132.5	–3.0	0.572	0.581	0.009	84.0	84.0	0.0	88.0	94.0	6.0
4	133.5	129.0	–4.5	0.573	0.574	0.001	110.0	106.5	–3.5	102.5	104.0	1.5
5	140.0	135.0	–5.0	0.550	0.593	0.043	111.0	102.0	–9.0	93.0	95.0	2.0
6	121.0	118.0	–3.0	0.562	0.576	0.014	86.0	86.0	0.0	90.0	89.0	–1.0
7	131.0	128.0	–3.0	0.550	0.555	0.005	103.0	104.0	1.0	101.5	102.0	0.5
8	131.0	125.0	–6.0	0.576	0.576	0.000	98.0	102.0	4.0	101.0	101.0	0.0
9	134.5	129.0	–5.5	0.554	0.581	0.027	108.5	107.0	–1.5	108.0	107.0	–1.0
10	135.0	132.0	–3.0	0.556	0.560	0.004	93.0	93.0	0.0	94.0	96.0	2.0
11	129.0	125.0	–4.0	0.543	0.584	0.041	110.0	107.0	–3.0	109.5	102.0	–7.5
12	136.0	126.0	–10.0	0.580	0.611	0.031	117.5	105.0	–12.5	99.0	95.0	–4.0
13	133.0	126.5	–6.5	0.549	0.565	0.016	102.0	100.0	–2.0	94.0	87.0	–7.0
14	151.5	148.0	–3.5	0.571	0.551	–0.020	102.5	100.0	–2.5	94.5	98.0	3.5
15	130.5	121.0	–9.5	0.533	0.554	0.021	106.0	101.0	–5.0	106.0	103.0	–3.0
16	128.0	120.5	–7.5	0.602	0.593	–0.009	86.0	84.5	–1.5	86.0	86.0	0.0
17	134.0	127.0	–7.0	0.567	0.567	0.000	112.5	114.5	2.0	112.0	104.0	–8.0
18	123.0	126.0	3.0	0.549	0.540	–0.009	101.5	106.5	5.0	96.0	96.0	0.0
Group 2												
19	122.5	121.0	–1.5	0.555	0.554	–0.001	96.5	98.0	1.5	104.0	99.0	–5.0
20	149.0	147.0	–2.0	0.591	0.585	–0.006	111.0	115.0	4.0	104.0	107.0	3.0
21	113.0	114.0	1.0	0.575	0.574	–0.001	91.0	95.0	4.0	90.0	98.0	8.0
22	128.0	130.0	2.0	0.531	0.538	0.007	93.0	93.0	0.0	91.0	92.0	1.0
23	124.0	123.0	–1.0	0.597	0.593	–0.004	101.0	97.0	–4.0	88.0	92.0	4.0
24	134.5	132.5	–2.0	0.561	0.558	–0.003	108.0	110.0	2.0	98.0	96.0	–2.0
25	131.0	131.0	0.0	0.565	0.561	–0.004	105.0	104.0	–1.0	99.0	98.0	–1.0
26	126.0	123.5	–2.5	0.603	0.583	–0.020	105.0	105.0	0.0	95.5	97.0	1.5
27	119.5	118.0	–1.5	0.527	0.576	0.049	103.0	97.5	–5.5	98.0	92.5	–5.5
28	115.0	117.0	2.0	0.557	0.543	–0.014	120.0	112.0	–8.0	99.0	102.0	3.0
29	121.0	120.0	–1.0	0.537	0.550	0.013	119.0	119.5	0.5	106.0	104.0	–2.0
30	119.0	121.0	2.0	0.555	0.603	0.048	95.0	95.0	0.0	102.0	101.0	–1.0
31	125.0	123.0	–2.0	0.576	0.553	–0.023	98.0	98.0	0.0	96.0	99.0	3.0
32	122.0	121.0	–1.0	0.566	0.554	–0.012	82.0	88.0	6.0	99.0	103.0	4.0
33	121.0	121.0	0.0	0.529	0.554	0.025	101.5	103.0	1.5	91.0	99.0	8.0

ATFH, anterior total face height; LAFH, lower anterior face height.
Group 1 (1–18), patients who had at least 3 mm of vertical change in ATFH; group 2 (19–33), patients who had less than 3 mm of vertical change in ATFH.

Table 2 The relationships between anterior total face height (ATFH), lower anterior face height (LAFH)/ATFH, NSL/OPT and NSL/VER in groups 1 and 2.

	ATFH	LAFH/ATFH
Group1		
NSL/OPT	r = 0.532, P = 0.023	r = –0.635, P = 0.005
NSL/VER	r = 0.406, P = 0.095	r = –0.392, P = 0.108
Group 2		
NSL/OPT	r = –0.247, P = 0.376	r = –0.182, P = 0.515
NSL/VER	r = 0.239, P = 0.391	r = –0.338, P = 0.218

correlation was also higher (r = –0.635, P = 0.005) than in group 2 (r = –0.182, P = 0.515, not significant). In group 1 the mean change in NSL/OPT angulation was a reduction of 3.6 degrees, SD 3.41 (flexion), and in group 2, 2.5 degrees, SD 2.56 (flexion).

Regarding face height reduction and cranio-vertical angulation (ATFH and NSL/VER), for group 1 patients the correlation was not significant (r = 0.406, P = 0.095). This also applied to group 2 patients (r = 0.239, P = 0.391). Additionally, the LAFH/ATFH and NSL/VER correlation for the two groups was not significant (r = –0.392, P = 0.108 and r = –0.338, P = 0.218, respectively).

Regression graphs (Figure 2) indicate the response of the angle NSL/OPT to a change in face height for group 1. The relationship between ATFH (overall face height) and NSL/OPT was such that with a decrease in overall face height there was a corresponding decrease in the angle NSL/OPT (Figure 2a). With an increase in the ratio LAFH/ATFH there was a corresponding decrease in the angle NSL/OPT (Figure 2b).

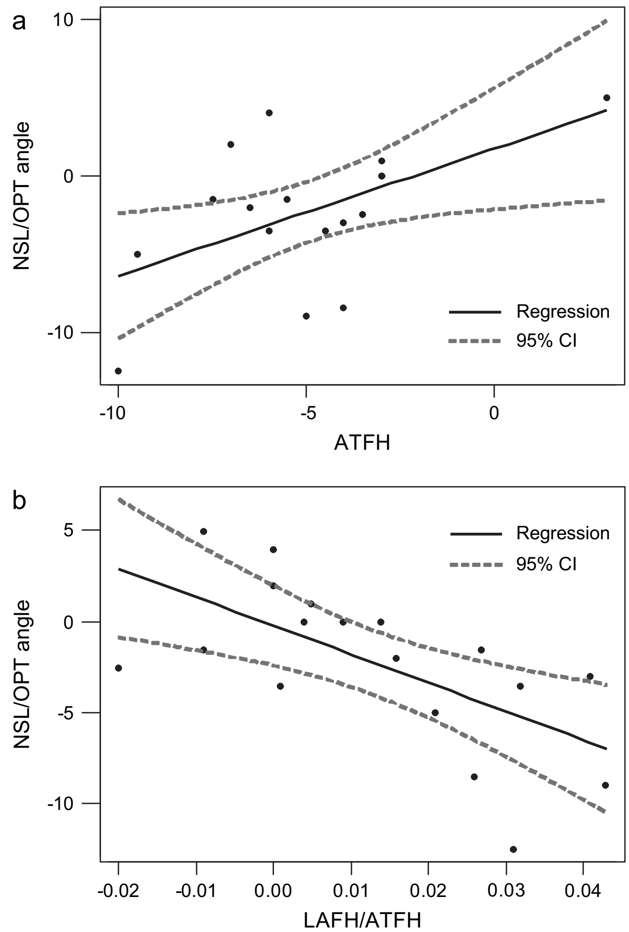

Figure 2 Regression graphs showing (a) the relationship of change in NSL/OPT angle to the change in ATFH and (b) the relationship of change in NSL/OPT angle to the change in LAFH/ATFH ratio.

Repeatability

NHP.

With reference to the second radiographer's technique, the repeatability coefficients were 3.60 and 4.00 for the facial plane and E-line, respectively. Using the one-sample t-test, the differences with respect to zero were not significant (P > 0.05). Method error as assessed using Dahlberg's (1940) formula was 1.2 for the soft tissue facial plane/true vertical and 1.4 for the E-plane/true vertical.

Cephalometric tracing error.

Two approaches were used. After an interval of 1 month, 18 cephalograms were retraced and remeasured. The SD of the repeat measurements for ATFH was 0.9 and the mean difference –0.4 and for LAFH/ATFH ratio, the SD of the repeat measurements was 0.005 and the mean difference 0.003. For NSL/OPT, the SD of the repeat measurements was 1.2 and the mean difference 0.2. Using the one-sample t-test, the differences with respect to zero were not significant (P > 0.05), except for the LAFH/ATFH difference (P = 0.043). LAFH/ATFH results show that the maximum difference in the ratio was approximately 0.01.

An alternative approach to estimating error was also used, in order to take into account the possibility of errors arising after more than just one interval between measurements. Five films, taken randomly from group 1, were re-traced on five separate occasions (over a 5 week period). The results are shown in Table 3. The median range for ATFH was 2.0 mm, for the LAFH/ATFH ratio 0.014, and for NSL/OPT 2.0 degrees.

Photographic tracing error.

The SD of differences for tracing the facial plane was 0.7 and E-plane was 0.6 in series 1, and 0.7 for the facial plane and E-plane in series 2.

Discussion

While the mean change in neck posture (NSL/OPT) of 3.6 degrees in group 1 was broadly similar to post-surgical

Table 3 Tracing repeatability for five randomly chosen lateral cephalograms traced on five separate occasions.

	ATFH (mm)	Range	Mean	LAFH/ATFH (%)	Range	Mean	NSL/OPT (°)	Range	Mean
1	135.5			0.572			84.0		
Pre-surgery	136.0			0.574			83.5		
	136.0			0.566			85.0		
	136.0	2.0	136.3	0.574	0.018	0.571	83.0	2.0	83.9
	137.5			0.571			84.0		
	136.5			0.568			84.0		
2	118.0			0.576			86.0		
Post-surgery	118.0			0.576			84.5		
	118.5			0.574			84.0		
	119.5	1.5	118.4	0.569	0.014	0.571	85.0	2.0	85.0
	118.5			0.562			84.5		
	118.0			0.568			86.0		
3	151.5			0.571			102.5		
Pre-surgery	150.0			0.573			102.0		
	151.5			0.578			103.0		
	150.5	2.0	151.2	0.575	0.008	0.574	101.0	2.5	102.0
	152.0			0.579			100.5		
	151.5			0.578			103.0		
4	126.5			0.565			100.0		
Post-surgery	126.5			0.561			98.0		
	127.0			0.563			98.0		
	126.0	2.0	126.8	0.563	0.004	0.564	98.0	2.0	98.8
	127.0			0.566			100.0		
	128.0			0.563			99.0		
5	134.0			0.567			112.5		
Pre-surgery	133.0			0.556			115.0		
	133.0			0.556			114.0		
	134.0	1.5	133.3	0.567	0.014	0.563	113.0	3.5	113.0
	132.5			0.570			112.0		
	133.0			0.564			111.5		
Median		2.0			0.014			2.0	

ATFH, anterior total face height; LAFH, lower anterior face height

change recorded and considered significant in other investigations (Phillips *et al.*, 1991; Achilleos *et al.*, 2000), it is not possible to make comparisons with other studies, as it appears that the relationship between face height change and head/neck posture has not previously been investigated.

At least one study involving patients who had undergone maxillary impaction found an immediate head flexion after surgery, followed by a return to pre-treatment values after 1 year (Schellhase, 1984). Wenzel *et al.* (1989) found a significant correlation between the change in mandibular morphology due to surgery and head posture. It has also been suggested that an increase in cranio-cervical extension (as measured by an increase in NSL/OPT angle) provides a compensatory mechanism to maintain airway adequacy following mandibular setback surgery (Achilleos *et al.*, 2000).

One study that examined relapse following mandibular setback for prognathism correlated hyoid position, head posture and mandibular morphology (Gu *et al.*, 2000). The majority of relapse occurred within 6 months of surgery; head posture was found to be 'raised' (presumably, extended) and the hyoid bone moved downward and backward, suggesting that a mandibular setback alters the relationship between the hyoid position, head posture and pharyngeal airway.

As indicated, there appears to be a relationship between a reduction in vertical face height following orthognathic surgery and neck posture (as indicated by the cranio-cervical angle NSL/OPT), in those patients who had a minimum of 3 mm of change in vertical face height. There was no significant relationship between a reduction in face height and 'head' posture as shown in the cranio-vertical angle (NSL/VER).

Dahlberg's (1940) formula is commonly used to assess NHP repeatability. However, a particular limitation of that method is that the effect of 'outliers' can be masked, leading to an apparently acceptable level of error that may not be justified (Bister *et al.*, 2002). This is illustrated by the very acceptable Dahlberg scores achieved (1.2 and 1.4 for the soft tissue facial plane and aesthetic plane, respectively), which failed to reveal an existing outlier. Bland and Altman's (1986) method has been found to be most appropriate for method agreement and was used in this study. Accordingly, while it may not be appropriate to rely on cranio-vertical measurements when planning treatment, or recording treatment changes in an individual patient (who may be an outlier), it may be perfectly legitimate to use cranio-cervical measurements when making comparisons between groups of patients, where the effect of a lone outlier would be ameliorated.

Conclusions

1. Following orthognathic surgery there was evidence of a relationship between a reduction in vertical face height and cranio-cervical angle in those patients who underwent a minimum of 3 mm of change in vertical face height.
2. There was no significant change in cranio-vertical angle with a reduction in face height, indicating that it is neck posture, rather than head posture, that had changed.
3. The repeatability of all measurements was found to be acceptable.

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