The validity of maxillary expansion indices

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The current emphasis on nonextraction therapies has resulted in a significant reduction in the number of teeth extracted for orthodontic purposes.[1,2] Contemporary techniques to relieve dental crowding, apart from extractions, include interproximal tooth reduction, posterior molar movement, anterior incisor flaring, and arch expansion.[3-8] Crowding is a result of a discrepancy between combined tooth width and arch perimeter. Arch perimeter in turn, is dependent on several factors, including arch form, arch length, and arch width.

Numerous indices have been suggested to guide the clinician in determining the amount of expansion required to achieve a proposed ideal arch width. In 1909, Pont[9] described a method which assumed a constant relationship between the sum of the maxillary incisor widths (SI=Sum of Incisors) and the width of the dental arch in an ideal uncrowded dentition. He concluded that the ratio of SI to arch width was 0.80 in the premolar region and 0.64 in the molar area. The formula was then transposed to allow arch width prediction:

Required premolar width = SI/0.80

Required molar width = SI/0.64

Stifter[10] tested Pont's index on normal and ideal Class I dentitions and reported that a significant correlation existed between SI and the interpremolar and intermolar arch widths. In an evaluation of Pont's index, Joondeph and

Abstract

Numerous indices have been proposed to help the clinician decide how much maxillary expansion will be required to alleviate crowding. The purpose of this investigation was to examine the validity of Pont's index, Schwarz's analysis and McNamara's rule of thumb. Records of 40 patients (20 females and 20 males) were selected from 155 consecutive pretreatment records. The discrepancy between actual intermolar/interpremolar widths and the index-generated widths were correlated against measures of crowding, and linear regressions were computed. Statistical analysis revealed that (1) males had more significant correlations between arch width and crowding than females, (2) interpremolar widths were more strongly correlated than intermolar widths, (3) Pont's index and McNamara's rule of thumb overestimated required arch width by 2.5 mm to 4.7 mm and 2.7 mm to 3.7 mm respectively, and (4) Schwarz's analysis overestimated interpremolar width by 2.5 mm to 4.3 mm but was reasonably accurate for intermolar width in males. The results suggest that these indices potentially overestimate the arch expansion required to alleviate crowding.

Key words

Maxilla • Expansion • Pont • Schwarz • McNamara

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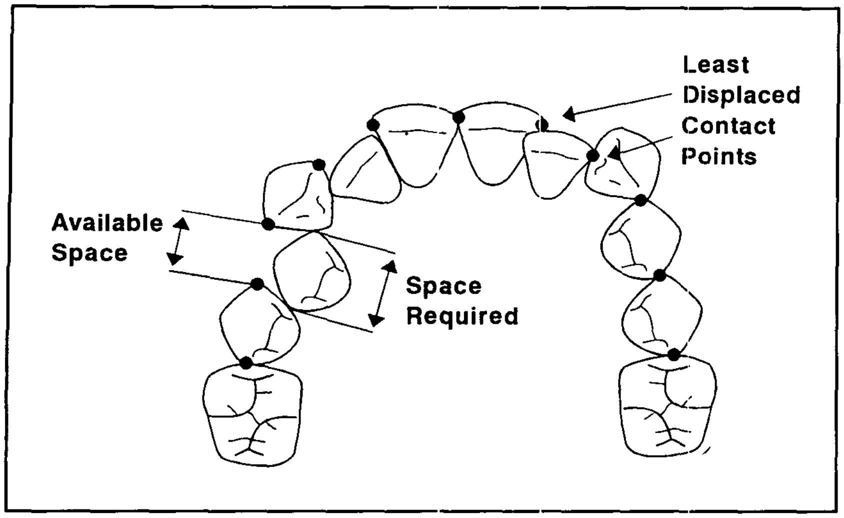

Figure 1
Crowding index

colleagues[11] reported the measurements taken from dental casts of 20 subjects prior to treatment, at completion, and 10 years out of retention. They found poor correlations and a lack of agreement between calculated Pont's ideal premolar and molar arch widths and actual premolar and molar arch widths 10 years out of retention. Correlations between end of treatment premolar and molar arch widths with SI were calculated from their raw data and were also found to be low (r=0.39 and r=0.33 respectively). The authors stated that measurements derived from Pont's index were of no value in predicting ultimate arch width in the premolar and molar regions. This is in agreement with the findings of Worm and coworkers.[12] When examining 91 Navajo children and 133 dental students with ideal occlusions and less than 1 mm of crowding or spacing, they found that low correlations existed between Pont's index and observed arch forms, and that a significant difference existed between calculated interpremolar and intermolar widths and observed values. In most participants, the observed measurements were less than the calculated ones.

Pont also proposed that a relationship existed between the form of the skull (dolichocephalic, mesocephalic, and brachycephalic) and the form of the dental arch.[9] Schwarz[13] presented an analysis for ideal interpremolar and intermolar widths that was corrected for facial type. The use of both Pont's and Schwarz's indices has been advocated for the calculation of desired interpremolar and intermolar widths, despite any proven clinical validity of these indices.[14]

More recently, McNamara proposed a simple rule of thumb indicating an ideal average intermolar width in males of 37.4 mm and in females of 36.2 mm.[15] This was based on the data of Howe and coworkers,[16] who compared arch widths of two subjectively selected groups of dental casts. The uncrowded group consisted of Class I normal occlusions with little or no crowding. The crowded group consisted of cases exhibiting gross dental crowding. The three investigators had to agree on the inclusion of a cast in either group or the cast was excluded. Such a process is open to potential, subjective selection bias. Personal concepts of what constitutes a desired or ideal archform may unknowingly impact the selection of cases. Such cases, therefore, may not be representative of the population at large, but instead merely reflect those characteristics most desired by the selection panel.

Previous studies examining any potential relationship have also been potentially biased in their sample selection or categorization[16,17] and have used estimations of crowding.[17,18,19] As the increments of crowding are small and there is a potential for the error of the measurement to be large, an accurate and valid measure of crowding is required to allow significant relationships to be detected. A more objective measure of crowding was therefore devised for use in this study.

If the above proposed indices and guides are to be considered useful, then the amount of crowding in any given untreated case should correlate with the discrepancy between observed arch width and the predicted or recommended arch width. The purpose of this investigation was to examine the relationship among Pont's index, Schwarz's analysis, and McNamara's rule of thumb, as well as both subjective and objective measures of crowding, in order to determine their validity.

Materials and methods

Sample

A total of 155 consecutive pretreatment records of patients undergoing treatment in the graduate orthodontic clinic at the University of Pittsburgh were examined until records of 20 males and 20 females that met the following inclusion criteria were obtained: (1) all permanent teeth back to the permanent first molars were present in both arches, (2) no supernumerary teeth or peg-shaped laterals present, (3) no previous orthodontic treatment, (4) same racial group (Caucasian), and (5) pretreatment frontal facial photographs were available for facial type analysis.

Measurements of study models

Measurements were taken from the study models using digital calipers and were recorded to the nearest 0.1 mm. The widest mesiodistal dimensions of all teeth and the available space for each tooth were measured and used to calculate the crowding index (CI). Other measurements included the width between the distal pits of the occlusal fissures of the maxillary first premolars, the width between the central pits of the occlusal fissures of the maxillary first molars (Schwarz,[13] Pont[9]), and the width between the midpoint of the lingual surface of the maxillary first molars as described by Howe, McNamara, and O'Connor.[16] In this study, Schwarz's interpremolar width, measured at the distal pits of the first premolars, was substituted for Pont's definition, which involves the center of the occlusal surfaces between the mesial and distal pits. This difference was not considered methodologically significant.

In occlusal view, the CI was determined by measuring the available horizontal space parallel to the occlusal plane, between the least displaced interproximal contact points (Figure 1). The least displaced contact is that point on adjacent mesial and distal surfaces that is most in line with the overall arch form. The actual width of the corresponding tooth was then deducted from the available space to give a resultant amount of crowding (positive measure) or spacing (negative measure) for each tooth. This procedure was repeated for each tooth starting and ending at the mesial contact of the first molars. The CI was then calculated by summing the individual differences. This method was used to reduce bias in the subjective interpretation of crowding while still taking into consideration incisor position and arch symmetry. The maxillary casts were subjectively assessed by the three orthodontic faculty members to quantify the amount of crowding in millimeters (SC), and the mean SC was calculated for each model (SCavg).

Evaluation of facial photographs

The study models and frontal photographs were assessed in random order by three orthodontic faculty members who were blinded to the purpose of the study and to the relationship between the models and photos. Facial types were classified as narrow, normal, or broad according to Schwarz.[13] If a disagreement occurred in the classification of a facial type, then a consensus opinion was used.

Calculation of arch widths

Schwarz's analysis was calculated with the appropriate formula as described by Schwarz.[13] In narrow faces, the first premolar width is SI + 6 mm while the intermolar width is SI + 12 mm; in the average face the widths are SI + 7 mm and SI + 14 mm; in broad faces they are SI + 8 mm and SI + 16 mm respectively. The difference between the predicted and actual arch widths were calculated for each index using the following formula:

Discrepancy=predicted width-actual width

The following abbreviations are used to represent the discrepancies obtained for each index: SM = Schwarz's molar discrepancy, SP = Schwarz's premolar discrepancy, PM = Pont's molar discrepancy, PP = Pont's premolar discrepancy, and MW = rule of thumb molar width discrepancy.

Error of the method

Ten randomly selected cases were remeasured after a 1-week interval to assess intrajudge reliability of the CI, SC, and arch width measures. The original and repeat measurements were compared with paired t-tests to examine for the error of the method. The only cast width measurement found to significantly differ between measurements was interpremolar width ($P=0.02$). This had a very high correlation ($r=0.999$) with a mean difference of only 0.26 mm, which was not clinically or methodologically significant. The CI was found to have a mean difference of 0.01 mm ($P=0.97$, S.E. of mean = 0.22 mm) indicating a high reproducibility. The repeated subjective crowding assessments by each rater were less reliable than the CI and demonstrated higher mean differences of 0.25 mm ($P=0.47$), 1.13 mm ($P=0.14$) and 2.38 mm ($P=0.06$) respectively.

Statistical analysis

The CI was correlated with the individual rater SC measures and with the SCavg (mean subjective crowding) using Pearson's product-moment coefficient to validate the CI as a measure of crowding. An independent t-test was also conducted between CI and SCavg to examine the agreement of the two measures of crowding. Correlation coefficients and linear regression models were calculated for the measures of crowding (CI and SCavg) with the discrepancies between actual and the computed measures of arch width (SM, SP, PM, PP, and MW). Linear regression equations were used to ascertain the intercept (no crowding or spac-

Table 1
A positive value indicates the amount of arch width, in millimeters, that the index overestimates is required to achieve no crowding or spacing. The correlation coefficients (r) and variability explained by the relationship (r^2) for the indices of crowding and the discrepancies between the computed and actual arch widths are also included.

Table 1
Intercepts of the regression analysis (including 95% confidence intervals) between measures of crowding and the differences between proposed and actual arch widths

Index	Crowding Index		Subjective Crowding (Avg)	
	Males	Females	Males	Females
Pont's molar	3.8 mm ± 1.9	4.3 mm ± 1.9	2.5 mm ± 2.0	4.0 mm ± 2.5
	r=0.69**	r=0.32	r=0.70**	r=0.26
	r^2=48%	r^2=10%	r^2=50%	r^2=7%
Pont's premolar	4.5 mm ± 1.6	4.7mm ± 1.3	3.2 mm ± 1.7	4.0 mm ± 1.7
	r=0.72**	r=0.58*	r=0.73**	r=0.57*
	r^2=52%	r^2=34%	r^2=50%	r^2=32%
Schwarz's molar	0.1 mm ± 1.7	1.5 mm ± 1.8	-1.0 mm ± 1.7	1.3 mm ± 2.4
	r=0.64*	r=0.36	r=0.69**	r=0.24
	r^2=40%	r^2=13%	r^2=50%	r^2=6%
Schwarz's premolar	3.6 mm ± 1.5	4.3 mm ± 1.2	2.5 mm ± 1.5	3.6 mm ± 1.6
	r=0.72**	r=0.63*	r=0.74**	r=0.58*
	r^2=50%	r^2=40%	r^2=55%	r^2=34%
McNamara's width	3.5 mm ± 1.1	3.7 mm ± 1.1	2.7 mm ± 1.1	3.7 mm ± 1.6
	r=0.71**	r=0.49	r=0.73**	r=0.30
	r^2=50%	r^2=24%	r^2=50%	r^2=9%

*P<=0.01; **P<=0.001

ing) and the associated maxillary arch width with 95% confidence intervals calculated.

Results

Validity of the crowding index

Each rater's measure of crowding (SC) and the average (SCavg) was found to correlate very highly with the CI (SC range r=0.88 to 0.96, SCavg females r=0.94, SCavg males r=0.95). The amount of crowding recorded by the subjective method was larger than that of the CI, ranging from 0.8 mm to 3.4 mm. When compared via an independent t-test, the SCavg was found to be 1.8 mm (P=0.24) greater than the CI in males and 1.9 mm (P=0.10) in females.

Correlation and linear regression

All indices demonstrated significant correlations for all measures in males but only for interpremolar width in females (Table 1). The regression of intermolar arch width against the crowding values (CI and SCavg) was not significant in females. This was observed for all three indices (Table 1). The regression of intermolar width in males and interpremolar width in males and females against crowding measures, although significant, explained only a small percentage of the variance (r^2). The variation explained by the significant linear regressions ranged from 32% to 52% for Pont's index, 34% to 55% for Schwarz's analysis, and 50% for McNamara's rule of thumb (Table 1). Pont's index overestimated intermolar and interpremolar arch widths by 2.5 mm to 4.7 mm respectively, Schwarz's analysis overestimated interpremolar width for both males and females by 2.5 mm to 4.3 mm, and McNamara's rule of thumb overestimated intermolar width by 2.7 mm to 3.7 mm (Table 1). Although Schwarz's mean estimated intermolar widths for males were close to their actual values, the 95% confidence intervals were large, indicating wide variability.

Discussion

The crowding index (CI) was designed to reduce potential subjective impressions regarding the amount of crowding, yet still allow arch form to be taken into consideration. It also provides a reproducible method of appraising dental crowding for research purposes. The significant correlation of the CI with subjective assessment of crowding (SCavg), and its substantially higher reproducibility when compared with the individual raters, indicate that it is a suitable measurement tool for this purpose.

The results of this study support the contention that intermolar arch width is associated with the amount of crowding in males and interpremolar width in males and females. In males, both interpremolar and intermolar widths were more strongly associated with crowding. The lack of a significant correlation for intermolar width with crowding in females highlights the degree of variability in this sample. In a study of untreated "normal" occlusions, Sinclair and Little[17] demonstrated that arch length and intercanine width decrease with age while incisor irregularity increases during the permanent dentition stage. These changes were larger in females. Intermolar width demonstrated an insignificant increase in males but a significant decrease in females. This study demonstrated an average 2.3 mm to 2.4 mm crowding in females and 2.1 mm to 2.4 mm wider arches in males (Table 1). It has been reported that females, on average, have smaller teeth than males, a fact also noted in this study.[18,19] These gender differences in crowding, arch width, and tooth size may account for the differences evidenced between the correlations for males and females in this study.

When interpreting the data in Table 1, the intercepts calculated from the linear regression equations indicate that Pont's index overestimated the necessary arch width by an average of 2.5 mm (males with SCavg) to 4.7 mm (females with CI). Schwarz's analysis appeared to be more precise on average for male molar width (-1.0 mm to 0.1 mm) but also overestimated desired premolar width in both sexes by 2.5 mm to 4.3 mm. Similarly, McNamara's molar width was an average of 2.7 mm to 3.5 mm too wide in males. In females, the regression of molar width against CI indicated that an average overexpansion of 3.7 mm may be expected. The lack of statistical significance depicts the high variability of intermolar width in females. These data suggest that these indices are advocating an overexpanded arch width.

Although the correlations are significant and therefore representative of the sample, they also indicate the large amount of variation in crowding that is not explained by arch width. The higher correlations between crowding and Pont's index observed in this study, when compared with those reported by Joondeph,[11] are most likely due to the differing samples selected. Joondeph's sample consisted of post-treatment models which have already had their arch dimensions artificially altered as opposed to the models of untreated subjects used in this study. The results of this study do agree with Worm's[12] untreated sample in that Pont's index overestimated the required arch width and a great degree of variation existed.

McKeown[20] examined a sample of photographs of casts which were categorized as to their degree of crowding. She reported an average intermolar arch width (measured from the mesiolingual surface of the maxillary first molars) of 36 mm in uncrowded individuals, which is in agreement with the results of Howe et al.[16] when considering the measurement techniques used. Possible explanations for the difference between the results of McKeown's study and this one include photographic magnification, measurement error, sampling bias, and/or true population differences. As McKeown estimated anterior crowding by subjective criteria without considering the posterior segments or curve of Spee, this may have weighted the sample to appear less crowded than would be measured by more objective means. When considering the results of all studies, the degree of variation should be noted. Although arch width is an important factor related to dental crowding, it should not be the sole dictate of a treatment stratagem.

The intent of this article is not to discredit expansion per se, but to examine the validity of indices proposed to indicate the desired amount of expansion in any given case. Treatment plans should not be based on simplistic mathematical concepts but formulated with regard for sound biological rationale. This involves the balanced consideration of future growth and/or aging and the potential risks and benefits, including periodontal health and altered lip support, of each strategy.

Conclusions

1. The crowding index (CI) is a valid and more reproducible measure of dental crowding than objective assessments.
2. Only males demonstrated significant correlations between intermolar arch width discrepancy and crowding. Interpremolar widths were more consistently correlated with the amount of crowding in both males and females.
3. Pont's index overestimated desired arch width by an average 2.5 mm to 4.7 mm.
4. Schwarz's analysis was reasonably accurate as a potential indicator of intermolar arch width in males but overestimated interpremolar width by 2.5 mm to 4.3 mm.
5. McNamara's rule of thumb overestimated required intermolar width by 2.7 mm to 3.7 mm in this sample.

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