

Average Arch Widths and Associated Changes between Initial, Post-treatment and Post-retention Measurements

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Computer image monitoring was used for evaluation of dental arch changes. A new special device captured geometrically calibrated images permitting comparison of several different dental casts. In the first part of this study 792 sets of study casts were screened. Measurements of dental arch width between reference points of canines, first premolars and first molars were made: upper jaw: men: canines: 35.1 ± 0.13 mm; first premolars: 37.5 ± 0.13 mm; first molars: 48.1 ± 0.19 mm; women: canines: 33.4 ± 0.13 mm; first premolars: 35.6 ± 0.15 mm; first molars: 46.7 ± 0.19 mm. In the second part of the study, changes between initial, post-treatment and post-retention alignment (5-years after orthodontic therapy) of upper and lower dental arch of 36 subjects were analyzed. Upper and lower arch compression in first premolars and molars area was visible before treatment. We conclude that computer image monitoring can be used for evaluation of dental arch changes during the different steps of treatment.

Key words: dentistry, orthodontics, computer image monitoring.

INTRODUCTION

Proper diagnosis is important in both prosthetics and orthodontics. The diagnostic procedure commences with the initial examination, during which a large number of individual findings and analyses of the etiology and specifics of the occlusion or malocclusion are clarified. The objective of this study was to describe the morphological and functional characteristics of each patient using specific guidelines, and then to provide a prognosis of therapy.

Due to possible unexpected developments and reactions during the course of treatment, this initial diagnosis should be reviewed regularly. The data obtained during the initial diagnosis is again evaluated to ensure that it is still relevant. The objective of periodic examinations is to reassess the success of the therapeutic method and to establish whether further procedures

are advisable. Sometimes the treatment plan is changed. This is called continuing diagnosis. The main objective of the final check-up is to assess the stability of the treatment results.

Study cast analysis is a three-dimensional assessment of the maxillary and mandibular dental arches and the maximal intercuspation relationship is one of the basic tools of diagnosis and treatment planning. Arch form, dimensions, and variations obtained from orthodontic and prosthodontic treatment have been studied for many years. Some authors have tried to identify a geometric curve, which would enable them to accurately define arch form. According to Bonwill and Hawley (1), the alignment of the upper anterior teeth are a circumference arch; whilst MacConaill and Scher (2) maintained that the dental arch looked like a catenary curve. Izard (3), trying to relate the dimension of the dental arch to the facial dimensions, found that the

arch form could be accurately represented by an elliptical curve.

With present-day knowledge, the study cast analysis as a whole is often considered to have a limited diagnostic value (4). A new method of computer imaging and measurements on a dental stone cast is a ubiquitous tool in dentistry and helps to record precise information. Currier (5) compared the arch form of 25 dental casts with parabolic and the elliptic curves. By computerized analysis, he discovered that the curve of the incisal edge of the incisors and canines, together with the buccal cusps of premolars and molars, could be expressed as an ellipse in both arches. Brader (6), on the other hand, maintained that the teeth were arranged in formation as in the constricted end of a trifocal ellipse. De La Cruz et al. (7) identified the lower arch form as an ellipse in 96% of subjects. BeGole and Lyew (8) developed a method, using cubic spline function, to analyze change in dental arch form pre- and post-treatment and post-retention. The spline curves were within normal limits for dental arch form.

Currently computers are widely used for numerous tasks in the modern dental practice, including word processing, practice management, diagnosis and treatment planning, and recording pertinent information for restoration machining (9).

Computer image monitoring in dentistry is one of the methods which is helpful for both diagnosis and therapy evaluation. Typical systems use a digitizing tablets for landmark coordinate input; a computer with graphic capabilities for display, analysis, and manipulation and a special printer for image generation. Video

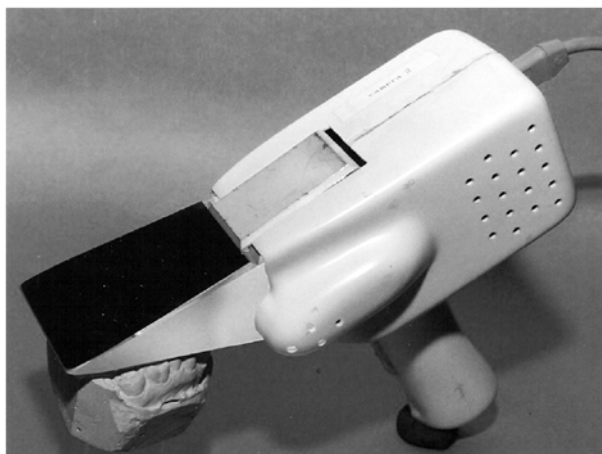


Figure 1. Computer device - research prototype of the Czech Technical University.

or CCD cameras are the second tool for capturing images in the human mouth. This type of image is converted to a digital representation using a frame grabber, which provides a computer interface. The third method of acquiring images is scanning. It is important for all these techniques to acquire images, so the dentist can utilize them – e.g. measure the changes, check the surface morphology, or to simulate the therapeutic effect (4).

The aim of the present study was to use computer imaging of dental stone casts for evaluation of dental arch changes.

MATERIAL AND METHODS

Technical Description of Device

A special device (research prototype of the Czech Technical University) was prepared (Figure 1). It consists of an optical head, a power supply, and a PC computer. The optical head contains a digital color camera, a source of illumination, and a removable prism. The optical head is a handheld device. Its front part consists of a removable prism, which is put into the mouth. The device is manufactured in various sizes and shapes to fit all varieties of arch sizes. The optical prism can be sterilized by heat as well as chemically. The central part of the device forms a handle, which contains the light source and control buttons. The back part is occupied by the camera. The connection to the computer and power supply is by a soft cable. The digital camera is connected to PC via FireWire to allow live image display.

Software Description

The software is designed to work on a PC running MS Windows 2000. It can display live images from the camera as well as archived images. The functionality supports all common image enhancing techniques like contrast/brightness control, palette changing or zooming. The camera is calibrated by reference samples placed in front of the camera, after which the images captured have a known scale and geometric measurements can be performed on them for specific distances, distance ratios, angles, and areas.

Two overlapping images can be displayed in the same scale for comparison, and the user can also con-

trol their relative position by translation and rotation of one image with respect to the other. Special palettes allow easy discrimination of differences between the images being compared.

Database Interface

All measurements performed on images are stored in the database (Figure 2). The copied images are prompted to “archive” them and new captured images overwrite the archived images according to FIFO (first in, first out) strategy. The images are stored in JPEG format. The image processing part also allows export and import in other formats like BMP, etc.

Sample

In the first part of the study, measurements of dental arch width between the canines, first premolars

and first molars were made on 792 sets of study casts (Charles University students).

In the second part of the study, the association between initial, post-treatment and post-retention alignment (5-years after orthodontic therapy) of upper and lower dental arch was analyzed for 36 patients with 108 sets of study models.

The reference points were found, and the distance was measured (Figure 2). Definition of reference points: *maxillae*: distance between a) cusps of canines; b) lower-most points of the transverse fissure of the first premolars; c) points of intersection of the transverse fissure with the buccal fissure of the first permanent molars; *mandible*: distance between a) cusps of canines; b) lower-most points of the transverse fissure of the first premolars (second part of study – 108 study models); c) points of intersection of the fissures of the first permanent molars (second part of study – 108 study models).

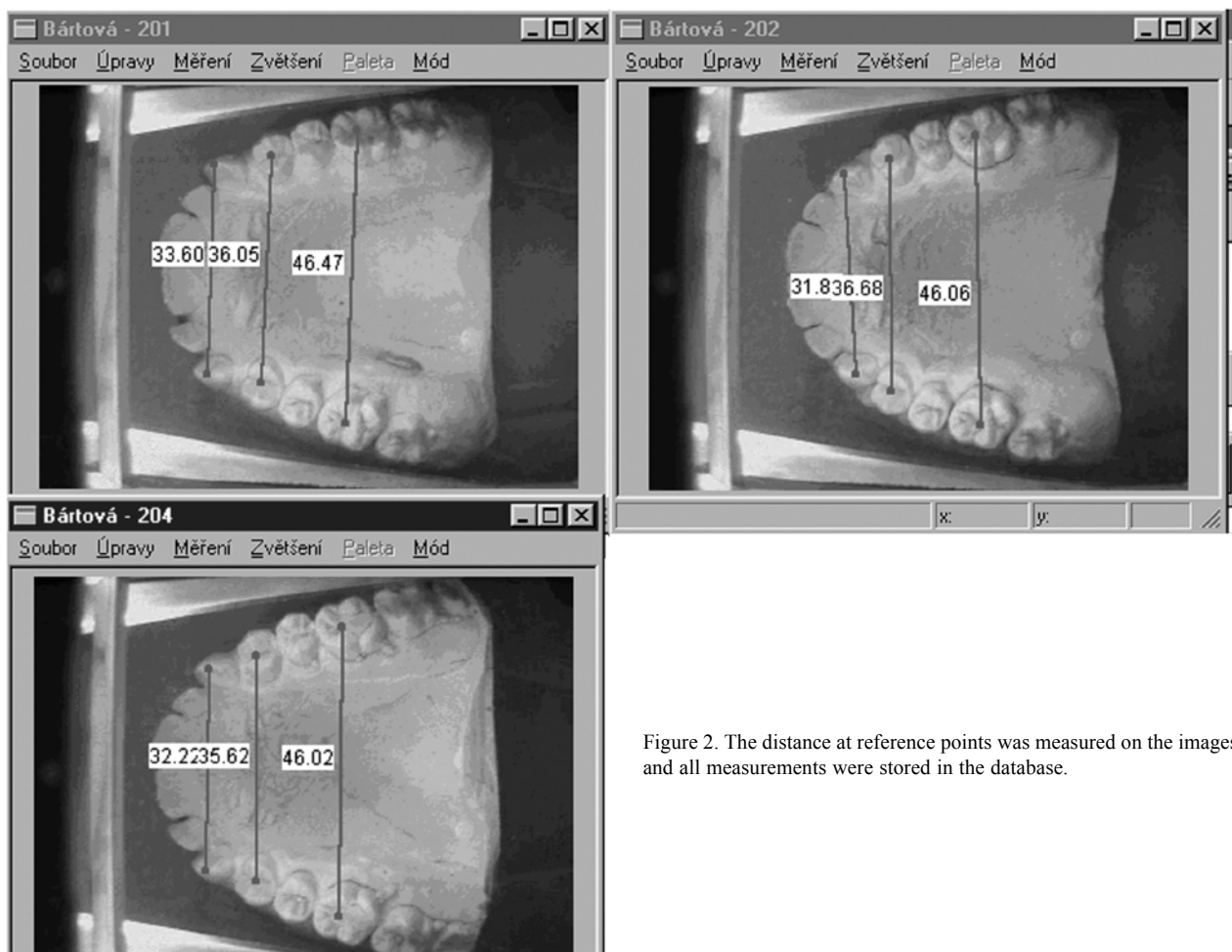


Figure 2. The distance at reference points was measured on the images and all measurements were stored in the database.

The metric analysis of dental arch form was made. The models were evaluated side-by-side (juxtaposition), the reference points were found and the dental arch width was measured.

RESULTS

For the control group of 792 sets of study casts (Charles University students – control group), the following dental arch width measurements were recorded between reference points of canines, between the first premolars, and between the first molars respectively: upper jaw: men: canines: 35.1 ± 0.13 mm; first premolars: 37.5 ± 0.13 mm; first molars: 48.1 ± 0.19 mm; women: canines: 33.4 ± 0.13 mm; first premolars: 35.6 ± 0.15 mm; first molars: 46.7 ± 0.19 mm (Table 1).

The ideal values from healthy students were compared with orthodontic patient values before and after treatment. The correlation analysis of the 5-year recall was prepared and the sets of upper and lower dental arch study cast were analyzed (Table 1). Nonstructural data were also collected. Upper and lower arch compression in first premolar and molar area was visible before treatment: upper jaw: men: canine: 34.59 ± 1.28 mm and 37.65 ± 0.78 ; first molar: 43.7 ± 0.81 mm and 44.28 ± 1.01 ; women: canine: 34.91 ± 0.46 mm and 36.06 ± 0.30 mm; first molar: 44.12 ± 0.45 mm and

43.86 ± 0.55 .

The size and shape of each dental arch was checked 5 years post-therapy (overlapping of images and measurements between reference points) (Table 1). Correlation analysis revealed that the pattern was the same. The shape of dental arch was wider mainly in the anterior region. A significant increase was found between canines (men: from 35.29 ± 0.83 to 36.39 ± 0.96 ; women: from 33.62 ± 0.39 to 34.53 ± 0.39) and first premolars (men: from 34.59 ± 1.28 to 37.65 ± 0.78 ; women: from 34.91 ± 0.46 to 36.06 ± 0.30).

Application of fixed (24 patients) or removable (12 patients) appliance had no influence on treatment stability.

Metric analysis of arch form shows a significant difference between patients before and after treatment – see values in Table 1. The arch form width in men was larger than in women. A significant difference was found in the distance between the first molars.

DISCUSSION

Study cast analysis is a three-dimensional assessment of the maxillary and mandibular dental arches and the occlusal relationships (10). The actual results of the individual cases were compared with the standard measurements of the “normal arch”. Human arch form

Table 1: Metric analysis of arch form. 3+3 = canines; 4+4 = first premolars; 6+6 = first molars.

dental arch width	control group (medical faculty students)			computer evaluation								
	number of persons	mean	SE	patients before treatment			patients after therapy			recall after 5 years		
	number of persons	mean	SE	number of persons	mean	SE	number of persons	mean	SE	number of persons	mean	SE
maxilla - men												
3 - 3	356	35.1	0.13	9	35.29	0.83	10	↑ 36.39	0.96	12	36.65	0.79
4 - 4	343	37.5	0.13	8	34.59	1.28	7	↑ 37.65	0.78	8	37.70	1.07
6 - 6	327	48.1	0.19	13	* 43.70	0.81	13	44.28	1.01	13	44.55	1.22
mandible - men												
3 - 3	358	26.4	0.19	10	26.53	0.62	11	27.03	0.57	12	27.11	0.59
4 - 4	-	-	-	7	29.09	1.04	9	31.05	0.56	11	30.72	0.90
6 - 6	-	-	-	12	38.64	0.69	12	39.83	0.62	12	40.26	0.76
maxilla - women												
3 - 3	327	33.4	0.13	16	33.62	0.39	22	↑ 34.53	0.39	23	34.02	0.33
4 - 4	312	35.6	0.15	16	34.91	0.46	16	↑ 36.06	0.30	16	↓ 35.20	0.50
6 - 6	318	45.7	0.19	24	* 44.12	0.45	24	43.86	0.55	24	43.40	0.53
mandible - women												
3 - 3	334	25.2	0.12	18	25.30	0.43	21	25.78	0.32	24	25.28	0.28
4 - 4	-	-	-	14	28.96	0.48	17	30.30	0.35	20	29.67	0.33
6 - 6	-	-	-	23	38.78	0.41	22	39.21	0.69	24	39.26	0.67

* significant difference in comparison to control group ($P < 0.05$)

↑ significant increase ($P < 0.05$)

↓ significant decrease ($P < 0.05$)

varies considerably. The study of Cassidy et al. (11) analyzed the size and shape of the maxillary and mandibular dental arches of 320 adolescents. Arch dimensions were significantly larger in boys than in girls, both mediolaterally and anteroposteriorly, a sex difference largely established prior to the onset of the adolescent growth spurt. We observed a similar result and found that a certain correlation between arch length, width, and mesiodistal dimensions existed. Contradictory findings on shape and size of dental arch as a risk factor for relapse of optimal alignment have been discussed in the literature (12,13).

Measurements of the dental arch width between reference points of canines, first premolars, and first molars were made. In students, we found similar distances as observed in standard metric analyses of Faber (14). Photocopy of the dental arch and computer analysis during treatment was able to help to check the dental arch form. The occlusograms superimposed at reference marks allowed the transfer of reference crosshairs to following tracing during treatment. The measurements were not done. Our evaluation confirmed that the length of the dental arch can be modified by inclining the incisors without varying the inter-canine width. Our results indicate an expansion of the maxillary anterior arch segment during active treatment. Fixed or removable orthodontic appliances did not influence treatment stability. Orthodontic treatment was stable over a long-term period. We found that several irregularities of anterior teeth were observed in 7% of our 36 patients.

We conclude that computer image monitoring can be used for evaluation of dental arch changes. Geometrically calibrated images help to compare several different steps of the treatment. The analysis of arch shows a significant difference between patients before and after treatment.

RESUMO

Monitoramento de imagem computadorizada foi usado para avaliar as mudanças no arco dental. Um novo e especial dispositivo capturou imagens calibradas geometricamente permitindo a comparação de vários modelos de gesso. Na primeira parte desta pesquisa, 792 modelos de estudo foram medidos. Medidas de largura do arco dental entre pontos referentes aos caninos, primeiros pré-molares e primeiros molares foram feitas: arco superior: homens - caninos: $35,1 \pm 0,13$ mm; primeiros pré-molares: $37,5 \pm 0,13$ mm; primeiros molares: $48,1 \pm 0,19$ mm; mulheres - caninos: $33,4 \pm 0,13$ mm; primeiros pré-molares: $35,6 \pm 0,15$ mm; primeiros molares: $46,7 \pm 0,19$ mm. Na segunda parte

do estudo, mudanças entre o alinhamento inicial, pós-tratamento e pós-retenção (5 anos depois do tratamento ortodôntico) dos arcos superior e inferior de 36 pacientes foram analisadas. A compressão no arco superior e inferior na área dos primeiros pré-molares e molares foi visível antes do tratamento. Concluiu-se que o monitoramento de imagens computadorizadas pode ser usado para avaliação de mudanças na arcada dentária durante as diferentes fases do tratamento.

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REFERENCES

1. Tweed CH. The Frankfort mandibular incisor angle in orthodontic diagnosis, treatment planning and prognosis. *Angle Orthodontics* 1954;24:1212-1269.
2. MacConaill MA, Scher E. The ideal form of the human dental arcade, with some prosthetic application. *Dent Record* 1949;69:285-302.
3. Izard G. New method for the determination of the normal arch by the function of the face. *Int J Orthodontia* 1927;13:582-595.
4. Graber TM, Vanarsdall RL. *Orthodontics*. 2nd ed., St. Louis: Mosby, 1994;268-274.
5. Currier JH. A computerized geometric analysis of human dental arch form. *Am J Orthodon* 1969;56:164-179.
6. Brader AC. Dental arch form related with intraoral forces: PR = C. *Am J Orthodon* 1972;61:541-561.
7. De La Cruz AR, Sampson P, Little R, Firtun J, Shapiro PA. Long-term changes in arch form after orthodontic treatment and retention. *Am J Orthodon Dentofac Orthoped* 1995;107:518-530.
8. BeGole EA, Lyew RC. A new method for analyzing change in dental arch form. *Am J Orthodon Dentofac Orthoped* 1998;113:394-401.
9. Rakosi T, Jonas T, Graber TM. *Orthodontic diagnosis*. Georg Thieme Stuttgart: Verlag; 1993; p 207-217.
10. Surbeck BT, Artun J, Hawkins R, Leroux B. Associations between initial, posttreatment, and postretention alignment of maxillary anterior teeth. *Am J Orthodon Dentofac Orthoped* 1998;113:185-196.
11. Cassidy KM, Harris EF, Tolley EA, Keim RG. Genetic influence on dental arch form in orthodontic patients. *Angle Orthodontist* 1998;5:445-454.
12. Filser F, Kocher P, Weibel F, Luthy H, Scharer P, Gaucler LJ. Reliability and strength of all ceramic dental restorations fabricated by direct ceramic machining. *Int J Computerized Dent* 2001;4:89-104.
13. Corrucini RS. Mouth breathing, occlusion, and modernization in a north Indian population. An epidemiologic study. *Angle Orthod* 1985;55:190-196.
14. Faber DS. Occlusograms in orthodontic treatment planning. *Am J Orthodon Dentofac Orthoped* 1992;6:1-13.
15. Herberger RJ. Stability of mandibular intercuspid width after long periods of retention. *Angle Orthodontist* 1981;51:78-83.
16. Asanami S, Kasazaki Y. Expert third molar extractions. *Quintessence* 1990;21:21-22.

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