ORIGINAL ARTICLE

The magnification in the lower third and second molar region in the digital panoramic radiographs

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Abstract

Background: The aim of this study was to determine the accuracy of linear measurements of the lower third and second molar crowns in the digital panoramic radiographs and to compare them with plaster models as the calibration standard. **Materials and Methods:** The digital panoramic radiographs and plaster models of the orthodontic patients were used in the study. Standardized metal calibration gauges (MCGs) were bonded to the buccal surface of the lower molars bilaterally. Measurements in the panoramic radiographs were done using Dolphin Imaging 11.8 Premium program. **Results:** Forty-one panoramic radiographs and diagnostic plaster models of the orthodontic patients (mean age 18.45 ± 2.35) were analyzed. Eighty-two lower third molars, 82 second molars, and 82 first molars were evaluated. The magnification coefficients (MCC) calculated according to the plaster models ranged from 1.07 to 1.08. The magnification coefficients calculated according to the bonded MCG were about 1.04. The differences between the teeth groups and right-left sides were not statistically significant ($P > 0.05$). Spearman correlation showed a positive medium correlation between the magnification using the calibration with plaster models and metal gauges ($P < 0.05$). **Conclusions:** The magnification in the lower first, second, and third molars regions showed almost the same values. The calculation of magnification coefficient using bonded metal calipers was more accurate than calculation according to the plaster models, but the differences were not statistically significant. The use of the plaster models for calibration of the magnification coefficient in the good-positioned lower molars' region might be used as an alternative to the bonded MCGs.

Trial registration: The Lithuanian University of Health Sciences BC-OF-73 retrospectively registered.

Key words: Lower second molar, lower third molar, magnification

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Introduction

The crown widths of unerupted teeth in the molar region, mandibular asymmetry, bony pockets, space for the dental implants, and some other variables can be measured using different radiographic techniques.[1] Computed tomography (CT) is considered to be the gold standard for the bone thickness and dental crown measurements but involves the highest radiation exposure, which should be avoided, especially in the growing individuals due to the increased risk of developing cancer.[2-4] In comparison with CT and other expensive precision tests, panoramic radiography is rapid and inexpensive, and its radiation dose is low. Furthermore, if metal prostheses, posts, or pins are present, CT may generate streak artifacts.[5] Digital panoramic radiography, nowadays, is a common imaging technique in the dental, periodontal, surgical, or orthodontic practice as it provides a general view of the teeth and the surrounding structures.[6,7] However, for the measurements or relative comparisons, panoramic radiography should be used with caution due to image distortion and magnification.[8-12] There are many recommendations and studies done on how to calculate the magnification in digital panoramic radiographs. Starting from mathematical, theoretical analysis of dental panoramic imaging and ending with the use of the different calibration objects (steel ball bearings, implants, metal balls, or even gutta-percha as opaque markers) on dry skulls and live patients.[13-18] However, majority of the studies have been concentrated on anterior, premolar, or first molar region of the lower jaw and vertical measurements. There were no studies on the assessment of horizontal linear measurement accuracy in the third and second molar region in the digital panoramic radiographs.

One of the major necessities for precise measurements of the lower molar crowns width is prediction of the third molar impactions and assessment of the oral health problems related with this pathology. Today, however, in the 21st century, the routine removal of asymptomatic pathology-free third molars has become a dated practice that is rapidly running out of valid excuses, and it has no justification in contemporary dentistry and medicine. Despite the various guidelines, reviews, and risks associated with these extractions, many clinicians continue routinely remove pathology-free third molars just by their subjective judgment on the lack of space for these teeth to erupt.[19,20] The simple, accurate, and reliable method to measure molar crown widths and space available in the molar region could be useful for dental radiology practice and help define indications for the removal of the third molars.

The aim of this study was to determine the accuracy of linear measurements of the lower third and second molar crowns in the digital panoramic radiographs and to compare them with plaster models as the calibration standard. Our hypothesis was that magnification in the lower molar region is same, and calculation of the magnification coefficient using dental plaster models is an adequate method for precise measurements in the digital panoramic radiographs in the lower molar region.

Materials and Methods

Approval for the study was obtained from the Lithuanian University of Health Sciences Ethics Committee (BC-OF-73). The patients, entering university dental clinics, scheduled for panoramic radiographs and fabrication of plaster models for diagnostic and treatment planning purposes were examined. Forty-one patients were selected for the study. Inclusion criteria were: erupted, good-positioned lower third, second, and first molars, no crowns and fillings on the mesiodistal surfaces, good quality plaster models, and panoramic radiographs with lower third, second, and first molar. Exclusion criteria were: rotated, mesially or distally shifted lower molars, big restorations, especially in the mesiodistal surfaces, extracted at least one lower molar, bad quality plaster models, or panoramic radiographs.

To minimize radiation dose, digital panoramic system Carestream 9000 was used and ALARA radiation safety principle was followed. Just before taking panoramic radiograph, standardized 9 mm stainless steel gauges were bonded to the buccal surfaces of the lower third, second, and first molar on the right and left sides with a drop of flow composite (Filtek Ultimate, 3M). The metal calibration gauge (MCGs) was attached 2 mm lower and parallel to the occlusal surface using the orthodontic positioning gauge Rocky Mountains Orthodontics with accuracy 0.5 mm. Later, MCGs were removed and the teeth surfaces polished.

The diagnostic impressions were taken using "Prestige" (Vannini Dental Industry, Italy) silicon material and dental casts produced from stone "Marmorock N" class IV (Siladent, Germany).

The crown widths were measured from the most prominent mesial contact surface point to the most prominent distal contact surface point of the lower first, second, and third molars. All measurements were done twice by the same orthodontist with 2 weeks interval on the dental casts. The same crowns widths and 9 mm stainless steel gauge lengths were also measured in the panoramic radiographs [Figure 1]. The measurements on the dental casts were done using digital caliper with the tips sharpened to a point and 0.01 mm accuracy (Dentaurum, Germany). The measurements in the digital panoramic radiographs were done using commercially available software (Dolphin Imaging 11.8 Premium). All image measurements were compared with the physical measurements on the plaster casts or actual length of stainless steel gauge. The coefficients of image magnifications were calculated by dividing the width of

the molar crown in the panoramic radiograph by the actual molar width on the plaster casts or by dividing the length of the stainless steel gauge in the panoramic radiograph by 9 mm(actual length of gauge). The magnification coefficients of 9 mm were used as a standard (control group) and magnification coefficients calculated using plaster casts (MCC) comprised study group. Each group included 6 subgroups: lower right third, second, first molar and left third, second, first molar group magnification coefficients.

All statistical analyses were performed with the statistical software package SPSS 17.0 for Windows. The accuracy and repeatability (intraobserver reliability) of the measurements obtained from panoramic radiographs and plaster casts were evaluated with the interclass correlation coefficient (ICC). Descriptive statistics included the mean, standard deviation, and median values for each parameter. Hypotheses of interrelations between characteristics were verified using Wilcoxon test and Spearman correlation coefficients (r). A $P \leq 0.05$ was considered statistically significant.

Results

Forty-one panoramic radiographs and diagnostic plaster models of the orthodontic patients (mean age 18.45 ± 2.35) were analyzed. Eighty-two lower third molars, 82 second molars and 82 first molars were evaluated. ICC values for intraobserver agreement of the teeth width and bonded MCG length measurements showed very good agreement and no statistically significant differences between the measurements (ICC varied from 0.811 to 0.843, $P \leq 0.05$).

The magnification coefficient in the study group according to the dental casts (MCC) ranged from 1.07 to 1.08. The highest values were in the first molar region and the lowest were in the third molar region. However, the differences between the teeth groups were not statistically significant ($P > 0.05$). The magnification on the right and left showed the same tendency and did not differ statistically ($P > 0.05$).

Figure 1: The position of metal calibration gauges on the lower molars

In the control group, according to the bonded MCGs, the magnification coefficient was about 1.04. In addition the magnification coefficient was higher in the first molar region and the smallest in the third molar region. However, there were no statistically significant differences between the teeth groups and the right and left sides ($P > 0.05$) [Table 1].

By comparing MCC and MCG groups, the differences ranged from 0.03 till 0.04 and according to Wilcoxon test were not statistically significant ($P > 0.05$). Spearman correlation showed a positive medium correlation between the magnification using calibration with dental casts and metal gauges ($P < 0.05$). The correlation was strongest in the second molar region, but the differences were not statistically significant [Table 2].

Discussion

In the previous studies, estimation of the magnification in the panoramic radiographs was done using various methods, thus the results were different due to different X-ray machines, calibration methods, measurement techniques and evaluated regions etc.

Raoof *et al*. in their study concluded that there was no significant difference in the quality of images obtained with both conventional film-based and digital panoramic devices, but the amount of distortion and magnification varied between radiographs taken by different panoramic machines.[21,22] Greatest differences were noted for horizontal measurements and shifted skull positions.[23] The largest image distortions were found when head position was too far anteriorly or posteriorly on the chin rest. Panoramic radiographs had sufficient accuracy to measure the vertical dimension when a patient was correctly positioned. Film speed, type of machine, number of rotation centers, focal trough shape, and X-ray tube head were the main factors which could affect the results in different studies.

The studies did not agree that which method for the calibration was the best. Schulze *et al*. found that the

Table 1: Magnification coefficient in the lower molars region according to the dental casts (MCC) and metal calibration gauges(MCG)

	Lower right third molar region		Lower right second molar region		Lower right first molar region		Lower left first molar region		Lower left second molar region		Lower left third molar region	
	Mean±SD	Median	Mean±SD	Median	Mean±SD	Median	Mean±SD	Median	Mean±SD	Median	Mean±SD	Median
MCC	1.08±0.002	1.07	1.08±0.003	1.07	1.09±0.002	1.07	1.09±0.002	1.08	1.09±0.005	1.09	1.08±0.005	1.07
MCG	1.03±0.004	1.03	1.04±0.004	1.04	1.04±0.004	1.04	1.04±0.004	1.04	1.04±0.004	1.04	1.04±0.004	1.03

$P<0.05$. SD: Standard deviation, MCC: Magnification Coeficient using dental Casts, MCG: Magnification Coeficient using metal gauge

Table 2: Spearman correlation between magnification according to the dental casts and metal calibration gauges

MCC vs MCG	MCC in the lower right third molar region	MCC in the lower right second molar region	MCC in the lower right first molar region	MCC in the lower left first molar region	MCC in the lower left second molar region	MCC in the lower left third molar region
MCG in the lower right third molar region	0.526*	0.639*	0.532*	0.545	0.619*	0.543*
MCG in the lower right second molar region	0.567*	0.573*	0.540*	0.535*	0.555*	0.603*
MCG in the lower right first molar region	0.615*	0.654*	0.542*	0.555*	0.587*	0.582*
MCG in the lower left first molar region	0.652*	0.644*	0.597*	0.593*	0.611*	0.602*
MCG in the lower left second molar region	0.662*	0.762*	0.544*	0.506*	0.733*	0.682*
MCG in the lower left third molar region	0.694*	0.701*	0.503*	0.535*	0.695*	0.653*

*$P<0.05$. MCC: Metal ceramic crown, MCG: Metal calibration gauges

maximum variation for pins was 0.4% of actual object length while for spheres it was 1.2%, and stated that vertical measurements were less reproducible than horizontal measurements. Hence, the most reliable measurements were obtained of linear objects in the horizontal plane. In the study of McIver *et al*. the magnification using a Boley gauge caliper to replicate measurements on the conventional panoramic radiographs varied from 0.08 to 0.26 mm.[24] Frei *et al*. found that the vertical magnification factor with metal balls on panoramic radiographs in premolar and first molar sites was very constant (1.27 ± 0. 01) (1:1.27 ± 0.01).[25]

It is obvious that different measurement methods produced noticeably different intraobserver errors, but it was generally agreed that the performance of a single observer with any method was relatively reproducible. Thus in this study, all the measurements were performed by a single observer who was experienced in the radiographic diagnosis eliminating inter-observer variation and measurement errors presumed to be consistent with the single examiner.

The study by Catic *et al*. also showed that linear measurements in the panoramic X-rays, which were made only on one side of the mandible, were close to actual dimensions while the measurements which extended across the midline were greatly enlarged due to large magnification factors.[26] The magnification coefficient in the previous studies varied from 7% to 24% and differed according to vertical or horizontal plane.[27] The average of horizontal magnification was higher in the anterior part of the maxilla and mandible than in the posterior part. These findings matched with the results of Kim study, whereas the average horizontal magnification was about 19% for the maxillary central incisor.[28] Welander and Wickman found that there was considerable tolerance toward distortion for the lateral regions of a panoramic image compared to the anterior region.[29,30]

A lot of previous studies investigated magnification on dry skulls, but in such circumstances it was difficult to represent the real clinical situation and effect of different factors (patient's head position, constitution etc.,) which could affect the magnification. In the present study, the bonded to the teeth surfaces MCGs, in live patients simulated real conditions in the daily practice and gave very accurate clinical results, which were compared with the findings in plaster models. As the plaster models are routinely used in orthodontics and prosthetic dentistry, thus there might be no need for the additional instruments for the estimation of the magnification, and could be a simple calibration method. Thus, this method might be used for the measurements of unerupted lower molar width for the space analysis or prognosis of the teeth impaction. In the regions where lower molars are malposition, this method should be used with caution because more studies should be done for the approval of this method with angulated, rotated teeth.

Conclusions

The magnification in the lower first, second, and third molar region showed almost the same values and the differences were not statistically significant.

The calculation of magnification coefficient using bonded metal calipers was more accurate than calculation according to the plaster models, but the differences were not statistically significant. The use of the plaster models for the calibration of the magnification coefficient in the good-positioned lower molars' region might be used as an alternative to the bonded MCGs.

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Conflicts of interest
There are no conflicts of interest.

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