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DIFFERENT TEETH QUANTITATIVE EVALUATION OF SHAPES IN RADIOGRAPHIC IMAGES USING PROGRAM PACKAGE "SHAPE VER.1.3"

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Abstract. In 1998 "SHAPE ver.1.3" was developed by Assoc. Prof. Hiroyoshi Iwata for assessment of various biological shapes. We have decided to test this program in the odontology field as it is common to deal with the problem of recognizing teeth in radiographic images when teeth crowns are damaged or teeth position is changed. This can make the diagnosis and treatment more complicated. Our interest would be to create an additional and more precise teeth shape database, which could help to recognize teeth from radiograph images. This method is more precise because we draw the outer edge of the tooth shape, and other methods draw the bounding boxes around the tooth shape (Hegde et al., 2023), (Bilgir et al., 2021). Besides, creating a teeth shape database could help identify human postmortem (Nomir & Abdel-Mottaleb, 2007), (Nomir & Abdel-Mottaleb, 2005). Moreover, this program package could help us compare prostheses or dental fillings with natural teeth anatomy. Our study aimed to compare different teeth shapes (single-rooted and double-rooted) and evaluate the prosthetic quality of a lower jaw 4th quarter tooth by comparing it to the same lower jaw tooth with dental filling in the 3rd quarter. Dental radiographs of each 43rd, 45th, and 46th with dental filling, 47th and 36th with zirconia crown teeth were made with a dental X-ray machine. Afterwards, dental radiographs were processed by using the "Image-J" and "Adobe Photoshop" programs. The methodical part was followed by Assoc. Prof. Hiroyoshi Iwata's publication with Japanese radish (Iwata et al., 2000). Images were uploaded to "SHAPE ver.1.3" software package following programs: "ChainCoder", "CHC2NEF", "PrinComp", "PrinPrint". Using the third program "PrinComp", principal components analysis was applied and harmonics were calculated for each 43rd, 45th, 46th, 47th, 36th teeth radiographic images. Eigenvalue and proportions results were calculated. 43rd teeth radiographic images 1st harmonic made up – 58,47%, 45th teeth radiographic images – 62,45%, 46th teeth radiographic images – 88,45%, 47th teeth radiographic images – 79.82% and 36th teeth radiographic images – 78.64%.
Keywords: SHAPE VER.1.3, teeth shape, radiographic image, principal component analysis

Introduction

In 1998, "SHAPE ver.1.3" was developed by Assoc. Prof. Hiroyoshi Iwata for assessment of various biological shapes. The Japanese radish root shape was used as one of the examples to assess contour (Iwata et al., 2000). In odontology, it is quite common to deal with the problem of recognizing teeth in radiographic images when teeth crowns are damaged or teeth position is changed. Sometimes time pressure, clinical experience, and the complexity of dental radiographs can make a difference in interpreting radiographic images (Hegde et al., 2023). These before mentioned factors can make the diagnosis and treatment more difficult. Our interest would be to create an additional and more precise teeth shape database, which could help to recognize teeth from radiograph images. Programs that identify teeth based only on their shape in panoramic photos have already been developed. However, our method is more precise since we draw the outer edge of the tooth shape, while other methods draw the bounding boxes around the tooth shape (Bilgir et al., 2021), (Mahdi et al., 2020). Additionally, when forensic medicine encounters situations where postmortem human identification proves to be challenging, teeth shape identification can be another useful tool. There have already been attempts to use teeth shapes to identify human postmortem (Nomir & Abdel-Mottaleb, 2007), (Nomir & Abdel-Mottaleb, 2005). However, a more profound and better teeth shape database is much needed. "SHAPE ver.1.3" program package could help us compare prostheses or dental fillings with natural teeth anatomy and, therefore, evaluate the quality of prostheses or dental fillings. As reported in 2021, a system for detecting dental caries is already in development (Lee et al., 2021). Thus, by comparing variations in tooth shape using the "SHAPE ver.1.3" program, we could also enhance the dental caries detection system. Therefore, this study aimed to compare different teeth shapes (single-rooted and double-rooted) and evaluate the prosthetic quality of a lower jaw 4th quarter tooth by comparing it to the same lower jaw tooth with dental filling in the 3rd quarter. We used principal component analysis to evaluate tooth shape.

Methods

Following teeth identification, the ISO system was used (ISO 3950:2016). Dental radiographs of the 46th and 47th teeth (double-rooted), 43rd and 45th teeth (single-rooted) and radiograph images of the 36th (double-rooted) teeth with zirconia crown were made with a dental X-ray machine (Fig. 1. a, b). Later, each tooth contour was drawn and filled with black colour five times using the program "Image-J". Each tooth contour drawn five times was uploaded into one image, and the background was set to be grey. The black marker (1 cm x 1 cm) was cut from the dental radiographic image and added to the photo as well. Image processing was performed with "Adobe Photoshop" program (Fig. 2.). The methodology was adapted according to assoc. Prof. Hiroyoshi Iwata's publication with Japanese radish (Iwata et al., 2000). Edited images were uploaded to "SHAPE ver.1.3" software package programs. The first program "ChainCoder" helped to digitise processed photos. The shapes of teeth were recorded as a chain code of numbers (Fig. 3. a) and estimated by describing a close shape contour made of pixels. The evaluation was made by going around along the contour in a clockwise manner. The contour was converted into a specific length and direction sequence of pixels, which was afterwards recorded as a sequence of numbers (from 0 to 7). The second program "CHC2NEF" helped to create Fourier transforms of contours using a chain code (Fig. 3. b). When the chain code was created, Elliptic Fourier Descriptors were employed. Elliptic Fourier Descriptors quantitatively evaluated the shape of teeth according to characteristics of a shape contour and its inner area. The third program "PrinComp" performed principal component analysis (Fig. 3. c), while the PrinPrint visualised each computer-estimated variation of the shapes of single-rooted and double-rooted teeth (Fig. 3. d).

a) b)

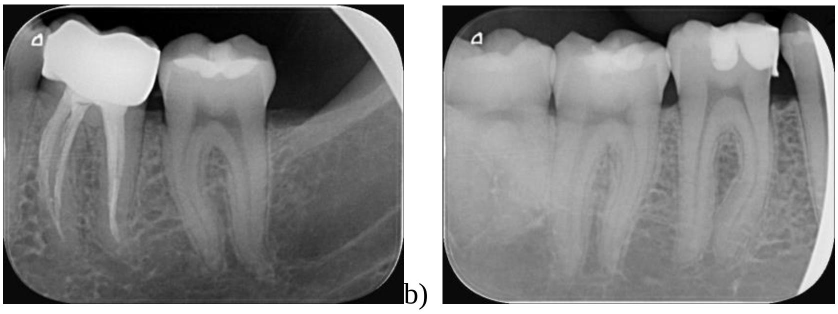

Fig. 1. Dental radiographic images of a) the 36th tooth with zirconia crown and the 37th tooth with dental filling in mandibular left quarter; b) the 46th, 47th teeth with dental filling and unimpacted the 48th teeth in mandibular right quarter

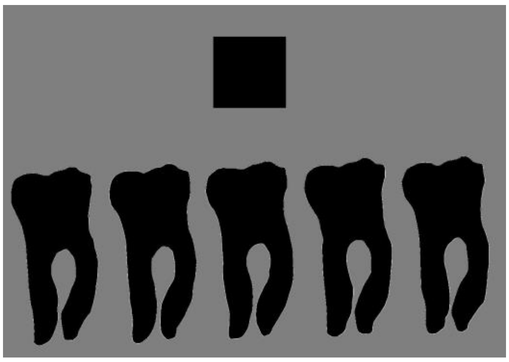

Fig. 2. Edited image with "Adobe Photoshop" program

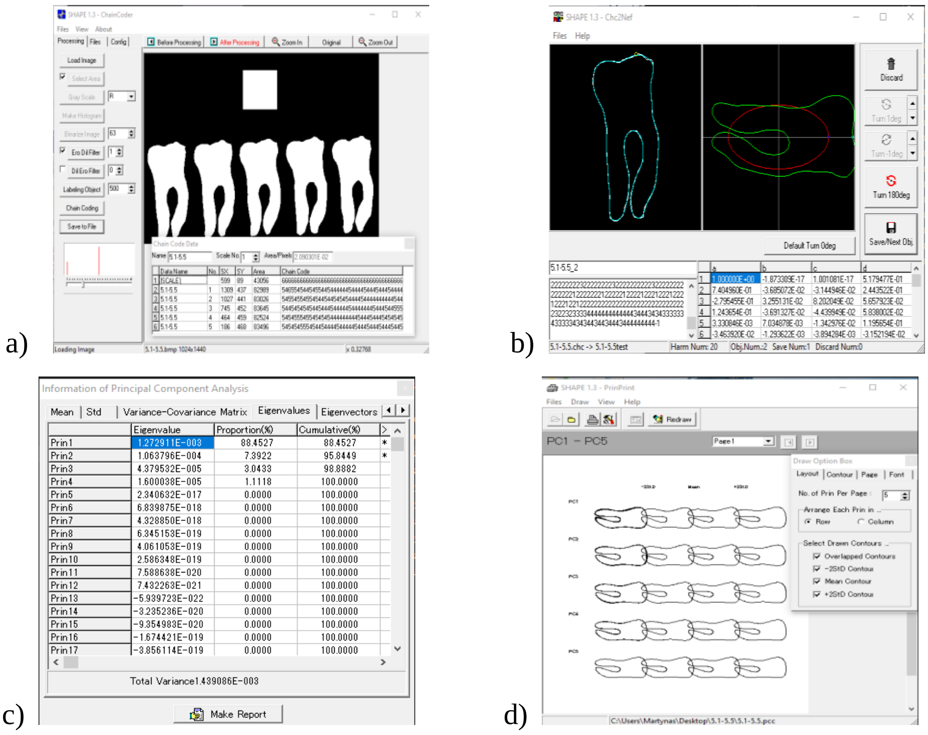

Fig. 3. a) First program "ChainCoder"; b) Second program "CHC2NEF"; c) Third program "PrinComp"; d) Fourth program "PrinPrint"

Results

Principal Components analysis was applied, and harmonics were calculated for each 43rd, 45th, 46th, 47th, and 36th teeth radiographic images. Eigenvalue and proportions results were calculated. Results of the 43rd tooth show that the amount of principal components we need to describe this tooth is four units. Also, the first harmonic made up 58,47% (Table 1.). The results of the other single-rooted teeth, the 45th, show that it needs six principal components to describe contour. The first harmonic made up 62.45% (Table 2.). Double-rooted tooth 46th needs four units of principal components to describe the shape. The first harmonic made up 88.45%, which is the highest value of all first harmonics and shows that it is more digitally informative. The 47th tooth needs 14 principal components to describe contour, but only the first 2 of them make the biggest part - 99.77%. This tooth is more digitally informative because the first harmonic made up 79.82% (Table 4.). The last tooth 36th with zirconia crown needs 4 principal components to evaluate shape. The first harmonic made up 78.64%, which means that like the rest of double-rooted teeth, it is more digitally informative than single-rooted teeth (Table 5.).

Table 1. 43rd tooth eigenvalue and proportions results

Component	Single-rooted 43rd tooth		
	Eigenvalue	Proportion (%)	Cumulative (%)
1	8.42E-005	58.47	58.47
2	3.34E-005	23.24	81.72
3	1.84E-005	12.78	94.51
4	7.90E-006	5.48	100.00

Table 2. 45th tooth eigenvalue and proportions results

Component	Single-rooted 45th tooth		
	Eigenvalue	Proportion (%)	Cumulative (%)
1	6.97E-005	62.45	62.45
2	2.56E-005	22.96	85.41
3	1.08E-005	9.69	95.11
4	5.23E-006	4.69	99.81
5	1.76E-007	0.15	99.96
6	3.52E-008	0.03	100.00

Table 3. 46th tooth eigenvalue and proportions results

Component	Double-rooted 46th tooth		
	Eigenvalue	Proportion (%)	Cumulative (%)
1	1.27E-003	88.45	88.45
2	1.06E-004	7.39	95.84
3	4.37E-005	3.04	98.88
4	1.60E-005	1.11	100.00

Table 4. 47th tooth eigenvalue and proportions results

Component	Double-rooted 47th tooth		
	Eigenvalue	Proportion (%)	Cumulative (%)
1	1.84E-001	79.82	79.82
2	4.60E-002	19.95	99.77
3	3.43E-004	0.14	99.92
4	1.18E-004	0.05	99.97
5	2.07E-005	0.009	99.98
6	1.61E-005	0.007	99.993
7	5.41E-006	0.0023	99.9957
8	4.25E-006	0.0018	99.9975
9	2.15E-006	0.0009	99.9985
10	1.50E-006	0.0007	99.9991
11	9.04E-007	0.0004	99.9995
12	6.36E-007	0.0003	99.9998
13	3.45E-007	0.0001	99.9999
14	1.37E-007	0.0001	100.00

Table 5. 36th tooth eigenvalues and proportions results

Component	Double-rooted 36th with zirconia crown		
	Eigenvalue	Proportion (%)	Cumulative (%)
1	1.08E-003	78.64	78.64
2	2.23E-004	16.24	94.88
3	6.08E-005	4.42	99.31
4	9.49E-006	0.69	100.00

Discussion

We have demonstrated that the program package “SHAPE ver.1.3”, which was initially created for agricultural purposes, could be used and applied to evaluate tooth contour in radiographic images. Our results have shown that the double-rooted 36th tooth with zirconia crown did not have a significant difference in its proportion of the first component compared to the 46th teeth with dental filling. It means that the shape of the 36th tooth with prosthesis is similar to the 46th tooth with dental filling shape.

It is worth mentioning that this program package needs to be tested with other dental prostheses, such as inlays, onlays, and veneers, to evaluate smaller prostheses' impact on teeth shapes. Dental bridges could cause more problems evaluating the quality of prosthesis because the middle part has no root. Thus, it would be defined as a smaller and different shape compared to anatomical teeth.

These days aesthetic and more natural-looking teeth prostheses are in high demand. Having a teeth shape database would provide the possibility to compare the quality of prosthesis shape or dental fillings to patients who lost natural teeth anatomy shape. It could help dentists and dental technicians evaluate the quality of teeth prostheses and recreate teeth prostheses that resemble the patient's natural teeth if teeth have been lost.

Moreover, teeth digitising systems like this could be used with artificial intelligence to help dentists and radiologists recognize damaged teeth or teeth in different positions. To create such a database of teeth shape, more teeth contours need to be digitised in radiographic images to create an artificial intelligence for tooth shape recognition. Nowadays, artificial intelligence is finding new ways in the dentistry field, and our work could help to improve this (Agrawal & Nikhade, 2022), (Chen et al., 2023).

Conclusion

Overall, we have demonstrated that the program package "SHAPE ver.1.3" is suitable for comparing teeth prosthesis shapes with natural teeth anatomy in radiographic images. The minimum amount of principal components that can be used to evaluate the shapes of the 43rd, 46th and 36th teeth is 4 units, the 45th are 6 units, and the 47th are 14 units of which only 2 units make up a significant proportion of principal component analysis. Our results revealed that both single-rooted 43rd and 45th teeth are digitally similar to each other, and double-rooted 46th, 47th, and 36th teeth shapes are digitally similar to each other as well. Moreover, we have shown that single-rooted teeth are less digitally informative than double-rooted teeth shapes. Additionally, even though the 43rd and 45th teeth shapes are digitally similar, the 45th and 47th teeth have more principal component units compared to the 43rd, 46th and 36th teeth shapes.

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