Original Article

The Effect of the Number of Clinical Bracket Points on the Accuracy of Curve Fitted to Dental Arch Form by 3D Method

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Abstract

***Background and Aim*:** Adjustment of an accurate curve to the dental arch is an im portant part of orthodontic treatment. Our goal was comparing the fitting accuracy of two curves constructed by different numbers of clinical bracket points (CBP) to the dental arch form using 4th degree polynomial function.

***Materials and Methods*:** A mathematical formula associated with a polynomial function was used to reconstruct the dental arch forms of 18 adolescents (18 casts) with normal occlusion. CBPs were marked on every tooth present in each maxillary and mandibular model (second molar to second molar) using an orthodontic bracket positioning gauge. A coordinate measuring machine (CMM) was used to record the coordinates of each CBP (x, y). Then a curve fitting software was used to obtain the best 4th degree polynomial function and the associated curve fitted to all 14 CBPs. Another polynomial 4th degree function curve was obtained for the same models us ing CBPs only on central incisors, canines and second molars. Curves for each model were compared using statistical values including correlation coefficient, standard error, sum of residuals and R^2.

***Results*:** The mean root squares for curves fitted to 14 points in all samples were 0.8855 and it was 0.9629 when 6 points were compared with 14 points . The intraclass correlation coefficient (ICC) between curves fitted to 6 and 14 points was 0.946 in mandible, 0.983 in maxilla and 0.969 for both.

***Conclusion*:** Six CBPs were enough for proper fitting of 4th degree polynomial func tion to dental arch forms of both jaws.

***Key Words*:** Diagnosis, Imaging, Three-dimensional, Orthodontics, Decision-making computer-assisted, Dental arch

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Introduction

One of the principal factors associated with orthodontic treatment planning is determination of the patient's dental arch form [1,2]. Determination of a suitable dental arch in order to achieve the principal goals of orthodontic treatment i.e., esthetics and functional and stable occlusion has been a matter of concern for long. Triangular mandibular arch form was considered functionally suitable for the first time [3]. Later descriptions of suitable arch form consisted of semi-elliptical [4], sagittal [5] catenary [6] and trifocal-elliptical [7] In recent

years, cubic spine mathematical formulas [8], cubical sections [9], beta functions [10] and polynomial functions [11] have been utilized to predict and describe dental arch forms. Along with the efforts on an exact description of dental arch form, obtaining suitable points in order to trace dental arch is an additional challenge. In some investigations, centers of incisal edges and buccal cusp tips have been used for tracing the dental arch [12,13]. Since the aim of dental arch form determination is to create a guide for placement of brackets and selection of a proper wire type, some studies have prioritized use of facial surface points as well as points of clinical bracket attachment. [14-17]

Devices used to digitally record coordinations of the pertinent points included radiographic devices [14], photocopiers [18], two-dimensional scanners [16] and Coordinate Measuring Machine [CMM] [10] CMM is a meticulous coordinate registration system used in industry and research projects and is widely utilized in reverse engineering of structures, military industries etc.

The aim of the current study was to evaluate the effect of decrease in number of clinical bracket attachment points in accuracy of tracing dental arch with the use of Coordinate Measuring Machine.

Materials and Methods

This diagnostic experimental study was performed on orthodontic casts of 18 mature people with class I normal occlusion. All selected casts had fully erupted permanent teeth without any problem such as wear, fracture, ectopic eruption, crowding and midline deviation from permanent second molar on one side to permanent second molar to the other side.

All models were painted black using a brush and a soluble black dye (Pars, Tehran, Iran) in order to produce maximal contrast. Then, clinical bracket attachment points were finely marked on each tooth using a white-colored nail polish (Nail Design Polish, Victoria, Taiwan) and an orthodontic gauge (Unitek, USA) according to the bracket placement guide for pre-adjusted appliances [19] (see fig.1)

Figure 1: An orthodontic cast after painting and defining clinical bracket attachment points

Spatial coordinated of these points were measured by a Coordinate Measuring Machine (Mora, Aschaffenburg, Germany) with an accuracy of 10 ± 0.01 micro-meters and digitally saved as. txt formatted files. (See fig.2). A curve fitting

Figure 2: right: CMM, left: A cast fixed in the machine

software (Curve Expert Professional version 1.01) was used for adaptation of the best polynomial ($Y=Ax^4+Bx^3+Cx^2+Dx+E$) to each coordinate related to the casts. In order to trace the dental arch, the Z coordinate for each point was considered zero [10]. This software uses the least square technique to find the best adaptable curve on a series of points. This is a precise method to adapt a curve on points with known coordinates. [20] The form of the curve, correlation coefficient of the points with the resultant function, squared sum of residuals and standard error was calculated and saved by the software. Then, within the primary. txt file, coordinates of the lateral, first and second premo-

lar and first and second molar teeth were omitted and the results were saved as another .txt file containing coordinates of selected teeth including central incisors, canines, and second molars. Then the whole procedure performed in the primary file on all 14 points was done on the new file and the results were saved. In the next step a customized function was defined in the software for each cast by using function coefficients obtained from coordinates of the selected points in the previous step. Afterwards, the coordinates of the primary .txt file pertaining to each cast which contained all 14 clinical bracket attachment points was entered in the customized function of the cast and correlation coefficient, squared sum of the residuals and standard error was calculated and recorded. (Figs.3 and 4)

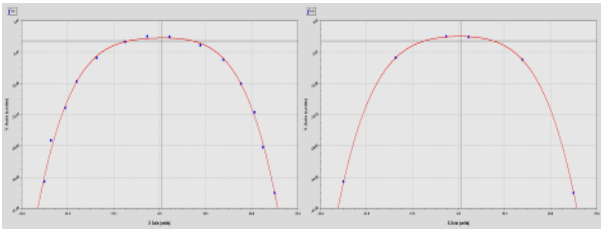

Figure 3: right: A curve obtained from 14 points. Left: A curve obtained from 6 points. Both curves are related to a same cast

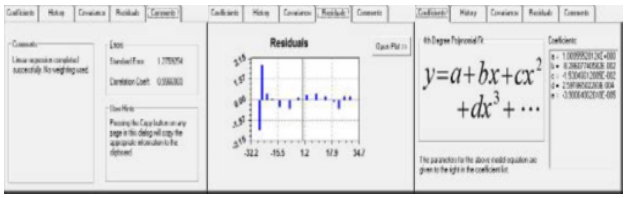

Figure 4: Representation of mathematical properties of the fourteen-point curve showed in fig.3

Descriptive statistical measurements including mean, standard deviation, minimum, and maximum were separately performed for maxillary and mandibular casts. Root mean square (RMS) was used to compare curves in both conditions. This criteria is a standard mathematical method to evaluate similarity between two curves. The smaller the RMS, the higher will be the similarity between the real and proposed model. Also, in order to evaluate validity of data obtained from the two methods, intraclass correlation coefficient (ICC) was used. SPSS version 16 for Windows was used as the statistical tool.

Results

The results showed that the mean recorded measurements were 69.98740 mm with the range of 0.004 and standard deviation of 0.016. The difference between measurements and real values were -0.0066mm. The results of descriptive statistical analysis is represented in table 1. The mean correlation coefficient between 14 points and the adapted curved thereupon for all samples was 0.996 (SD=0.006) The mean correlation coefficient between 14 points and the adapted curved upon 6 selected points for all samples was 0.995 (SD =0.004) The mean RMS for all samples in the curve obtained from 14 points was 0.8855 . The same value was 0.9629 for the curve obtained from 6 points after adaptation of 14 relevant points. ICC for the RMS of the obtained curves from 14 and 6 points was 0.946 in mandible, 0.983 in maxilla and 0.969 for the whole samples.

Discussion

In the present study the mean correlation coefficient of 14 clinical bracket attachment points and the curve obtained from 6 selected clinical bracket attachment points (including central incisors, canines and second molars) was 0.995 (SD =0.004) In comparison with correlation coefficient of 14 clinical bracket attachment points with their specific curves in each cast (0.996 with SD =0.006), the aforementioned method had a very good accuracy.

Theoretically the higher the degree of the polynomial function, the higher will be the adaptability of the curve with the points. On the other hand, such increase causes distortions that limit clinical application of the curve. Quartic functions have been used in some other investigations as well [11, 22, 23].

Some authors suggested six-degree polynomials for

Table 1: correlation coefficient of adaptation of clinical buccal points with the curve adjusted upon 14 and 6 buccal points in maxilla and mandible

	Sample number	RMS* 14 points mandible	Correlation coefficient 14 points mandible	RMS 6 points mandible	Correlation coefficient 6 points mandible	RMS 14 points maxilla	Correlation coefficient 14 points maxilla	RMS 6 points maxilla	Correlation coefficient 6 points maxilla
1	1	0/87400	0/99772	0/88110	0/98866	1/77700	0/96795	1/81420	0/99019
2	2	1/41000	0/99347	1/43000	0/99177	1/03700	0/99505	1/04520	0/99129
3	3	1/02000	0/99669	1/06600	0/99100	2/25000	0/98694	2/30880	0/98255
4	4	0/95390	0/99733	0/95950	0/99485	1/63070	0/99299	1/82360	0/98876
5	5	1/30210	0/99512	1/63420	0/99164	1/30100	0/99512	1/62320	0/99190
6	6	0/91800	0/99758	0/92000	0/99517	1/64600	0/99289	1/66940	0/99115
7	7	0/51960	0/99878	0/52200	0/99820	0/46720	0/99922	0/48770	0/99808
8	8	0/89320	0/99699	1/30080	0/99699	0/48730	0/99911	0/49200	0/99785
9	9	0/84210	0/99644	0/79100	0/99789	0/59230	0/99872	0/63130	0/99819
10	10	1/14010	0/99620	1/30520	0/99489	0/97550	0/99616	0/95870	0/99690
11	11	1/15290	0/99590	1/30130	0/99512	0/62840	0/99892	0/78690	0/99604
12	12	1/81320	0/99020	1/91030	0/98281	0/58590	0/99848	0/72750	0/99701
13	13	0/72061	0/99774	0/78280	0/99490	0/39730	0/99939	0/45740	0/99805
14	14	0/42840	0/99920	0/44720	0/99901	0/33480	0/99957	0/40000	0/99910
15	15	0/44400	0/99913	0/50140	0/99949	0/42920	0/99934	0/49780	0/99930
16	16	0/35150	0/99947	0/36540	0/99704	0/50140	0/99908	0/54180	0/99847
17	17	0/42420	0/99910	0/44230	0/99960	0/78510	0/99758	0/79680	0/99680
18	18	0/37790	0/99924	0/50210	0/99904	0/46900	0/99923	0/54110	0/99860
total	Number of samples	18	18	18	18	18	18	18	18
	Mean	0/8658728	0/9970160	0/9479222	0/9948925	0/9052833	0/9953186	0/9779667	0/9950136
	Standard deviation	0/40475982	0/00235403	0/45394107	0/00438561	0/57615526	0/00759695	0/59558425	0/00463166
	minimum	0/35150	0/99020	0/36540	0/98281	0/33480	0/96795	0/40000	0/98255
	maximum	1/81320	0/99947	1/91030	0/99960	2/25000	0/99957	2/30880	0/99930

*** RMS= Residual Mean Square**

better adaptation [16]. It has been observed that in case index points are used in all teeth, use of six-degree polynomials can cause the aforementioned distortions. This is in accordance with the study car ried out by Kageyama and co-workers [22]. The results of the present study show that use of a four-degree polynomial with the suggested points can provide a model with an adequate accuracy. On the other hand, it is easier to customize a model for each cast if four-degree polynomials are used in comparison with six-degree functions due to lower number of terms in each equation. Braun an colleagues made use of a coordinate measuring machine to form dental arches using midpoints of incisal edges and buc

cal cusp tips of teeth in Angle's class I, II, and III occlusal relationships as index. They introduced beta function as a template to predict arch form using intercuspal distance as arch width between distobuccal cusps of second molars. They also measured arch depth up to the connecting line between the aforesaid cusps. The mean correlation coefficient of the registered index points and the defined functions was 0.98 with a standard deviation of 0.02. These values are slightly less than those obtained in our investigation.

Kageyama et al [22] stated that beta functions tend to underestimate intercanine width in comparison with polynomial functions of degree 4 created by the total dental index points in prediction of dental arch width. Hence, they reported that quartic functions have a better adaptation to the real condition in determination of the dental arch form. Within the current study, the intercanine width corresponded with the real condition because the coordinates of the clinical bracket attachment points on canine teeth were located in the group with selected points and also according to the point that no statistically significant difference existed in standard error between the graphs obtained from 6- and 14-point models and were highly reliable.

Noroozi and co-workers [24] declared that a polynomial function such as $Y=Ax^6+Bx^2$ can adequately fit the beta function suggested by Braun et al. They calculated arch width distance between distobuccal cusps of second molars, arch width distance between cusp tips of canines and arch depth from the midpoint on incisal edge to the connecting line between the canine cusp tips and arch depth up to the connecting line of the distobuccal cusp tips of second molars in order to calculate the coefficients of A and B. Then, correlation coefficient of 18 points including midpoints of incisal edge and all buccal cusp tips which were digitized by a photocopier, a scanner and AutoCad software on each dental cast with Angle's class I normal occlusion were measured according to the pertinent curves. They obtained a correlation coefficient of 0.98 (SD=0.02). Also, the minimum RMS was calculated using of the mentioned formula, with the mean of 0.6058 for all casts, therefore the aforementioned polynomial was in a high accordance with the beta function. The advantage of the suggested function in their study was lack of decrease in intercanine width in comparison with beta function [24]. In the current study, the selected index points for arch determination were clinical bracket attachment points. In addition, digitization of these points with the use of CMM has a higher accuracy in comparison with photocopier and scanner. It can also be said that correlation coefficient of all clinical bracket attachment points with the use of the obtained function was more than that obtained by the selected points. This can be due to some factors; firstly, selected points used to create a model in this study were samples of points whose adaptation with the 6-point model had been previously evaluated. Secondly, within the polynomial models used in this study none of the terms had a zero coefficient. Thirdly, mean RMS for all samples in the current study showed a higher value in adaptation of 14 points with the resultant curve and 14 points with a curve resulted from 6 points.

This was due to the comparison of both conditions with a polynomial function but not a beta function.

Trivino et al [16] marked and scanned midfacial points on mandibular teeth by attaching 1.5 millimeter balls to classify different dental arch forms in Brazilian population with the use of 6-degree polynomial functions and least square technique. Eventually, 23 dental arch forms were introduced. They used balls to enhance detectability of the points in two-dimensional images obtained from the scanner and to simulate bracket width. Since, brackets have varying dimensions in different teeth , it seems that use of balls with same dimensions can decrease accuracy of measurements to a large extent. In the current study use of CMM and registration of points on teeth caused more accurate correspondence of the obtained dental arches with real conditions.

Conclusion

It can be concluded that it is possible to decrease the number of index points required for tracing dental arch from 14 to 6 clinical bracket attachment points from second molar on one side to the other side. The six selected clinical bracket at-

tachment points to trace highly accurate dental arches can be located on central incisors, canines, and second molars in each dental arch.

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References

1-Strang RHW. Factors associated with successful orthodontic treatment, Am J Orthod. 1952 Oct; 38 (10):790-800.

2-Rickets RM. A detailed consideration of line of occlusion. Angle Orthod. 1978Oct;48(4):274-82.

3-Bonwill WGA. Geometrical and mechanical laws of articulation, Trans Orthod. Soc Penn. 1885; 109-33.

4-Black GV. Descriptive anatomy of the human teeth. 5th ed. Philadelphia: White Dental Mfg. Co; 1902, 130-152.

5-Broomell IN. Anatomy and histology of the mouth and teeth. ed. 2nd. Philadelphia: P Blackiston's Son & Co; 1902, 99.

6-Stanton FL. Arch predetermination and a method of relating predetermind arch to the malocclusion to show the minimum tooth movement. Int J Orthod. 1922 Oct; 8(10):757-78.

7-Brader AC. Dental arch form related with intraoral forces: PR=C. Am J Orthod. 1972 Jun;61 (6):541-61.

8-Beagle EA. Application of the cubic spline function in the description of dental arch form. J Dent Res. 1980Sep; 59:(9):1549-1556.

9-Sampson PD. Dental arch shape: A statistical analysis using conic sections. Am J Orthod. 1981 May;79(5):535-48.

10-Braun S, Hnat WP, Fender DE, Legan HL. The form of the human dental arch. Angle Orthod. 1998 Feb;68(1):29-36.

11-Ferrario VF, Sforza C, Miani A, Jr, Tartaglia G. Mathematical definition of the shape of dental arches in human permanent healthy dentitions. Eur J Orthod. 1994 Aug;16(4):287-94.

12-Ellen A, BeGole, A computer program for the analysis of dental arch form using the catenary curve. Com Prog In Biomed. 1981 March-Jun; 13 (1-2):93-99.

13-Taner TU, Ciger S, El H, Germec D, Es A. Evaluation of dental arch width and form changes after orthodontic treatment and retention with a new computerized method. Am J Orthod Dentofacial Orthop. 2004 Oct;126(4):464-75.

14-Currier JH. A computerized geometric analysis of human dental arch form. Am J Orthod. 1969 Aug;56(2):164-79.

15-Fujita K, Takada K, QianRong G, Shibata T. Patterning of human dental arch wire blanks using a vector quantization algorithm. Angle Orthod. 2002 Aug;72(4):285-94.

16-Trivino T, Siqueira DF, Scanavini MA. A new concept of mandibular dental arch forms with normal occlusion. Am J Orthod Dentofacial Orthop. 2008 Jan;133(1):10 e5-22.

17-Ronay V, Miner RM, Will LA, Arai K. Mandibular arch form: the relationship between dental and basal anatomy. Am J Orthod Dentofacial Orthop. 2008 Sep;134(3):430-8.

18-Nojima K, McLaughlin RP, Isshiki Y, Sinclair PM. A comparative study of Caucasian and Japanese mandibular clinical arch forms. Angle Orthod. 2001 Jun;71(3):195-200.

19-McLaughlin RP, Bennett JC. Bracket placement with the preadjusted appliance. J Clin Orthod. 1995 May; 29(5):302-11.

20-Wolborg J, Data analysis using the least squares: Extracting the most information from experiments, 1st ed. Berlin: Springer Co; 2005, 1-27.

21-Wakabayashi K, Sohmura T, Takahashi J, Kojima T, Akao T, Nakamura T, et al. Development of the computerized dental cast form analyzing system--three dimensional diagnosis of dental arch form and the investigation of measuring condition. Dent Mat J. 1997;16(2):180-90.

22-Kageyama T, Dominguez-Rodriguez GC, Vigorito JW, Deguchi T. A morphological study of the relationship between arch dimensions and craniofacial structures in adolescents with Class II Division 1 malocclusions and various facial types. Am J Orthod Dentofacial Orthop. 2006 Mar; 129 (3):368-75.
23-Nouri M, Padisar P, Edalat A, Valipoor B. Evaluation of dental size form changes in 12-16 years old normal occlusion Iranian adolescents (A 4 year longitudinal study, Qazvin city) Journal of Dental School Shahid Beheshti University of Medical Sciences, 21(4):781-794.
24-Noroozi H, Nik TH, Saeeda R. The dental arch form revisited. Angle Orthod. 2001 Oct;71(5):386-9.