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The Use of Computer Technology in Dental Arch Crowding Assessment

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Abstract

Background: Correct alignment of teeth is a fundamental goal of Orthodontic treatment. The accurate assessment of dental crowding and the space required to alleviate it, is critical for correct orthodontic diagnosis and treatment planning.

Objectives: To assess dental crowding by using two different methods, which are manual and computerized in order to compare the advantages and disadvantages of both methods.

Methods: In this cross –sectional study, we studied a convenient sample of 100 individuals (50 male and 50 female) with different degrees of crowding. Upper and lower dental casts were obtained for each subject and these casts were analyzed by using two methods, manual and computerized.

Results: It was found that there is a significant difference between the manual and the computerized method in all measurements (crowding, space available and space required). Also, it was found that the computerized method is a quick method and more practical for the storage of a large number of dental casts and more reliable for the measurement of the space available than the manual method. But, there was some difficulty in the assessment of severely crowded groups (>4mm).

Conclusions: The degree of dental crowding increased when the teeth size increased and arch perimeter decreased. The degree of crowding in the upper arch is more affected by the size of the teeth rather than the size of the arch, while the degree of crowding in the lower arch is more affected by the arch size rather than teeth size.

Key words: Orthodontic treatment, teeth, crowding.

Introduction

Dental crowding is a common multifactorial orthodontic problem and it is a good example of space anomalies. Three conditions may predispose to dental crowding; these are large teeth, small bone bases of the jaws or a combination of both [(1)].

Space analysis requires a comparison between the amount of space available for the alignment of the teeth and the amount of space required to align them properly [(2)].

The degree of crowding within the arch is determined by subtracting the space required from the space available and may be expressed directly in millimeters or by means of a crowding index [(3)].

Computer technology is expanding to include more areas in various scientific fields, and orthodontics is no exception. Orthodontists use computers for record keeping, practice management, patient education, and

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communication with colleagues, restorations fabrication, and many other tasks. Computers have become a necessity rather than an option. The introduction of digital models offers the orthodontist an alternative to the plaster study models routinely used [4].

We are in the twenty first century, a century in which people depend upon computers in almost every aspect of their life, to facilitate work and to gain more accurate results. Orthodontics is one of the fields that took advantage of high speed personal computers such as Pentiums by utilizing specialized orthodontic programs (software) which have automated some of the more laborious tasks in diagnosis and treatment planning, storage and sorting of information. So the use of computers is obligatory in our modern life and that’s why in the present study a computer analyzing method was introduced as a more modern method for the assessment of dental crowding.

This study aimed to assess the Class I dental crowding by using two methods; manual and computerized to shed light upon the advantages and disadvantages of both methods.

Materials and Methods

The convenient sample of this study consisted of 100 individuals (50 male, 50 female), 13-16 years old, with different degree of crowding in their teeth. The sample that was selected possesses Cl I molar relation (Angle, 1889) with upper and lower crowded dentition and after measurements they were divided according to the severity of the crowding into 3 groups: Minor crowding (1 to less than 2 mm), Moderate crowding (2-4 mm), and severe crowding (>4 mm) [5].

The total samples were selected according to the following criteria:

1-All permanent teeth were present with the exception of the third molar in the dental casts of both maxillary and mandibular arches.

2-There had been no previous orthodontic treatment.

3-There was no obvious loss of tooth material mesiodistally as a result of caries, fracture, interproximal wear, congenital defects or impression flows.

4-All cases had Angle Class I molar relationship.

5-No voids in the plaster model. No fractures on the teeth on the plaster model.

Every individual who has dental crowding was examined clinically with dental mirror and checked to evaluate his\her fulfillment according to the sample specification. Then a case sheet questionnaire was filled for each one. Then, the individual was taken to a room specially prepared for impression taking procedure. The person was seated on a chair; the size of the perforated impression tray was checked in the subject's mouth (by researcher). A suitable amount of alginate (hydrocolloid impression material) is mixed with water as indicated by the manufacturer's instructions, and loaded in the tray. The loaded tray was carried to the subject’s mouth, introduced and secured in place by the operator’s fingers. After complete setting of the alginate, according to manufacturer’s instructions the impression is removed quickly (one shoot), washed under tap water, then checked for accuracy and poured with dental stone immediately. A suitable amount of dental stone is mixed with water using the exact water/powder ratio indicated by the manufacturer's instructions. Then the impression is poured by the prepared stone. Before the final setting of the dental stone, a suitable amount of plaster of Paris is prepared to a thick consistency, and poured in a base mold, and then the poured impression is inverted and placed over it. After the final setting of the gypsum, then the impression material is removed carefully and the base is trimmed uniformly and numbered to be ready for the scanning procedure.

After production of dental casts the contact point of the teeth were remarked by a sharp lead pencil to facilitate accurate recognition on the computer screen later on and then the study models of each subject were placed on the occlusal surface directly on the glass window of the scanner between the Y and X axis and then an accurate 1:1 image of the casts was saved in a special folder in the computer under (BMP) format. They were then transferred to the Autosketch program where the analysis of dental crowding was done. AutoSketch software provides a complete set of CAD tools for creating professional-quality precision drawings [(6)].

A Millimetric ruler was scanned and the image was transferred to the AutoSketch software and then it was measured by using the AutoSketch measuring tools. The recorded measurements of the software exactly coincide with the length of the ruler; this was done in order to eliminate the risk of inaccurate results due to unequal magnification.

The assessment of the dental crowding was obtained by measuring the discrepancy in millimeters between the dental arch space available and the dental arch space required by using manual and computerized techniques as follows:

Calculation of Dental Arch Space Available:

Manually space available of the upper and lower dental casts was measured by using the brass wire which was extended from mesiobuccal cusp tip of first permanent molar on one side to that on the opposite side passing through the line of occlusion over the buccal cusps tips of the premolars, over the normal cuspal position of the canine and the incisal edge of incisors. Then the wire was carefully straightened and measured with a Millimetric ruler [(7, 8, 9, 10, 11)].

Computerized measurement of space available was done by drawing a line from mesiobuccal cusp tip of first permanent molar on one side to that on the opposite side passing through the line of occlusion over the buccal cusps tips of the premolars, over the normal cuspal position of the canine and the incisal edge of incisors and the measurement of the length of the drawn line directly recorded by the program. The software gives the option of correcting the path of the line without the need for drawing new line in case if there was an error [(3)].

Calculation of Dental Arch Space Required:

The procedure of measuring the mesiodistal crown width manually was done by measuring the greatest mesiodistal crown width of the teeth which were measured from the anatomical mesial contact point to the distal one. The measurements were made to the nearest 0.1 mm by using the modified sliding caliper gauge (Vernier) with pointed beak inserted in a plane parallel to the long axis of the tooth. The measurements started from the first permanent molar to the central incisor on one side up to and including the corresponding teeth on the opposite side [(12)]. After the mesiodistal crown width of each tooth was measured, the summation of these measurements in both right and left sides were calculated to determine the sum total of the mesiodistal crown width in the dental arch needed to calculate the space required [(12)].

These measurements were used to quantify' the manual dental arch length discrepancy by employing the basic equation: **Dental Arch Space Available – Dental Arch Space Required = Arch Length Discrepancy**

Negative values indicate crowding. When space deficiency of less than 2 represents a minor crowded group, while crowding of 2 to 4 represents a moderate crowded group and finally a crowding of > (4) represents a severe crowded group [(5)].

For the digital measurement of dental space required the mesiodistal crown width of each tooth was measured by drawing a line from the marked mesial contact point to the marked distal contact point and the AutoSketch software then shows the reading directly on the screen , and after recording the measurements of the teeth on each side the summation of these measurements on both right and left sides were calculated to determine the amount of the total mesiodistal crown width in the dental arch needed to calculate the space required, and by using the same equation the digital dental arch length discrepancy was calculated.

Statistical Analysis used in this study was under statistical package SPSS program loaded on Pentium 4. The suitable statistical methods were used in order to analyze and assess the results, they include: -

1- Descriptive statistics: (Mean value, Standard deviation (SD), minimum, maximum and percentages).
2- Inferential statistics: These were used in order to accept or reject the statistical hypotheses, they include:
   A- Student t-test for comparison significance between manual and computerized measurements for crowding measurements, space available (arch perimeter) and space required among the total sample and in both arches.
   B- Analysis of variance (ANOVA) with Least Significant Differences (LSD) between the three crowded groups.

Results

Table (1) demonstrates the descriptive statistics and analysis (student t-test) for both manual and computerized measurements including the means, SD, Min., and Max. Values of all variables for the total sample and in upper and lower arches. It was found that there was a high significant difference between the mean value of manual and computerized measurements (in which the former demonstrated a higher value than the latter) for crowding measurements, space available (arch perimeter) and space required among the total sample and in both arches.

Tables 2 and 3 show sample distribution by number according to gender and severity of crowding (minor, moderate, severe), arch frequency for both manual and computerized measurements in upper and lower arches. It was found that moderate crowding shows the highest percentage in both manual and computerized measurements.

For the manual measurements , the upper arch moderate crowding has a higher percentage (49%) which appears more frequent in the male sample, followed by the severe crowding percentage (35%) which appear more frequent in female sample, and finally the minor crowding percentage proved to be the least frequent (16%). In the lower arch severe crowding showed a higher percentage (42%) and appears to be more frequent in female sample, followed by moderate crowding percentage, and minor crowding percentage was the least frequent. While for the computerized measurements Figure (4-5) show that in the upper arch the moderate crowding had the highest percentage (55%) which appear more prominent in the male sample followed by severe crowding percentage (23%) which is more frequent in the female sample and minor crowding had the lowest percentage (22%). In the lower arch severe crowding shows the lowest percentage (24%) while minor and moderate crowding show similar percentages of crowding. In these types of crowding females had a higher percentage of moderate crowding while males showed a higher percentage of the minor crowding.

Table 4 comparing between manual and computerized measurements in each group of dental crowding and by using t-test the results show that there is no significant difference in the minor and moderate groups while a high significant difference was found in the severe group.

Table 5 shows the ANOVA test for the total sample. Using manual measurements it was found that there is a significant difference among the three groups of crowding for space available and for the teeth size. While Table 6 shows the ANOVA-test for the total sample, using computerized measurements. The results indicate that there is a high significant difference among the three groups of crowding for both space available and for the mesio-distal dimension of the teeth.

Table 7 shows the mean and SD of tooth size and arch size discrepancy in both upper and lower arches among the three groups of crowding. By using ANOVA-test it was found that in the upper arch there is no significant difference among different degrees of dental crowding for space available but a significant difference did occur among teeth dimensions. As for the lower arch it is obvious that a high significant difference occurs among the three groups of crowding for space available, but the mesio-distal dimension of the teeth revealed no significant difference. While Table 8 shows that in the upper arch a high significant difference does occur for both space available and teeth mesio-distal dimension, but in the lower arch a significant difference does occur for space available only but the teeth showed no significant difference.

Discussion

The results show that there is a high significant difference between manual and computerized measurements for crowding. It is obvious that the mean value of manual crowding is (4.48mm) which are higher than the computerized indicating severe crowding. This is because there were a large number of cases in the total sample having severe crowding depending on manual method, while the mean value of the computerized crowding was smaller than the mean value of manual crowding (3.08mm) which indicates a moderate crowding. This is because most of the crowding values depending on computerized measurements were moderate for the same sample. Also, the difference between manual and computerized crowding is due to that since the crowding values obtained from the basic equation which is:

Space available - Space required = Crowding. And since all the values of space available and space required were smaller in the computerized measurements than in the manual measurements and according to that equation it must be expected that the mean values of the computerized crowding will be smaller than the mean values of manual crowding. This comes in agreement with [3, 4, 13].

It was found that the space available shows a high significant difference between manual and computerized measurements in the total sample (68.5, 65.6) respectively, and in the upper (73.1, 70) respectively, and lower arches (63.9, 61.2) respectively, as shown in Tables (1), (2) which were higher in the manual mean values than the computerized and this could be due to the fact that the determination of arch form alignment needs an individual judgment which in turn is related to the interpretation of the arch form presented by individual case. However, the greater the crowding the more the arch form is obscured [14]. This may offer a possible explaination as to why the mean arch perimeter measurements (space available) in the total sample and in the upper and lower arches were consistently higher manually than those recorded by the computer. Another cause may be attributed to the use of brass wire, which may be distorted when applied so as to lie over the line of occlusion the wire tends to lean over labially or lingually which in turn leads to a change in the measurement of arch circumference (space available), while in the computer a uniform curve can be drawn precisely without any distortion on the line of occlusion of the dental arch. So this could be another reason which might lead to the difference between manual and computerized measurements.

The third cause is related to the experience of the operator because the least experienced operator showed the greatest intra-examiner variability using the brass wire technique, but by using the computer the results were closer to the other examiners.

All the above mentioned causes are in agreement with [13, 14, 15, 16, 17, 18].

The space required also shows a high significant difference between manual and computerized measurements in the total sample (72.3, 68.7) respectively, and in the upper arch (76.7, 73.1) respectively, and in the lower arch (67.9, 64.2) respectively, as shown in Tables (1,2) and also present higher values in the manual means than in the computerized and this is due to the inclination, rotation and crowding of the teeth. The precise measurements of the mesio-distal width of the teeth in these cases are difficult when using the computer, but in the manual method and by using a vernier we can easily insert the beaks of the vernier into an inclined or severely malposed tooth. So this may produce a difference between manual and computerized measurements in severe cases but cases with lesser degree of inclination, rotation and crowding, the points on the mesial and distal contacts of the teeth using a computer can be marked precisely. But with a vernier it’s a little difficult because the beak of the vernier is not very pointed unlike the pointer of the computer. So, that’s why there was a difference between manual and computerized measurements in minor and moderate cases. These findings are in agreement with [3 and 19].

It's found that the moderate crowding group demonstrate a higher percentage in both manual and computerized measurements and this may be due to the fact that there was a large number of moderate cases in the total sample, and additionally, the computer can give measurements which is closer to the manual measurements for the moderate crowding cases [19].

The high percentage of moderate crowding in the upper arch for both manual and computerized measurements as to why the computerized measurements were closer to the manual measurements and this indicates the capability of the computer to evaluate the moderate crowding cases easily; this is in accordance with [19]. In addition to that, most of the sample in the present study has moderate crowding. The reason behind the prominent percentage of moderate crowding in the male sample in both manual and computerized measurements is that, although there is a difference in the value of these percentages between the two methods nevertheless they show the same distribution, and this could be due to the males having larger teeth than females. So in the upper arch, the males may have more crowding percentage than females, this come in acceptance with [20,21,22, 23, 24 ,25, 26, 27 , 28].

According to the distribution of crowding percentages it is obvious that by using the computer there will be a difficulty in the evaluation of severe crowding cases due to the rotation, inclination and overlapping of the teeth. So, this is the cause for the low percentage of the severe crowding in the computerized measurements and also this explains the big difference in the value of crowding percentage between manual and computerized measurements. This confirms the findings of **Garino and Garino** [19] **and** ***Zilberman et al.*** [23].

In the severe manual crowding percentage it is obvious that the females had a higher crowding percentage than males and this may be attributed to the small arch perimeter of the female [24, 8, , 25] which lead to the increase in the percentage of crowding in females. This is in agreement with ***LaVelle and*** [26]***, and Foster et al.*** [27].

The non-significant difference between manual and computerized measurements in the minor and moderate crowding groups could be attributed to that the computer can easily evaluate the dental crowding in the minor and moderate crowding groups while in the severe crowding group the high significant difference may result from the difficulty of evaluating severe crowding cases by using the computer due to the inclination, rotation and overlapping of the teeth. This is in accordance with [3, 19, 29].

The results also showed that as the tooth size increased or arch perimeter decreased the degree of crowding increased. These results coincide with the findings of ***Lundstrom*** [32]**, and** ***Randzic*** [33].

These results can be explained thus: the significant difference in the space available among the three groups of dental crowding for both manual and computerized measurements is due to the reduction in the arch circumference specially in the severe crowding cases as demonstrated obviously by the LSD test, which shows a significant difference between (minor and severe), (moderate and severe). These results are in agreement with ***Mckeown(34) and Randzic*** [33] .According to the teeth dimension, the high significant difference among the three groups of crowding for both manual and computerized measurements,is due to the increase in the mesiodistal width of the teeth which is clearly demonstrated by the use of LSD test,), in which there is a significant difference between (minor and moderate), (minor and severe) crowding groups in both manual and computerized measurements. These results are in agreement with ***Lundstrom*** [36].

In the upper arch it is found that the mesiodistal widths of the teeth have more effect on the degree of dental crowding than the arch circumference. The results in the present study demonstrate a significant difference among the three groups of crowding in both manual and computerized measurements Tables (4-10), (4-12) and this is due to the increase in the mesiodistal width of the teeth which is obviously demonstrated by the LSD test, Tables (4-11), (4-13) in which the significant difference appears between (minor and moderate), (minor and severe). These results are in conformity with ***Lundstrom*** **[36]*****, Doris et al.*** **[37].**

According to the space available, manual measurements of space available demonstrates non significant difference among the three groups of crowding Table (7) while in the computerized measurements of space available there was a high significant difference Table (8). This may be due to the big difference in the number of the sample between moderate and severe crowding groups so that this significant difference appears only between these two groups. The above result indicates that the more causative factor implicated in dental crowding in the upper arch is the increase in the mesiodistal dimension of the teeth rather than the reduction in the arch perimeter.

In the lower arch the significant difference in the space available among the three groups of crowding for both manual and computerized measurements Tables (7), (8) indicated that the more causative factor for dental crowding in the lower arch is the reduction in the arch perimeter rather than the increase in the teeth size, and this was confirmed irrevocably by the LSD test, where a significant difference (between minor and severe) in both manual and computerized measurements. This is in agreement with ***Howe et al.*** **[38],** who concluded that dental crowding was associated with smaller dental arches rather than large teeth.

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Table 1: Comparison between manual and computerized measurements for upper and lower dental arches (Unite of measurement: mm).

Variables		Method	Mean	SD	T	p. value
Upper	Crowding	Manual	3.69	1.69	5.543	0.001 HS
		Computerized	3.12	1.45		
	Space available	Manual	73.13	3.51	17.005	0.001 HS
		Computerized	70.03	3.72		
	Space required	Manual	76.79	3.40	10.382	0.001 HS
		Computerized	73.15	3.70		
Lower	Crowding	Manual	6.09	1.60	2.637	0.01 S
		Computerized	5.82	1.75		
	Space available	Manual	63.91	3.74	17.59	0.001 HS
		Computerized	61.24	3.65		
	Space required	Manual	67.97	3.37	10.571	0.001 HS
		Computerized	64.28	3.72		

S: Significant difference at level p<0.05. HS: Highly significant difference at level p<0.01.

Table 2: Sample distribution by number according to gender and arch frequency for manual measurements

		Minor	Moderate	Severe	Total
Upper	Male	7	27	16	50
	Female	9	22	19	50
	Total	16	49	35	100
Lower	Male	10	22	18	50
	Female	8	18	24	50
	Total	18	40	42	100

Table 3: Sample distribution by number according to gender and arch frequency for computerized measurements.

		Minor	Moderate	Severe	Total
Upper	Male	15	31	4	50
	Female	7	24	19	50
	Total	22	55	23	100
Lower	Male	22	15	13	50
	Female	16	23	11	50
	Total	38	38	24	100

Table 4: Comparison between manual and computerized measurements in each group of dental crowding (Unite of measurement: mm.)

Crowding	Methods	N	Mean	SD	t-test	P-value
Minor	Manual	34	1.59	0.31	0.21	0.83 NS
	Computerized	60	1.58	0.30		
Moderate	Manual	89	3.14	0.58	1.67	0.08 NS
	Computerized	93	2.99	0.57		
Severe	Manual	77	7.29	2.45	4.38	0.001 HS
	Computerized	47	5.53	1.35		

NS: non significant difference at level p>0.05. HS: Highly significant difference at level p<0.01.

Table 5: Tooth size-arch size discrepancy by manual measurement for the total sample (Unite of measurement: mm).

		N	Mean	SD	F	p.value
Space available	Minor	34	69.06	5.69	4.221	0.016 S
	Moderate	89	69.60	5.57		
	Severe	77	67.04	6.05		
Tooth size	Minor	34	7.04	0.53	5.496	0.005 HS
	Moderate	89	7.34	0.51		
	Severe	77	7.27	0.60		

Table 6: Comparisons of the total computerized measurements among three groups of dental crowding (Unite of measurement: mm).

		N	Mean	SD	F	p.value
Space available	Minor	60	64.85	5.01	5.805	0.004 HS
	Moderate	93	67.03	5.92		
	Severe	47	63.87	5.66		
Teeth	Minor	60	6.64	0.50	7.18	0.001 HS
	Moderate	93	6.98	0.59		
	Severe	47	6.94	0.56		

Table 7: Tooth size-arch size discrepancy by manual measurement in both arches

			N	Mean	SD	F	p.value
Upper	Space available	Minor	16	73.75	4.34	1.307	0.275 NS
		Moderate	49	73.47	3.35		
		Severe	35	72.37	3.27		
	Teeth	Minor	16	7.55	0.42	2.21	0.01 S
		Moderate	49	7.69	0.29		
		Severe	35	7.76	0.33		
Lower	Space available	Minor	18	64.89	2.65	4.808	0.01 HS
		Moderate	40	64.85	3.76		
		Severe	42	62.60	3.80		
	Teeth	Minor	18	6.75	0.32	0.56	0.57 NS
		Moderate	40	6.83	0.30		
		Severe	42	6.80	0.40		

S: significant difference at level p<0.05. HS: Highly significant difference at level p<0.01.
NS: non significant difference at level p>0.05

Table 8: Tooth size-arch size discrepancy by computerized measurement Unite of measurement: mm.

			N	Mean	SD	F	p.value
Upper	Space available	Minor	22	69.41	4.01	5.757	0.004 HS
		Moderate	55	71.05	3.41		
		Severe	23	68.17	3.45		
	Teeth	Minor	22	7.10	0.40	4.921	0.009 HS
		Moderate	55	7.38	0.34		
		Severe	23	7.34	0.33		
Lower	Space available	Minor	38	62.21	3.38	3.522	0.033 S
		Moderate	38	61.21	3.39		
		Severe	24	59.75	4.07		
	Teeth	Minor	38	6.37	0.34	1.816	0.168 NS
		Moderate	38	6.40	0.34		
		Severe	24	6.55	0.44		

S: significant difference at level p<0.05. HS: Highly significant difference at level p<0.01.
NS: non significant difference at level p>0.05.