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A jig for measuring incisor inclination

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SUMMARY The aim of this study was to design and construct a jig for measuring the inclination of the upper incisors to the maxillary plane and of the lower incisors to the mandibular plane.

After several prototypes had been tested, the required properties for a successful jig were identified and a simple inexpensive device was produced. Measurements obtained when using the jig on 51 subjects were compared with cephalometric values by means of regression analysis. This revealed that measurements obtained using the jig against the upper and then the lower incisor crowns could be converted to cephalometric incisor angulations with 96 per cent accuracy to 10 degrees, by adding 23 and 3 degrees, respectively. The jig was accurate to 5 degrees on 69 per cent of occasions for the upper teeth. The 5 degrees accuracy with the lower incisors was only 27 per cent, although over a 6 degree range it improved to 78 per cent. For upper and lower tooth measurements combined, the jig was accurate to within 6 degrees on 75 per cent of occasions.

Introduction

An understanding of the importance of incisor inclination is central to orthodontic diagnosis and treatment. Downs (1948) and Steiner (1953) first suggested the concept of ideal or standard inclinations for upper and lower incisors. Over the succeeding years, studies have demonstrated a remarkable uniformity for incisor inclinations in Caucasian populations, with mean values derived from 15 studies found to be 109 degrees for the inclination of the upper incisors to the maxillary plane (UIA) and 93 degrees for the inclination of the lower incisors to the mandibular plane (LIA) (Hamdan and Rock, 2001). Along with the position on the palatal surface against which the lower incisors bite, the angle between the lower incisors and the palatal surface of the upper incisors (IIA) is an important factor for determining overbite stability. Backlund (1958) demonstrated that overbite stability at the end of treatment depended upon interaction between IIA and biting position; 20 degrees was a sufficient angle if a cingulum bite was achieved, but if the lower incisors were left contacting the palatal third of the upper teeth an angle of at least 50 degrees was required to prevent post-treatment over-eruption of the lower incisors.

Houston (1989) also believed that the anatomy of the palatal surface of the upper incisors influenced overbite stability, although his measurements were based on the relationship of the lower incisal edge to the root centroid of the upper incisor.

In addition to playing an important functional role in the determination of overbite stability, correct incisor inclination contributes to an attractive facial appearance, as exemplified by the work of Riedel (1957) based on a study of Seattle Seafair Princesses. For reasons of both function and appearance, it is therefore important to assess incisor inclinations before, during, and at the end of orthodontic treatment.

Accurate measurement of hard tissue relationships is possible only with the aid of radiographs. Unfortunately, the exposure of a patient to X-rays carries a small but quantifiable risk. For example, the dose of a lateral skull radiograph is 1–3 microsieverts, equivalent to 1–3 days of natural background radiation. This dose gives a cancer risk of 1:10 million (Faculty of General Dental Practitioners, 1998). Around 12 per cent of all radiation exposure in the UK is from medical sources and 100–250 UK cancer deaths each year may be due to diagnostic radiology (National Radiological Protection Board, 1990). Dental radiography constitutes around one-third of all medical exposure so that it is possible that dental X-rays may play a part in the deaths of 30–80 people annually in the UK. It follows that any method that could reduce the amount of radiation exposure while still allowing for accurate initial assessment and progress monitoring during orthodontic treatment would be of value.

The use of gauges to measure the incisor inclination and vertical jaw relationship directly from the patient, or from study models, has been investigated as a form of assessment alternative to radiographs. Measurements relevant to orthodontics were taken directly from the face by Salzmann (1945) using a device known as the maxillator. This was felt to be most useful for measuring the Frankfort–mandibular planes angle (FMPA) and LIA.

A clinical method for measuring incisor inclination must be based upon the crown, the labial face of which is easiest to visualize. However, the angle of the face of the incisor to the Frankfort plane is not the true axial inclination of the tooth crown, neither does it take into consideration the effects of crown/root angle upon the long axis of the whole tooth. Fredericks (1974) compared the angle between a tangent to the labial face of an upper incisor, measured on both extracted teeth and patients, with actual UIAs on radiographs. The difference was 23.9 degrees on extracted teeth and24.1 degrees on patients, an encouragingly high level of agreement.

Tebbett (1990) used standardized photographs to evaluate the most aesthetic labial face inclination of the upper central incisors. The ideal was 90 degrees to the maxillary plane, 19 degrees less than the standard radiographic UIA (Hamdan and Rock, 2001).

Richmond *et al.* (1998) used a tooth inclination protractor to obtain measurements of incisor inclination from study models. Upper incisor inclination showed better correlation with values taken from cephalometric radiographs than did lower incisor inclination. Richmond and Jones (1985) and Richmond (1987) had previously used a reflex metrograph to build up a three-dimensional image of a study cast and from it measured incisor inclinations to the functional occlusal plane. Significant differences were found between values obtained from study models and those measured on radiographs.

The aim of the present study was to design and test a device with which to measure the inclination of the upper and lower incisors to their respective planes.

Materials and methods

The initial design criteria set for a jig to measure incisor inclinations in the mouth were that it should be accurate and reliable, of simple design, sterilizable and biocompatible. Size and weight must be such that it would be comfortable to use and have an easily read scale. Readings should be possible with or without the presence of a fixed appliance on the teeth so that measurements can be taken to assess the progress of treatment.

In the present study the first prototype gauge was based on a Perspex protractor glued onto a clear acrylic base (Figure 1). This design could be used only on the upper incisors and it was not possible to sterilize the device, which was disinfected using alcohol wipes. Neither was it possible to use it with an upper fixed appliance *in situ*.

Attempts were made to remedy these deficiencies in a series of four further prototype gauges. Tests using these confirmed the features that were essential to a successful design:

1. Positive location of the incisal edge of the tooth on the platform of the gauge.
2. Positive location of the measuring pointer against the labial face of the tooth.
3. Weight: the jig had to be light enough to be easily held.
4. Easily read.
5. Patient acceptance: some designs had brass arms as Frankfort plane indicators. These caused the subjects to flinch and lose natural head posture (NHP).

The final design was based on a plastic vernier calliper from an orthodontic products catalogue (Ortho Care UK Ltd, Bradford, West Yorkshire, UK, catalogue number 60.814). A replaceable notched platform was added to locate the incisal edge of the tooth (Figure 2). A movable lever arm contacted the labial face of the tooth and activated the dial.

Reliable incisor inclination measurement in the mouth depends upon several variables; perhaps the most fundamental of these is the need to establish a reproducible horizontal. Attempts to achieve this using occlusal plane indicators or spirit levels were found to be impractical and in the present study all measurements were taken using NHP to orientate the Frankfort plane parallel to the floor. NHP was established using a modification of the method recommended by Solow and Tallgren (1971). The subjects were first asked to walk around and relax before sitting in a dental chair in an upright position. Once seated, they were asked to tilt the head forwards and backwards with decreasing amplitude until a natural head balance was achieved.

Upper labial face inclination was measured to the Frankfort plane by first palpating orbitale and marking it with an adhesive paper dot. The jig was then held parallel to a straight edge between porion and orbitale to obtain a measurement (Figure 3). As both the ruler identifying the Frankfort plane and the jig were held by hand it was possible

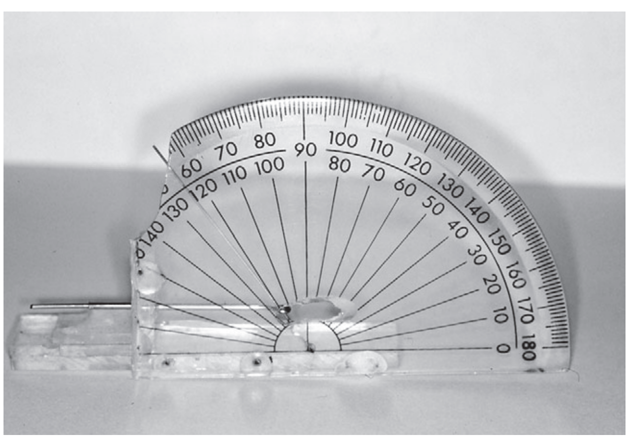

Figure 1 The first prototype incisor inclination gauge.

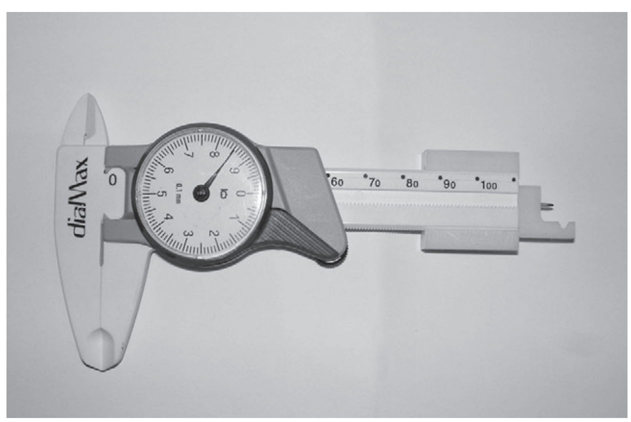

Figure 2 The incisor inclination gauge used in the study.

that inaccuracy may have been introduced into the method by positional variations of the ruler and the jig. Reproducibility was assessed by carrying out repeat measurements for 10 subjects. For the lower incisors the jig was held parallel to a straight edge along the lower border of the mandible.

Labial face inclination was calculated using Pythagoras' theorem. With the incisal edge of the tooth resting on the jig, the horizontal distance from a vertical to the labial face of the crown was measured at a fixed height so that the enamel surface formed the hypotenuse of a right-angled triangle. Labial face inclination was therefore the tangent of the horizontal distance divided by the vertical (Figure 4). In every case the most labially placed incisor was measured.

The measurements were taken from the teeth of 51 subjects as part of a new patient appointment at Queen's Hospital, Burton-on-Trent, UK. Ethical approval and patient consents were obtained. A pilot study on 26 subjects had revealed that standard deviations (SD) for the differences between clinical and radiographic measurements of incisor inclination were 8 degrees for both the upper and lower incisors. Acceptance of this as the maximum clinically acceptable variation would produce a standardized difference of 1 and suggest a sample size of 30 subjects for a study with a power of 80 per cent and 95 per cent probability (Altman, 1991). A SD of 5 degrees would have indicated a sample size of 75. As a compromise a sample size of 50 subjects was chosen.

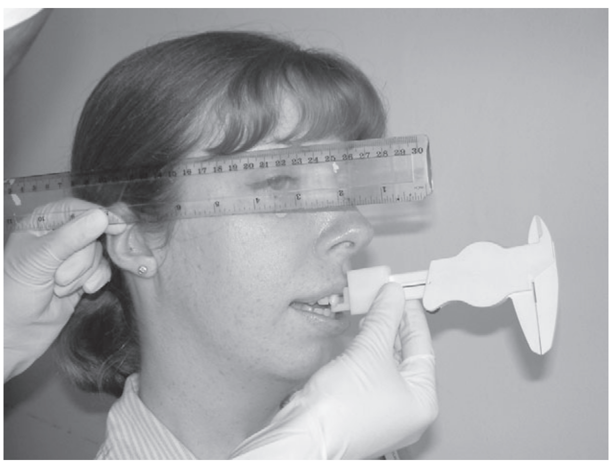

Figure 3 Upper incisor labial face angulation being measured on a subject.

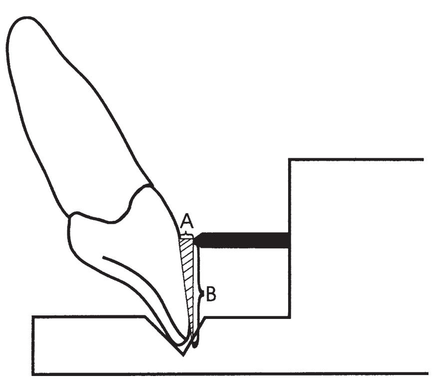

Figure 4 Calculation of upper labial face inclination. A = distance between the pointer zero and the tooth face; B = height of the pointer above the groove.

Using the incisor inclination gauge, two sets of readings were obtained, with an interval of at least 30 minutes between assessments. A cephalometric radiograph was taken at the same visit as part of the normal assessment procedure. Each radiograph was traced on two occasions 1 week apart, with appropriate blinding of the examiner, to allow the measurement of radiographic upper and lower incisor inclination. Measurements for the labial face inclinations of the upper and lower incisors obtained using the jig were then compared with the true values of the long incisor axes, as measured from the radiographs, by means of linear regression analysis, with the jig measurement as the predictor and the true cephalometric value as the response. Using the relevant regression equation it was then possible to calculate a predicted incisor inclination on the basis of the labial face inclination recorded by the jig.

Results

No significant differences were found between any clinical or radiological double determination. In each case, therefore, an average between each pair of readings was taken. The linear regression coefficients for each pair of jig and cephalometric measurements are shown in Table 1. The regression plots are shown in Figure 5a, b.

The overall results are presented in Table 2, which shows cephalometric values (UIA and LIA), jig labial face inclinations (ULFA and LLFA) and values calculated from them by application of the regression equation (Jig UIA and Jig LIA). The differences between the cephalometric incisor inclinations and those calculated from the jig measurements are also shown in Table 2. Descriptive statistics for these last values are provided in Table 3.

Discussion

During clinical use of the jig, each subject was positioned in the NHP. NHP may be obtained with the subject either seated or standing, and studies have shown that it is reproducible, with differences varying between 1.4 and 2.7 degrees (Solow and Tallgren, 1971; Siersbæk-Nielsen and Solow, 1982; Cooke and Wei, 1988). In the present study, NHP was supplemented by the use of a straight edge along the Frankfort plane when measuring upper labial face

Table 1 Results of the regression analysis between clinical and radiographic measurements.

Regression equation	R-Sq (per cent)
UIA = 21.79 + 1.06 Jig ULFA	47.1
LIA = 1.81 + 1.05 Jig LLFA	45.6

UIA, LIA, cephalometric incisor inclinations; Jig ULFA, Jig LLFA, labial face inclinations measured using the jig.

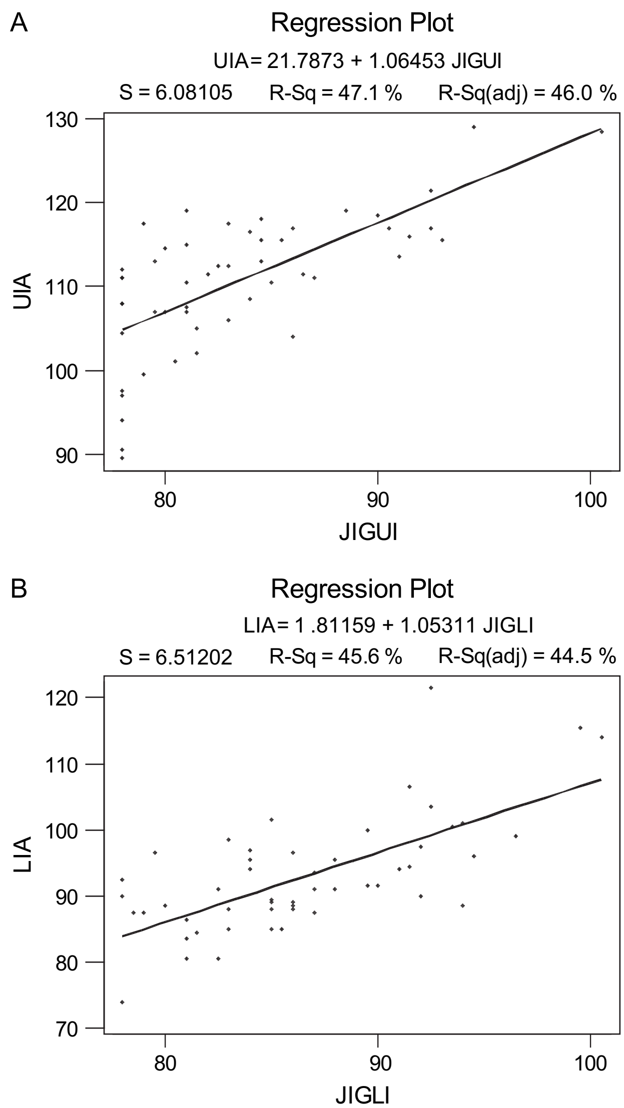

Figure 5 Regression plots for clinical and radiological angulation measurements. (a) Upper incisors, (b) lower incisors.

inclination so that the head position was not critical, although it was felt to be a useful aid to reproducibility.

The formulae produced by the regression analysis for the conversion of labial face inclinations to true cephalometric incisor inclinations were reasonably straightforward. With minimal rounding of the results in Table 1, Jig ULFA is converted to the relevant UIA by adding 23 degrees, a finding that agrees very closely with that of Fredericks (1974). For a lower incisor, 3 degrees must be added. The R-sq values of 47.1 and 45.6 per cent were acceptable in the context of the study, the aim of which was to produce and test a non-invasive method for measuring incisor angulations with reasonable accuracy.

Cephalometric UIAs ranged from 89.5 to 129 degrees, while Jig UIAs calculated by applying the regression equation to upper incisor labial face inclinations ranged from 104 to 128 degrees. Thirty-five (69 per cent) of the calculated values were within 5 degrees of the true cephalometric value, while 48 (94 per cent) were within 10 degrees.

Little information is available concerning the normal angulations of the upper incisors to the Frankfort plane as the much more reliable maxillary plane is more often used, the mean UIA to which is 109 degrees (Hamdan and Rock, 2001). For the 19 subjects with a cephalometric UIA below this value, the differences between true and calculated UIAs ranged between 4 degrees low and 14.5 degrees high, with a mean error of 4.1 degrees high. Calculated UIAs for the 32 subjects with UIAs above 109 degrees ranged from 8 degrees low to 7.5 degrees high, with a mean of 1.3 degrees below the true value. These figures suggest that the jig tended to overestimate the angulations of retroclined upper incisors and slightly underestimate the angulations of proclined teeth.

Jig LIAs for cephalometric values below the norm of 93 degrees ranged from 8.5 degrees low to 11.5 degrees high with a mean error of 4.6 degrees high. The range for cephalometric LIAs above 93 degrees was from 23.5 degrees low to 6.5 degrees high with a mean error of zero. The most inaccurate jig-based value was obtained for a subject with a cephalometric LIA at the unusually high value of 121.5 degrees. If this is ignored the range with respect to calculated lower incisor angles is from 10.5 degrees low to 11.5 degrees high.

Only 27 per cent of the lower incisor inclinations calculated from jig measurements were within 5 degrees of the cephalometric value but over a range of 6 degrees, accuracy was 78 per cent. This last finding suggests that the present jig has promise and could be developed further.

Conclusions

The results of the study show that the inclinations of the upper and lower incisors arrived at after using the jig were accurate to within 10 degrees of the cephalometric value on 96 per cent of occasions and to within 6 degrees on 76 per cent of occasions. Further research is planned in an attempt to identify the type of subject for whom the jig was less accurate and to produce a design to overcome the problem.

Table 2 Values for cephalometric upper (UIA) and lower (LIA) incisor inclinations and corresponding values calculated from jig measurements.

Subject	UIA	Jig ULFA	Jig UIA	Col 1/3 Difference	LIA	Jig LLFA	Jig LIA	Col 5/7 Difference
1.	107.0	81.0	108	1.0	85.0	83.0	89	4.0
2.	94.0	78.0	104	10.0	90.0	92.0	98	8.0
3.	106.0	83.0	110	5.0	89.0	86.0	92	3.0
4.	111.5	86.5	113	1.5	101.0	94.0	100	–1.0
5.	108.0	78.0	104	–4.0	88.5	94.0	100	11.5
6.	97.0	78.0	104	7.0	84.5	81.5	87	2.5
7.	113.0	84.5	111	–2.0	87.5	87.0	93	5.5
8.	112.5	82.5	109	–3.5	92.5	78.0	84	–8.5
9.	114.5	80.0	107	–7.5	89.0	85.0	91	2.0
10.	111.0	78.0	104	3.0	85.0	85.0	91	6.0
11.	108.0	78.0	104	–4.0	100.5	93.5	100	–0.5
12.	116.0	91.5	119	3.0	87.5	79.0	85	–2.5
13.	112.5	83.0	110	–1.5	94.0	84.0	90	–4.0
14.	102.0	81.5	108	6.0	97.5	92.0	98	0.5
15.	111.5	82.0	109	–2.5	103.5	92.5	98	–5.5
16.	107.5	81.0	108	0.5	101.5	85.0	91	–10.5
17.	128.5	100.5	128	–0.5	121.5	92.5	98	–23.5
18.	112.0	78.0	104	–8.0	91.0	82.5	88	–3.0
19.	118.0	84.5	111	–7.0	94.5	91.5	98	3.5
20.	89.5	78.0	104	14.5	94.0	91.0	97	3.0
21.	117.5	83.0	110	–6.5	96.0	94.5	100	4.0
22.	99.5	79.0	106	6.5	91.0	88.0	94	3.0
23.	105.0	81.5	108	3.0	106.5	91.5	98	–8.5
24.	111.0	87.0	114	3.0	114.0	100.5	107	–7.0
25.	129.0	94.5	122	–7.0	95.5	84.0	90	–5.5
26.	117.0	86.0	113	–4.0	96.5	78.5	85	5.5
27.	116.5	84.0	111	–4.5	89.5	85.0	91	6.0
28.	113.0	79.5	106	–7.0	83.5	81.0	87	6.0
29.	117.5	79.0	106	–1.5	95.5	88.0	94	6.0
30.	97.5	78.0	104	6.5	80.5	81.0	87	6.0
31.	113.5	91.0	118	4.5	86.5	81.0	87	6.0
32.	115.5	93.0	120	4.5	91.5	89.5	96	6.5
33.	115.5	85.5	112	–3.5	93.5	87.0	93	6.0
34.	90.5	78.0	104	14.5	85.0	85.5	92	6.5
35.	108.5	84.0	110	1.5	100.0	89.5	96	6.5
36.	117.0	90.5	118	1.0	97.0	84.0	90	6.0
37.	104.0	86.0	113	9.0	74.0	78.0	84	6.0
38.	118.5	90.0	117	–1.5	115.5	99.5	106	6.5
39.	107.0	79.5	106	–1.0	88.5	86.0	92	6.0
40.	119.0	88.5	116	–3.0	88.0	86.0	92	6.0
41.	115.5	84.5	111	–4.5	88.0	83.0	89	6.0
42.	117.0	92.5	120	3.0	96.5	86.0	92	6.0
43.	101.0	80.5	107	6.0	88.5	80.0	86	6.0
44.	119.0	81.0	108	–1.0	91.5	90.0	96	6.0
45.	110.5	81.0	108	7.5	87.5	78.5	84	5.5
46.	115.0	81.0	108	3.0	80.5	82.5	88	5.5
47.	110.5	85.0	112	1.5	91.0	87.0	93	6.0
48.	107.0	80.0	107	0.0	99.0	96.5	103	6.5
49.	121.5	92.5	120	–1.5	88.0	85.0	91	6.0
50.	111.0	78.0	104	3.0	90.0	78.0	84	6.0
51.	104.5	78.0	104	–0.5	98.5	83.0	89	6.0

Jig ULFA, Jig LLFA, labial face inclinations measured using the jig; Jig UIA, Jig LIA, incisor inclinations calculated by applying the relevant regression equation to Jig ULFA and Jig LLFA.

Table 3 Differences between cephalometric and jig measurements.

	Mean (degrees)	SD	Range
Upper incisors	0.8	5.3	–8.0 to 14.5
Lower incisors	2.6	6.2	–23.5 to 11.5

SD, standard deviation.

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