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Assessing incisor inclination: a non-invasive technique

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SUMMARY A method of recording incisor inclination is described using the Tooth Inclination Protractor (TIP). This instrument was used to record incisor inclination on dental casts. The scores were related to traditionally determined inclinations for the upper incisor to maxillary plane and the lower incisor to mandibular plane from the lateral cephalometric radiograph.

The TIP scores were closely related to the upper incisor to maxillary plane angle and lower incisor to mandibular plane angle. There was a systematic bias between the TIP and radiographically determined assessments. The TIP under-scored the lateral cephalometrically determined maxillary incisor inclination by 10.46 degrees and consistently over-scored the lower mandibular incisor angulation by 2.57 degrees.

The TIP is a reliable and valid measure for assessing left and right maxillary and mandibular crown inclinations, and may also be used to record changes of incisor inclination during treatment.

Introduction

The evaluation of maxillary and mandibular incisor inclination is an important aspect of orthodontic treatment planning, assessing treatment progress, as well as determining treatment outcome. Incisor inclination has traditionally been assessed by lateral cephalometric radiographic analysis. However, lateral cephalometric radiograph derived axial inclinations of incisors are prone to relatively large digitizing errors (Baumrind and Frantz, 1971a,b; Houston, 1983). In addition, ionizing radiation may cause a small, but significant mitotic risk (Wall and Kendal, 1983).

Dental casts have been useful in assessing tooth and arch parameters (Currier, 1971; Musich and Ackerman, 1973), arch asymmetry (Grueberg, 1912; Friel, 1914), and arch length (Nance, 1947). Few studies have utilized dental casts to assess incisor inclination. Carey (1952) used an incisor angulator whilst Lundström (1955) used a slide gauge. Three-dimensional assessment techniques and contour tracers have also been employed (Lear, 1976; Richmond and Jones, 1985; Richmond, 1987). Techniques have also been described relating study casts to lateral cephalometric radiographs (Bennett and Smales, 1968; Perera, 1981). However, none of these techniques is routinely used as they may be unreliable, costly, time-consuming, and require experienced personnel to record and process the data.

The aim of this study was to develop a valid, reliable, simple, inexpensive, and non-invasive method to record incisor inclination and compare it with the traditional lateral cephalometrically-derived angulations.

Materials and methods

The Tooth Inclination Protractor (TIP)

The Tooth Inclination Protractor (TIP) was developed to record the inclination of the maxillary and mandibular incisors on dental casts. The device consists of a perspex platform with a standard 180-degree protractor supported below. The platform was perforated to receive a hollow stainless steel tube with a retractable 0.5 mm wire inserted into it. The wire could be extended or shortened to lie against the labial surface of the incisor allowing for anatomical variation in crown height. Below the platform the other end

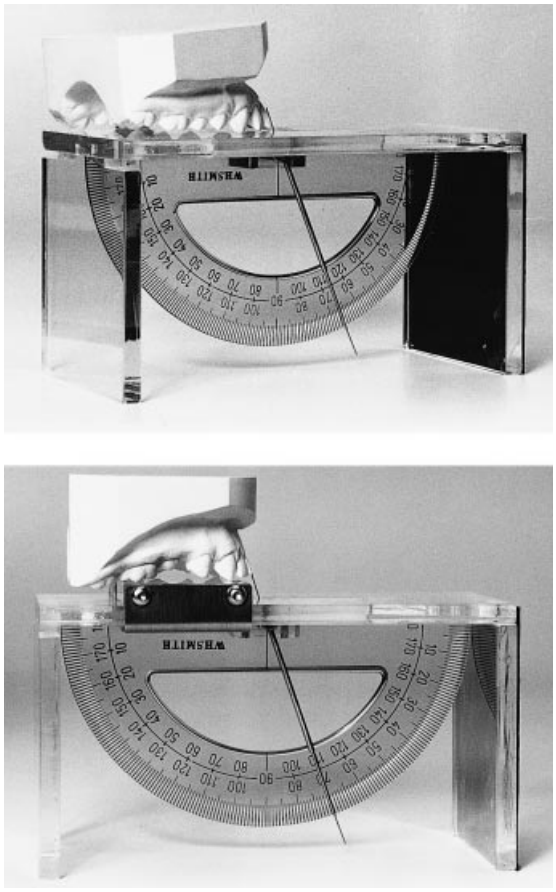

Figure 1 The Tooth Inclination Protractor recording the upper right incisor inclination (113 degrees) and lower left incisor inclination (110 degrees).

of the wire rested against the graduated scale of the protractor. The reading on the scale reflected the inclination of the labial face of the upper and lower incisors to their respective occlusal planes.

Recording procedure

The dental cast was placed on the platform so that the first molars were in contact with it (Figure 1). In the situation where there was a deep curve of Spee, the dental cast was positioned at a tangent to the deepest part of the curve in the premolar region using the additional moveable table on the platform. This table prevented unwanted contact at the heels or incisors of the dental casts. The wire pointer was then placed against the labial surface of the upper and lower incisors at their maximum bulbosity, so that the area above and below the contact was equal. The inclination was read off the graduated scale. Both left and right upper and lower incisor inclinations to the occlusal plane were assessed.

With regard to the orientation of the model, however, the technique is not without flaws, which require further evaluation. This is being investigated in future prospective trials of this technique.

Digitization of lateral cephalometric radiographs

Ten landmarks were digitized on the lateral cephalometric radiographs (anterior nasal spine, posterior nasal spine, gonion, menton, and the respective tip and root apex of the upper and lower incisors). The angles constructed were upper and lower incisor inclination to the respective maxillary and mandibular planes.

The sample

A sample of 47 upper and lower dental casts, and corresponding lateral cephalometric radiographs was collected to create a wide range of upper and lower incisor inclinations for both radiographic and dental cast measurement. The sample included 12 Class I, 13 Class II division 1, 10 Class II division 2, 10 Class III, and two anterior open bite cases.

The examiners

Three examiners with orthodontic qualifications digitized the eight landmarks and six examiners (five orthodontists and one non-dentist) recorded the incisor inclinations using the TIP. The assessments were repeated after an interval of 4 weeks to assess reliability.

Statistical analysis

Assessment of reliability. The 47 dental casts and radiographs were measured on two separate occasions 1 month apart. To assess intra-examiner error the root mean square (RMS =

Table 1 Intra- and inter-examiner reliability for dental cast and lateral cephalometric radiograph estimations of incisor inclination.

Dental cast and lateral cephalometrically determined radiograph assessments	Intra-examiner reliability (RMS)								Inter-examiner reliability
	Examiners								
	1	2	3	4	5	6	Mean	SD	Intraclass correlation coefficient
Dental cast									
Upper right incisor crown to occlusal plane	1.9	1.9	2.3	2.4	2.8	2.1	2.2	0.9	0.92
Upper left incisor crown to occlusal plane	1.7	2.7	2.6	2.5	3.6	2.6	2.6	0.8	0.91
Lower left incisor crown to occlusal plane	3.8	1.7	2.7	2.8	4	1.5	2.7	0.6	0.82
Lower right incisor crown to occlusal plane	2.7	1.3	2.7	3.5	3.2	1.7	2.5	0.3	0.87
Lateral cephalometric radiograph									
Upper incisor to palatal plane	2.6	1.7	2.9				2.4	0.5	0.82
Lower incisor to mandibular plane	1.9	1.4	3.6				2.3	1.0	0.85

$\Sigma d^2/2n$) was employed. To assess inter-examiner error the intraclass correlation coefficient was used (Fleiss, 1986).

Validity. The traditional cephalometric radiographic assessments were considered as the standard technique. A linear regression analysis was used to assess the association between the lateral cephalometric radiograph scores and TIP measurements. Systematic differences between the two techniques were analysed further using the method of Bland and Altman (1986), that is, the lateral cephalometric radiograph value of the upper incisor to the maxillary plane angle and the lower incisor to the mandibular plane angle were plotted against the difference between the cephalometric and TIP scores.

Results

Reliability assessments

The intra- and inter-examiner errors are shown in Table 1. The intra-examiner RMS for the TIP ranged from 1.3 degrees for examiner 2 recording the left lower incisor to the occlusal plane, to 4 degrees for examiner 5 recording the lower right incisor crown to the occlusal plane. The lateral cephalometric radiograph assessments tended to show a similar range from 1.4 to 3.63 degrees.

The inter-examiner errors assessed using the intraclass correlation coefficient indicated that assessments of incisor inclination showed similar reliability for both techniques (dental cast, 0.82–0.92 degrees; lateral cephalometric radiograph, 0.83– 0.85 degrees).

Validity

The linear regression analysis illustrated the relationship between the TIP (mean score for left and right incisors) and the lateral cephalometric radiograph derived scores (Figures 2 and 3). A greater association was found between the upper incisors as compared with the lower incisors (R = 0.77 upper incisors, R = 0.59 lower incisors). The regression analysis indicated systematic bias in the scoring of the upper and lower incisors (Table 2). The bias was assessed further using the technique described by Bland and Altman (1986). The differences between the TIP scores and the equivalent radiographic scores were plotted against the radiographic scores (Figures 2 and 3). The mean bias for the upper incisors was found to be 10.46 degrees and –2.57 degrees for the lower incisors (Table 2). For both

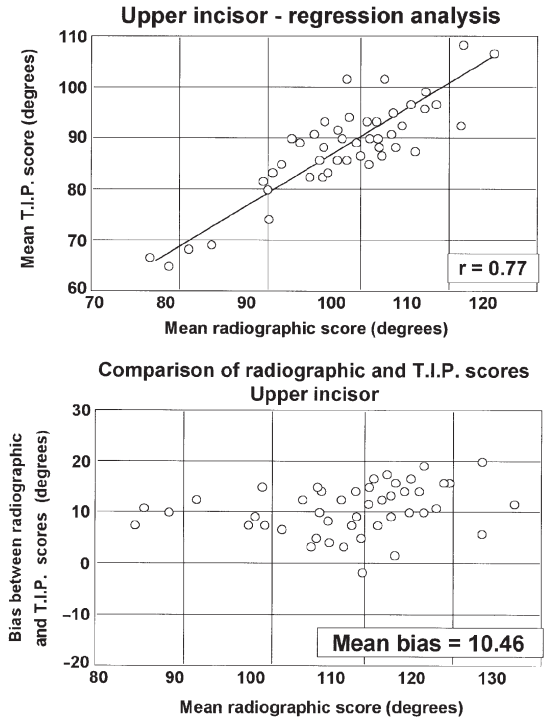

Figure 2 (Above) Regression analysis for upper incisor inclination determined from dental casts compared with lateral radiographically determined assessments. (Below) Systematic differences between the dental cast and radiographically determined upper incisor inclination.

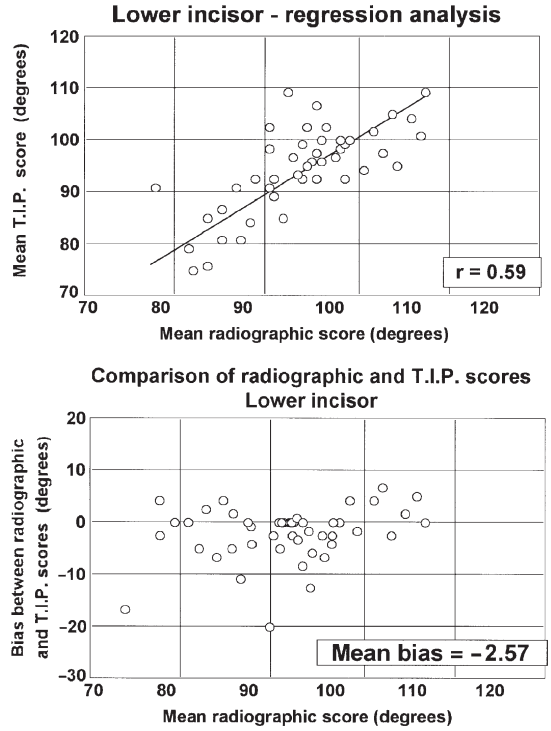

Figure 3 (Above) Regression analysis for lower incisor inclination determined from dental casts compared with lateral radiographically determined assessments. (Below) Systematic differences between the dental cast and radiographically determined lower incisor inclination.

Table 2 Assessment of the validity of the Tooth Inclination Protractor compared with the lateral radiograph.

Values	Upper incisors	Lower incisors
Linear regression		
Constant	3.22	11.56
Standard error of *y* estimate	4.46	5.31
R	0.77	0.59
Number of observations	46	46
Degrees of freedom	44	44
X coefficient	0.87	0.9
Standard error of coefficient	0.07	0.11
Level of agreement		
Mean bias	10.46	–2.57
Standard deviation of differences	4.56	5.3
Limits of agreement (d + 2 SD)	19.58	7.81
Limits of agreement (d – 2 SD)	1.34	–12.96
95% confidence limits	9.05–11.86	–1.81–3.33

upper and lower incisor assessment, the analysis highlighted a systematic bias and consistent differences over the full range of values.

Discussion

It is difficult to validate a technique to assess incisor inclination as the traditionally used radiographic assessment is well known to be less than ideal. Although both techniques assess incisor inclination, the TIP records incisor crown inclination only and the radiographic assessment crown/root inclination. Drawing a line between the incisor tip and apex may not reflect the inclination of the incisor in situations with diverse crown root angles. In addition, the radiographic technique usually records the most prominent incisor, and there may be superimposition and lack of clarity between the apices of the six anterior teeth.

Furthermore, the mandibular incisor inclination is subject to variation due to bony apposition at the symphysis and mandibular angle.

The TIP records crown inclination only. However, the device can record the individual inclinations of all eight incisors allowing more detailed assessment of proclined or retroclined teeth. The assessment of the crowns to the occlusal plane may be variable especially in the lower arch where there may be problems with a deep curve of Spee. Although the occlusal plane variability does not seem to be a factor in reliability it may cause a problem with validity when comparing the lower incisor to the occlusal plane and mandibular plane. The linear regression coefficient for the lower arch was less than the upper arch which may reflect the variation of occlusal and mandibular planes (the maxillary and occlusal planes apparently maintaining a more consistent relationship). In open bite cases it is possible to assess incisor inclination using the TIP in respect of upper and lower occlusal planes or to a pre-determined occlusal plane indicated by the open bite attributed to upper or lower arches.

The use of the TIP for lower incisor assessment should not be dismissed, as the radiographic assessment of the lower incisor is often poor due to lack of clarity of the incisor apex and tip. The greater systematic difference found in the upper arch between the TIP and the radiographic assessment also reflects differences between the maxillary, mandibular, and occlusal planes (a greater difference between maxillary and occlusal plane than mandibular and occlusal plane).

In this study the mean scores of the upper central incisors were obtained from the TIP and compared with the radiographically determined values. Therefore, the TIP was not used to its full potential in determining subtleties between left and right central and lateral incisors.

There is a problem in assessing validity of the TIP against the radiograph when the validity of the cephalometric technique itself must be questioned. Nevertheless, cephalometry is a technique which is commonly used throughout the world and any new technique should be compared with it. The TIP assessment is a simple, non-invasive, inexpensive, and quick technique to assess incisor inclination. The training required for this study was in the order of 30 minutes.

The TIP assessment may also be used as a clinical or research tool in assessing incisor correction during or at the end of treatment.

Conclusions

The TIP is a reliable and valid measure for assessing left and right maxillary and mandibular incisor crown inclination.

The TIP scores are closely related to the upper incisor to maxillary plane angle and lower incisor to mandibular plane angle. The TIP consistently under-scores the lateral cephalometric radiographic determined maxillary incisor angulation by 10.46 degrees and consistently over-scores the lower mandibular incisor angulation by 2.57 degrees. The TIP may also be used to record changes of incisor inclination during the treatment process. However, the effect of bracket positioning and its effect on assessing incisor angulation will require further investigation.

The device described is subject to patent application.

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References

Baumrind S, Frantz R C 1971a The reliability of head film measurements Part 1: landmark identification. American Journal of Orthodontics 60: 111–126

Baumrind S, Frantz R C 1971b The reliability of head film measurements Part 2: conventional angular and linear measurements. American Journal of Orthodontics 60: 505–517

Bennett D T, Smales F C 1968 Orientated study models. Dental Practitioner 18: 353–355

Bland J M, Altman D G 1986 Statistical methods for assessing agreement between two methods of clinical measurement. Lancet i: 307–310

Carey C W 1952 Diagnosis and case analysis in orthodontics. American Journal of Orthodontics 38: 149–161

Currier J H 1971 A computerised geometric analysis of human dental arch form. American Journal of Orthodontics 59: 164–179

Fleiss J L 1986 The design and analysis of clinical experiments. Wiley, Bristol, pp. 307–310

Friel S 1914 The diagnosis of malocclusion of the teeth. Dental Cosmos 56: 825–832

Grueberg J 1912 The symmetroscope. An apparatus for measuring the symmetry in dental arches. Dental Cosmos 54: 490–491 (Abstract)

Houston W J B 1983 The analysis of errors in orthodontic measurements. American Journal of Orthodontics 83: 382–390

Lear C S L 1976 Three dimensional analysis of changes in location of crowns and apices of maxillary incisors. Angle Orthodontist 46: 338–344

Lundström A 1955 Inter-maxillary tooth width ratio and tooth alignment in occlusion. Acta Odontologica Scandinavica 12: 266–292

Musich D, Ackerman J 1973 The catenometer: a reliable device for estimating dental arch perimeter. American Journal of Orthodontics 63: 366–373

Nance N H 1947 The limitations of orthodontic treatment. 1. Mixed dentition diagnosis and treatment. American Journal of Orthodontics 33: 177–223

Perera P S G 1981 Orientating dental casts to cephalometric radiographs. Angle Orthodontist 51: 246–251

Richmond S 1987 Recording the dental cast in three dimensions. American Journal of Orthodontics and Dentofacial Orthopaedics 92: 199–206

Richmond S, Jones M L 1985 A comparison of two and three dimensional incisor angles. British Journal of Orthodontics 12: 90–96

Wall B F, Kendal G M 1983 Collective doses and risks from dental radiology in Great Britain. British Journal of Radiology 56: 511–516