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# Estimating arch length discrepancy through Little's Irregularity Index for epidemiological use

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SUMMARY The objective of this study was to evaluate the diagnostic capability of Little's Irregularity Index (LII) in order to estimate the arch length discrepancy (ALD) in a dental arch. Dental casts with a full permanent dentition, excluding third molars, from 200 12- to-16-year-old schoolchildren from a representative high school located in Lima, Peru, were used. Incisal irregularity was measured using the LII, whereas ALD was calculated as the difference between available and required space in each dental arch anterior to the first permanent molars. The receiver–operator characteristic (ROC) curve was used to contrast the LII with three different dichotomized ALDs and locate optimized cut-off points.

Correlation between ALD and LII was –0.68 ($P < 0.001$). According to ROC curves, LIIs of 2.45, 4.00, and 4.55 mm were the optimized cut-off points to estimate negative ALDs higher than 0, 3, and 6 mm, respectively. LII's highest diagnostic capability was found for estimating negative ALD greater than 3 mm with a sensibility of 0.78 and a specificity of 0.76.

Based on the present findings, LII could potentially be used in epidemiological surveys as a valid and less time-consuming measurement of crowding compared with ALD; however, further studies are needed to test the reliability of this approach in field settings.

## Introduction

Crowding is considered unattractive (Prahl-Andersen *et al.*, 1979; Evans and Shaw, 1987) and is the main reason why patients request orthodontic treatment (Gilmore and Little, 1984; Gosney, 1986). Several methods have been reported in the literature to quantify the amount of crowding for epidemiological purposes. Little (1975) proposed the irregularity index as a valid and reliable quantitative method for assessing lower anterior alignment. Later, the Handicapping Labio-lingual Deviation index evaluated, by visual calculation, the anterior crowding in both arches (Parker, 1998), the Peer Assessment Rating index assessed the displacement between contact points of the anterior teeth using a ruler (Richmond *et al.*, 1992), and the Dental Aesthetic Index (DAI) determined not only the maximum incisor irregularity in each dental arch using a probe but also the anterior arch length discrepancy (ALD) in each arch visually [Jenny and Cons, 1996; World Health Organization (WHO), 1997]. In addition, the Index of Orthodontic Treatment Need (Brook and Shaw, 1989) and the Index of Complexity, Outcome, and Need (ICON; Daniels and Richmond, 2000) collect data, by dental cast analysis, of the 'worst' overall displacement of contact points in either dental arch and ALD in the upper dental arch, respectively.

Important reasons for using any index as an epidemiological tool include (1) improved accuracy of screening examinations conducted in non-clinical settings, (2) inexpensive procedures and equipment, (3) ease of performance, (4) little technical skill required, and (5) achievement of rapid results (Morrison, 1998).

ALD refers to an imbalance between the available and required spaces in a dental arch to accommodate all the teeth aligned perfectly (van der Linden, 1983). When the available space results in a deficiency, a negative ALD or dental crowding is diagnosed. When the available space exceeds the space required for adequate tooth alignment, a positive ALD or dental spacing is diagnosed (van der Linden, 1974, 1983). Several methods have been proposed to evaluate complete ALD (Lau *et al.*, 1984; Battagel, 1996; Battagel *et al.*, 1996; Lestrel *et al.*, 2004). Although these methods are less time-consuming than physical measurement of available (arch perimeter) and required (mesiodistal tooth size sums) spaces, all of these were proposed to be used in clinical settings or on dental casts. Only Little's irregularity index (LII) has previously been used in epidemiological surveys (Little, 1975; Jenny and Cons, 1996; WHO, 1997).

As most epidemiological indices only evaluate crowding in the anterior region of the dental arch (Richmond *et al.*, 1992; Jenny and Cons, 1996; WHO, 1997; Parker, 1998), this partial evaluation of crowding may significantly under- or overestimate the real magnitude of the ALD. A modest association between incisor irregularity and anterior ALD has been previously reported (Harris *et al.*, 1987). However, the association between incisor irregularity and ALD, when measured on complete dental arches and not only from

canine to canine, has not been reported previously. A distinctive disadvantage of ALD over LII (Little, 1975) determination is the need to measure the arch perimeter and mesiodistal tooth size of all permanent teeth, which requires significantly more working time.

The purpose of this study was to evaluate the diagnostic capability of LII in order to estimate ALD. The rationale for conducting this study was to evaluate if LII could be used in epidemiological surveys as a valid and less time-consuming measurement of ALD.

## Materials and methods

Two hundred schoolchildren were randomly selected from 321 children who fulfilled the selection criteria and attended a typical public high school in Lima, Peru. The ages of these children ranged between 12 and 16 years. All recruited students signed a consent letter indicating their voluntary participation. The selection criteria were Peruvian ancestors from at least one previous generation with both last names of Hispanic–American origin; permanent dentition completely erupted from the first permanent right molar to the first permanent left molar; and absence of any orthodontic treatment, dental caries, restorations, proximal attrition, or tooth anomaly.

Dental casts of both arches were obtained from all schoolchildren. On each dental cast, the sum of the mesiodistal tooth size (Moorrees *et al.*, 1957) of all permanent teeth were subtracted from the arch perimeter (Lundström, 1949) in order to calculate ALD. Then, dental arches with a negative ALD were defined as crowded, whereas those with a positive ALD (including 0 score) were defined as uncrowded or spaced. The same procedure was followed using two additional clinically significant cut-off points on ALD: moderate crowding (more than 3 mm) and severe crowding (more than 6 mm; Bishara, 2001). In addition, linear displacement of the anatomic contact points of the six anterior teeth was calculated using the LII (Little, 1975). Although formulated for use on the lower arch, it has also been applied to the upper arch (WHO, 1997).

All measurements were undertaken twice (4 weeks apart) by a single examiner (EB) with a sliding calliper (Dentaurum, Pforzheim, Germany) accurate to the nearest 0.1 mm. When the first and second measurements differed by more than 0.2 mm, the tooth was measured again and this third measurement was then registered. When both measurements differed by less than 0.2 mm, the original measurement was accepted (Bernabé and Flores-Mir, 2004; Bernabé *et al.*, 2004a,b).

A single examiner, trained and calibrated against a senior orthodontist (CF-M), measured five pairs of dental casts every 24 hours. Intra- and inter-examiner reliability was estimated using the intra-class correlation coefficient. Intra-examiner reliability was 0.997 and 0.908 for ALD and LII, respectively, whereas inter-examiner reliability was 0.994 and 0.916, respectively ($P < 0.001$ in all cases). Intra-examiner measurement errors, estimated as the mean difference between pairs of measurements, were 0.06 mm [95 per cent confidence interval, $CI_{95\%}$ (−0.04, 0.15)] and −0.08 mm [$CI_{95\%}$ (−0.17, 0.06)] for ALD and LII, respectively, whereas inter-examiner measurement errors were 0.07 mm [$CI_{95\%}$ (−0.02, 0.13)] and 0.16 mm [$CI_{95\%}$ (−0.14, 0.24)], respectively.

A two-way univariate analysis of variance was used to compare ALD and LII according to gender and dental arch, after establishing normality within each group (Kolmogorov–Smirnov test, $P > 0.123$ and $> 0.188$, respectively) and equality of variances between groups (Levene test, $P > 0.099$ and $> 0.068$, respectively). Thereafter, the linear association between LII and ALD was evaluated using the Pearson correlation coefficient after normality was demonstrated (Kolmogorov–Smirnov test, $P > 0.060$).

LII was contrasted with the dichotomized ALD (uncrowded = 0 and crowded = 1 was used for the statistical analyses). Sensibility and specificity with their respective 95 per cent CIs were then calculated. Finally, this information was used to plot a receiver–operator characteristic (ROC) curve to suggest an optimal cut-off point for the LII which allowed for the estimation of ALD (Morrison, 1998).

## Results

Distribution of the study sample according to gender, dental arch, and dichotomized ALD is shown in Table 1. Although ALD and LII presented larger values in the upper than in the lower dental arch as well as in males than in females (Table 2), no statistically significant differences were found between genders ($P = 0.385$ and 0.567 for the ALD and LII, respectively) or dental arches ($P = 0.140$ and 0.760, respectively).

In view of these findings, only one correlation coefficient was calculated, disregarding gender and dental arch. The

**Table 1** Distribution of the study sample according to gender, dental arch, and arch length discrepancy (ALD).

| ALD | Lower arch | | | | Upper arch | | | |
|---|---|---|---|---|---|---|---|---|
| | Female | | Male | | Female | | Male | |
| | *n* | % | *n* | % | *n* | % | *n* | % |
| Cut-off point of 0 mm | | | | | | | | |
| Crowded | 62 | 62.0 | 60 | 60.0 | 54 | 54.0 | 46 | 46.0 |
| Uncrowded | 38 | 38.0 | 40 | 40.0 | 46 | 46.0 | 54 | 54.0 |
| Cut-off point of 3 mm | | | | | | | | |
| Crowded | 23 | 23.0 | 22 | 22.0 | 18 | 18.0 | 13 | 13.0 |
| Uncrowded | 77 | 77.0 | 78 | 78.0 | 82 | 82.0 | 87 | 87.0 |
| Cut-off point of 6 mm | | | | | | | | |
| Crowded | 8 | 8.0 | 9 | 9.0 | 8 | 8.0 | 9 | 9.0 |
| Uncrowded | 92 | 92.0 | 91 | 91.0 | 92 | 92.0 | 91 | 91.0 |

**Table 2** Comparison of incisor irregularity and arch length discrepancy (ALD) according to gender and dental arch.

| Gender | Lower arch | | Upper arch | |
|---|---|---|---|---|
| | Mean | SD | Mean | SD |
| Little's Irregularity Index (mm) | | | | |
| Female | 2.78 | 2.87 | 3.71 | 4.26 |
| Male | 3.36 | 3.60 | 2.68 | 4.84 |
| Total | 3.07 | 3.26 | 3.19 | 4.58 |
| ALD (mm) | | | | |
| Female | −0.69 | 3.42 | −0.47 | 3.27 |
| Male | −0.69 | 3.63 | 0.17 | 4.11 |
| Total | −0.69 | 3.52 | −0.15 | 3.72 |

SD, standard deviation. Analysis of variance was used (for all comparisons $P < 0.05$).

linear association between ALD and LII was −0.68 which was statistically significant ($P < 0.001$).

ROC curves were plotted in order to contrast LII with dichotomized ALD and locate the optimal cut-off points. The most superior top-left point on the curve represents the maximized sensibility and specificity. When an ALD of 0 mm was used to define dental arches as crowded or uncrowded, an LII of 2.45 mm (optimized cut-off point) had a sensibility of 0.77 [$CI_{95\%}$ (0.70, 0.82)] and a specificity of 0.72 [$CI_{95\%}$ (0.65, 0.78)] in estimating negative ALD compared with the conventional cut-off point (0 mm of LII) which had a sensibility of 0.97 [$CI_{95\%}$ (0.93, 0.99)] and a specificity of 0.30 [$CI_{95\%}$ (0.24, 0.38)]. The area below 0.82 on the ROC curve [$CI_{95\%}$ (0.78, 0.86)] indicated the validity of LII in estimating a negative ALD in the dental arch (Figure 1a).

Similarly, when LII was contrasted with a negative ALD greater than 3 mm (moderately crowded dental arches), an optimized cut-off point of 4.00 mm on LII presented a sensibility of 0.78 [$CI_{95\%}$ (0.66, 0.86)] and a specificity of 0.76 [$CI_{95\%}$ (0.71, 0.80)] compared with 0.97 [$CI_{95\%}$ (0.90, 0.99)] and 0.18 [$CI_{95\%}$ (0.14, 0.23)], respectively, when the conventional cut-off point of LII was used (Figure 1b). In this case, the area below the ROC curve was 0.84 [$CI_{95\%}$ (0.79, 0.89)].

Finally, when a negative ALD greater than 6 mm was considered to classify severely crowded dental arches, an optimized cut-off point of 4.55 mm on LII had a sensibility and specificity of 0.74 [$CI_{95\%}$ (0.49, 0.90)] and 0.71 [$CI_{95\%}$ (0.66, 0.76)], respectively, compared with 0.99 [$CI_{95\%}$ (0.79, 1.00)] and 0.16 [$CI_{95\%}$ (0.13, 0.20)] for the conventional cut-off point of LII (Figure 1c). The area below the ROC curve was 0.81 [$CI_{95\%}$ (0.73, 0.90)].

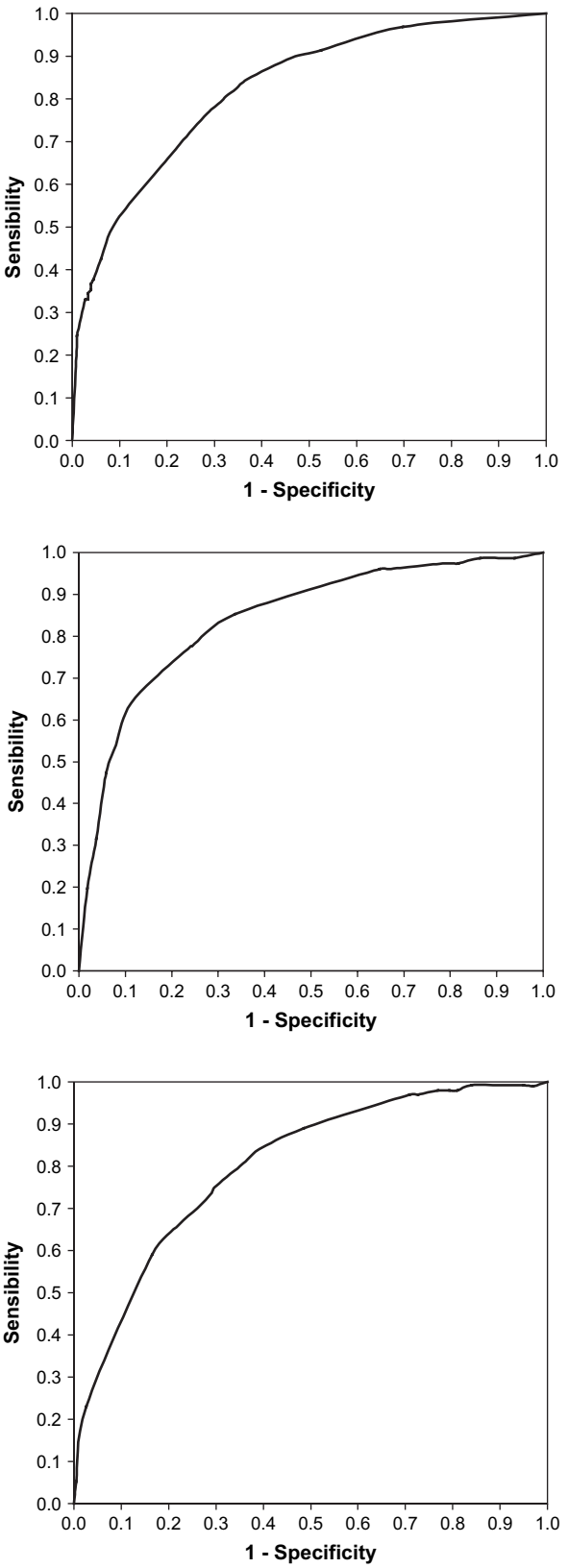


**Figure 1** Receiver–operator characteristic curve plotting Little's Irregularity Index contrasted with (a) 0 mm, (b) 3 mm, and (c) 6 mm arch length discrepancies (crowded versus uncrowded) in the dental arch.

## Discussion

The moderate correlation coefficient between LII and ALD (−0.68) offers theoretical support to propose incisor

irregularity as an estimator of ALD. This value represents a determination coefficient of 46.2 per cent. In fact, this resulted in higher correlation values than those previously reported by Harris *et al.* (1987) for the lower anterior teeth. Correlation values and, simultaneously, the related determination coefficient have been previously employed in orthodontics to estimate or predict clinical traits, especially in mixed dentition space analysis (Tanaka and Johnston, 1974; Moyers, 1988). A negative sign in the calculated correlation coefficient indicates that the higher the LII, the greater the negative ALD and *vice versa*. Although they are not measuring the same trait (Harris *et al.*, 1987), the moderate correlation coefficient (−0.68) could be explained because LII contribute complementary information with ALD.

Contrasting the extent of LII against the gold standards of ALD greater than 0, 3, and 6 mm allowed for the calculation of optimized LII cut-off points (Figure 1). ROC curves are normally used to describe the validity of diagnostic and screening tests (Morrison, 1998) and are equivalent to plotting sensibility and specificity of LII at all of its possible cut-off points (Morrison, 1998).

Three and 6 mm were chosen as cut-off points for defining moderate and severe crowding (Bishara, 2001) because different amounts of ALD tend to reflect different orthodontic treatment needs and also different approaches to solve them. Obviously, crowding alone does not determine the type of orthodontic treatment required, but it is one of the significant factors to be considered.

Despite that, Gilmore and Little (1984) reported that a score of 3.5 mm is the maximum irregularity consistent with minimal lower incisor crowding. In the present study, incisor irregularities of 2.45, 4.00, and 4.55 mm were the optimized cut-off points for estimating 0, more than 3, and more than 6 mm of negative ALD in the dental arches.

According to the present results, the LII had a higher diagnostic capability to estimate more than 3 mm of negative ALD compared with 0 or −6 mm of ALD. An LII of 4 mm presented a sensibility and specificity of 0.78 and 0.76, respectively, for estimating ALD greater than −3 mm in the dental arches.

For each of the three different ALD grades, comparison of sensibility and specificity values against the conventional cut-off point (0 mm of incisor irregularity) indicated that, for the optimized cut-off points, the specificity of the irregularity index increased but the sensibility decreased. A property of the diagnostic tests is the fact that any increase in sensibility or specificity achieved by changing the cut-off point will result in a decrease in the other parameter (Morrison, 1998). In many cases, decisions about where to place cut-off points are based on the costs, risks, and benefits associated with the proportion of those diagnosed as true positives and false positives (Morrison, 1998). Therefore, an optimized cut-off point has to be found based on these implications.

Although the sensibility and specificity of using LII as a test of the degree of total ALD do not depend on the prevalence of ALD in the sample (Morrison, 1998), the positive predictive values decrease and the negative predictive values increase as the prevalence of ALD decreases (Morrison, 1998; Rendón, 2001). Therefore, in the present study, these values could have been affected by the low prevalence of ALD in the total sample and increasingly low prevalence of crowding in each of the dichotomized groups. Thus, the prevalence of ALD greater than 0 mm in the total sample was 55.5 per cent, whereas the prevalence of ALD greater than 6 mm was only 8.5 per cent (Table 1). Further studies are encouraged which evaluate all spectrums of ALD (pre-treatment casts of treated cases, severe ALD, and impacted teeth) as well as severe and extreme incisal irregularity in the population.

Lately, the ICON (Daniels and Richmond, 2000) has been proposed to evaluate the degree of complexity, need, and orthodontic treatment outcome in epidemiological settings. It measures upper arch crowding as one of its components. The present results imply that time could be saved if only LII is used. It is recognized that the present results are based on dental cast analysis. Visual inspection is the preferred method for evaluating dental crowding in epidemiological surveys (Jenny and Cons, 1996; WHO, 1997; Parker, 1998). This is obviously due to limited access to dental casts in non-clinical settings; therefore, it would be interesting to also corroborate these results using only a visual inspection. Previous studies have reported that LII is a reliable measurement when compared with visual inspection or computerized analysis (Little, 1975; Tran *et al.*, 2003).

One limitation of this study was not being able to evaluate the Irregularity Index in a field setting, as an epidemiological tool, to corroborate its validity and also to probe its intra- and inter-examiner reliability. Therefore, further clinical and epidemiological studies including a variety of cases are required to support that incisor irregularity could be used as a valid and reliable estimator of ALD. Differences in incisor irregularity and ALD characteristics between the sample population and other populations would be expected because of differences in ethnic composition.

Another limitation is that LII is only a measurement of irregularity; therefore, it is insensitive to tooth rotations and tooth axial inclinations, which are evaluated with ALD. Although LII was designed to be used on study models with callipers, several authors have proposed its use in epidemiological settings (Little, 1975; Jenny and Cons, 1996; WHO, 1997).

## Conclusions

1. A moderate correlation (−0.68) was found between LII and ALD.
2. In the present study, LII proved to be a simple and

economic tool to estimate the existing total ALD in the dental arches.

3. Although the findings may suggest that LII could be used in epidemiological surveys as a valid and less time-consuming measurement of ALD, future studies are needed in field settings in order to support the present findings.

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