Area-Dependent Enlargement Ratios of Panoramic Tomography on Orthograde Patient Positioning and Its Significance for Implant Dentistry

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The aim of this work was to study the behavior of vertical and horizontal enlargement ratios in panoramic tomography in various implant regions of the maxilla and the mandible. A method is presented that admits determination of regional enlargement ratios as a function of the implant region. Clearly defined characteristics of the implant body (Frialit-2 implants) are used as reference points. The vertical enlargement ratio varied between 1.21 and 1.29 on optimal orthograde adjusted tomographs, depending on the measured area. The horizontal enlargement ratio at the coronal end of the implant varied between 1.15 and 1.35. As it is below the vertical value in the lateral tooth area, this contributes to the distortion of the implant structures depicted. The horizontal enlargement at the apical end of the implant varies between 1.12 and 1.44. The difference in horizontal enlargement ratios also causes a distortion of the implant structures shown on the panoramic tomograph. Based on this study scenario, panoramic tomography may be well suited to preimplant diagnosis, particularly in the vertical dimension. With regard to transparent templates designed for implant placement, an enlargement of 1.3 in the perpendicular line and 1.35 in the horizontal line is proposed.
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Key words: area-dependent, enlargement, Frialit-2, implant dentistry, panoramic tomography, radiographic measuring

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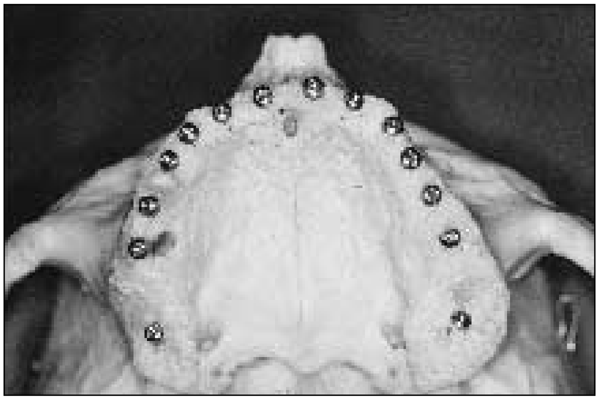
Within the framework of preimplant diagnosis, panoramic tomography plays an important role because of its good overview of osseous structures of the face.[1–3] This is especially beneficial for edentulous patients, in whom multiple implants may be placed, since the amount of radiation to the patient is only 0.3 mGy,[4] compared with sets of periapical films (2.1 to 2.5 mGy each).[5]

The enlargement ratios, which differ in the vertical and horizontal direction depending on the anatomic areas, are a basic problem in panoramic radiographs.[6,7] Thus, metal balls, which are frequently used in preimplant diagnosis, are depicted for instance as horizontally enlarged ellipses.[8] Based on the different behavior of enlargement ratios in the horizontal and vertical dimension, Tronje et al[9] concluded that horizontal evaluations of linear dimensions using panoramic tomographs are unreliable. As precise an assessment as possible



Figs 1a and 1b Implants are placed in the maxilla *(left)* and in the mandible *(right)*.

of distortions and enlargements conditioned by radiographic techniques is of paramount importance in preimplant diagnosis. The aim of this study was to examine how vertical and horizontal enlargement ratios behave on panoramic tomography in various maxillary and mandibular areas, with optimal positioning in the Orthophos panoramic radiograph apparatus of a skull provided with 26 Frialit-2 implants (Friatec, Mannheim, Germany). This experimental design does not consider less than ideally positioned skulls, different patient sizes, type of occlusion, or maxillomandibular shape and the resulting differently positioned implants. Likewise, the impact of scattering from metallic restorations and of more or less extended soft tissue is not discussed.

Materials and Methods

The examinations were carried out on an average-shaped, edentulous skull of unknown sex, age, and race that provided sufficient bone volume for the placement of endosseous implants in all sections of the maxilla and mandible. Positioning of the maxilla to the mandible of the skull in an approximately normal relation was carried out using rubber tape and bite blocks made of autopolymerizing acrylic resin (Palavit-G, Kulzer, Wehrheim im Taunus, Germany). The middle of the mandible (indicated by the mental spine and the center between the mental tubercles) and the middle of central face (characterized by the internasal fissure and the center of the palatal plate) were aligned.

Frialit-2 stepped-cylinder implants 11 mm long and 3.8 mm in diameter were placed in all regions of the maxilla, with the exception of the maxillary left and right second molars, and in all regions of the mandible except the central incisors and third molars, both left and right, so that 14 implants were available in the maxilla and 12 implants were available in the mandible (Fig 1). Implant placement took place initially in one half of the arch; then the distances between the implants themselves and between the implants and the center of the arch were measured using a compass to determine the corresponding implant locations on the contralateral side. The distances of implants were thus consistent with one another in both halves of each arch. At the same time, distances between the implants and the midsagittal plane of one half of the arch were identical to those of the corresponding implants of the other half of the arch. The angles of inclination were matched as far as possible.

The skull was precisely positioned in an Orthophos panoramic x-ray apparatus (Siemens, Bensheim, Germany) using a solid double-jointed tripod (Linhof, Frankfurt am Main, Germany). Between the skull and the movable part of the tripod slide, a rod made of autopolymerizing acrylic resin (Palavit-G, Kulzer) was inserted, corresponding to the spinal column. Tilting avoiders made of synthetic material were fixed, thus ensuring a high position consistent with an even alignment of the Frankfort horizontal plane of the skull (Fig 2).

Radiographic Technique. All panoramic radiographs of the skull were made with the Orthophos panoramic x-ray apparatus. Figure 3 provides a sample view of the optimally positioned skull. The radiographs were taken with the exposure program #1 supplied by the manufacturer. Because of the missing soft tissue cover, the tube voltage was reduced to 60 kV, the current was reduced to 9 mA, and the exposure time was reduced to 14.1

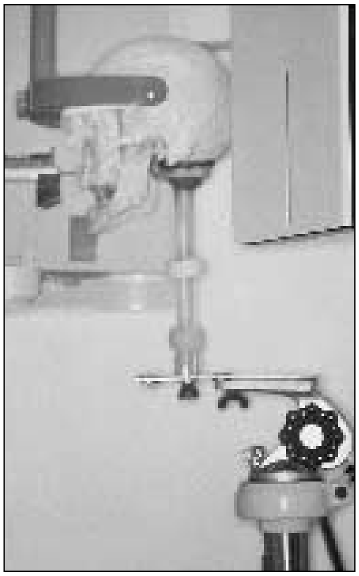


Fig 2 Photographic visualization of skull positioning on the x-ray apparatus.

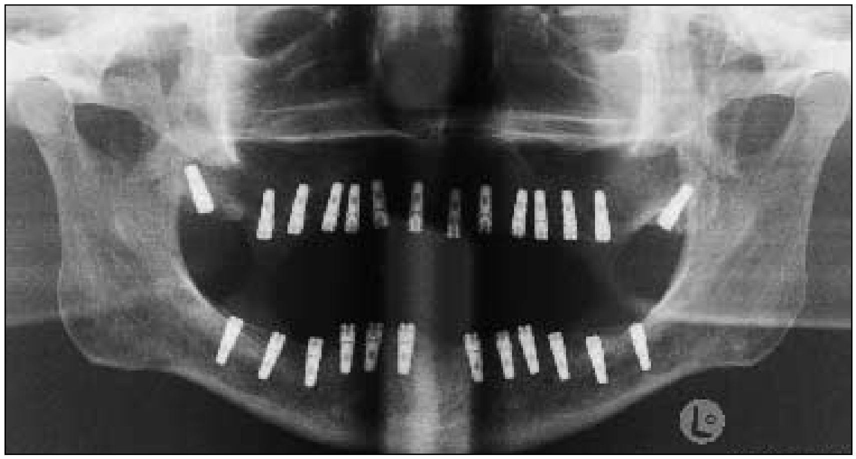


Fig 3 Panoramic tomograph of the skull with the implants.

seconds. A glass rod 20 mm wide was also fixed in front of the slide diaphragm to further improve contrast. All radiographs of the skull were taken with T-MAT G 5500 (Kodak, Rochester, NY) x-ray film of 15 cm × 30 cm format in original film cartridges (Siemens) with reinforcing films of Lanex medium type (Kodak). They were developed in 7 minutes with a dental XR apparatus (Dürr, Bietigheim-Bissingen, Germany) at a temperature of 28°C.

In a clinical setting, the patient's head is placed in the x-ray apparatus using bite block supports for dentate patients or subnasal supports for edentulous patients. Accordingly, the edentulous skull was positioned using the subnasal support, the missing soft tissue cover being taken into account by a 5-mm extension of the distance. To reproduce this fixed 5-mm interspace, a sliding template was fixed horizontally on the bite block support and an 18-mm spacing to the bony subnasal point was adjusted. On the skull, the upper border of the external auditory meatus and the inferior border of the orbit were then marked; the connecting line between both marked points was aligned parallel to the horizontal line of the faded-in light-beam localizer. The sagittal plane was set at the vertical beam of the light-beam localizer.

A bar made of autopolymerizing acrylic resin accurately adjoining the mandibular border was rigidly connected to the removable bite block, in the optimal position, by means of an acrylic glass rod, to reproduce as exactly as possible this orthograde adjustment for the comparative radiographic evaluation and reliability of the settings. The orthograde adjustment could thus be safely obtained once more. Altogether, 18 views were taken in the orthograde optimal position; of these, 10 were taken after repositioning the tripod and the skull.

Cephalometric Analysis. All the panoramic radiographs were measured using a tenfold enlarged precision-scale magnifying glass (Eschenbach, Nuremberg, Germany). The magnifying lens had a measuring range of 20 mm and a scale division in 0.1 mm steps. The Prolite 5000 model (Kaiser Fototechnik, Buchen-Odenwald, Germany) served as radiographic viewer.

Measurement of the Implants. The measurements were based on the reference points on the implant, which are defined for the Frialit-2 implant system according to Fig 4.

The metric determination of the enlargement ratio of the implants was based on the following measured sections (all measured sections are located within the implant body):

- vertical: distance between reference position 1 and reference position 2
- horizontal: *(a)* width of the implant at the coronal end; and *(b)* width of the implant at its apical end.

The measured values were compared with the effective implant dimensions.

Statistical Methods. According to the problem definition, a descriptive evaluation was carried out, computing the mean values, minimal and maximal, together with the spans (the absolute differences between the extreme values). For instance, the maxillomandibular width and form and the course of the anatomic structures of the facial skull vary considerably among individual patients, as does, to a small extent, the angle of placement of the implant. In the present study, however, all the examinations were carried out on the same skull, so as to be independent of interindividual variations. An extended statistical analysis would therefore simulate a degree of accuracy that cannot be transferred to routine clinical application.

Reproducibility of the cephalometric analysis using the magnifying glass was tested in a preliminary experiment. Six orthograde panoramic radiographs were each measured twice for comparison of the data obtained. The second measurements were carried out 8 weeks after the end of the first data acquisition. The distance from reference position 1 to reference position 2 was measured in the vertical dimension and the width of the coronal and apical end of the implants was measured respectively area-dependent in the horizontal dimension. All calculations were carried out with a commercially available spreadsheet program (Lotus 1-2-3, Lotus Development, Staines, Middlesex, England).

Results

Reproducibility of Cephalometric Analysis. The data collected in the second series of measurements for implant-related measured sections differ from the corresponding reference values obtained at the first data acquisition as follows. At the vertical distance from reference position 1 to reference position 2 (Fig 4), the largest absolute difference between the first and second measurements was determined to be 0.3 mm. In the horizontal dimension, coronal widths of the implants differed up to 0.2 mm, whereas at the apical end the differences were 0.4 mm. All median values were 0. Therefore, errors of the cephalometric analysis may be ignored.

Reproducibility of the Settings on the X-ray Apparatus. The spans of the views after each repositioning of the tripod and the skull were used to check the reproducibility of the settings concerned. In the vertical dimension, average values of 3.5% were obtained; whereas in the horizontal dimension, at the coronal end of the implant, average values of 5% were found, and average values of 9% were found at the apical end.

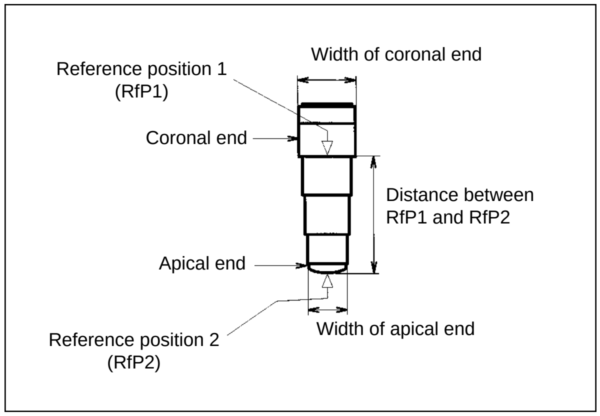


Fig 4 Measuring specifications for the Frialit-2 stepped-cylinder implant.

Vertical Enlargement Ratio. The distribution among implant areas concerned with the enlargement ratios measured between reference position 1 and reference position 2 is shown in Figs 5 and 6. In the anterior area of the maxilla, the average values of 18 analyzed views were between 1.23 and 1.29. In the anterior area of the mandible, the enlargement ratio varied between 1.26 and 1.27, being thus subjected to lesser variations than in the maxilla. In the lateral maxilla, the enlargement ratio was between 1.26 and 1.29; in contrast to this, in the lateral mandible, it was between 1.21 and 1.26. Vertical enlargement, therefore, does not exceed a ratio of 1.29 in any implant region.

Horizontal Enlargement Ratio at the Coronal End of the Implant. Figures 7 and 8 show the respective mean enlargement ratios for the implant area concerned. The horizontal enlargement ratio at the coronal end of the implant varied between 1.24 and 1.27 in the maxillary region of the incisors, whereas in both canine areas the ratio of 1.19 was clearly below the vertical enlargement in the anterior maxilla. In the lateral area of the maxilla, horizontal enlargement was also clearly lower than the vertical enlargement (with the exception of the third molar regions). The values varied between 1.17 and 1.20, whereas in the third molar regions there were enlargements of 1.35 and 1.28.

In the mandible, the values of the horizontal enlargement ratio in the anterior were between 1.27 and 1.32. In none of the implant regions did horizontal enlargement exceed a ratio of 1.35 at the coronal end of the implant.

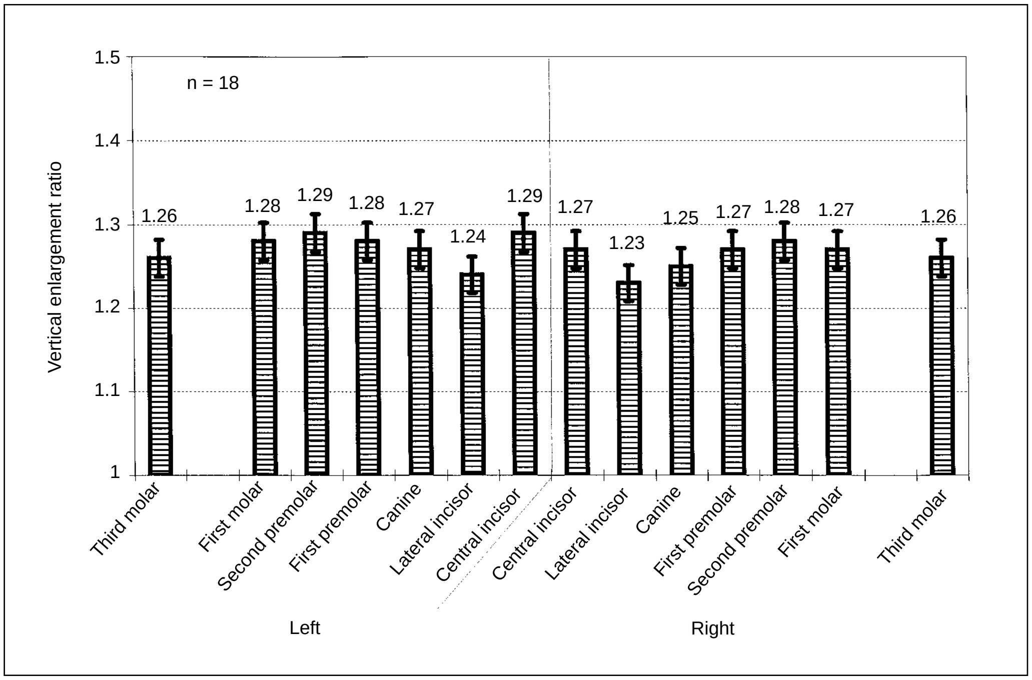


Fig 5 Graph showing mean vertical enlargement at orthograde setting in the maxilla. The perpendicular lines are spans of 3.5%. Eighteen panoramic radiographs were analyzed.

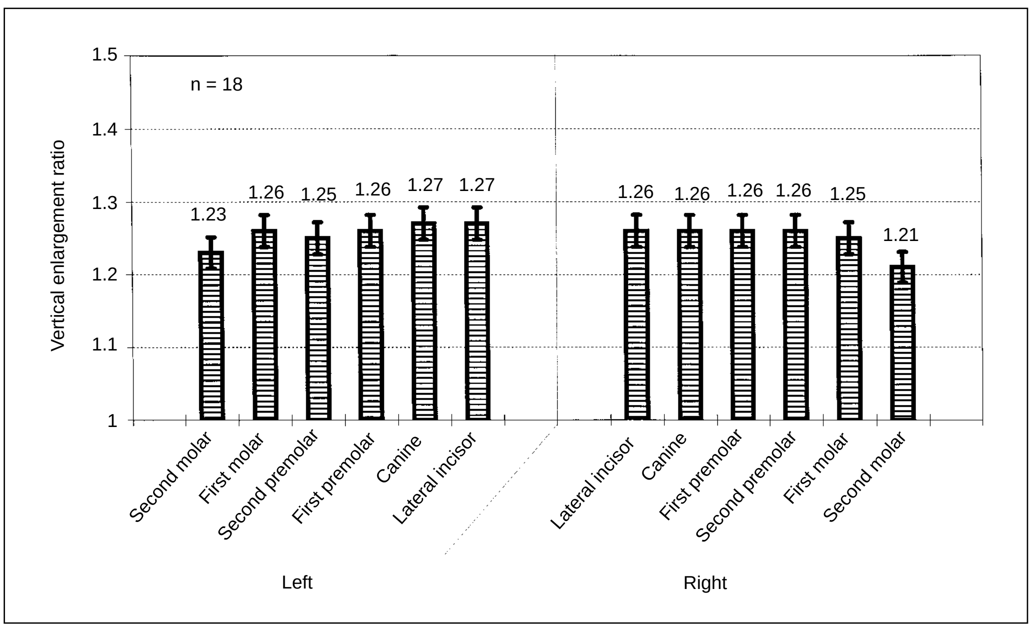


Fig 6 Graph showing mean vertical enlargement at orthograde setting in the mandible. The perpendicular lines are spans of 3.5%.

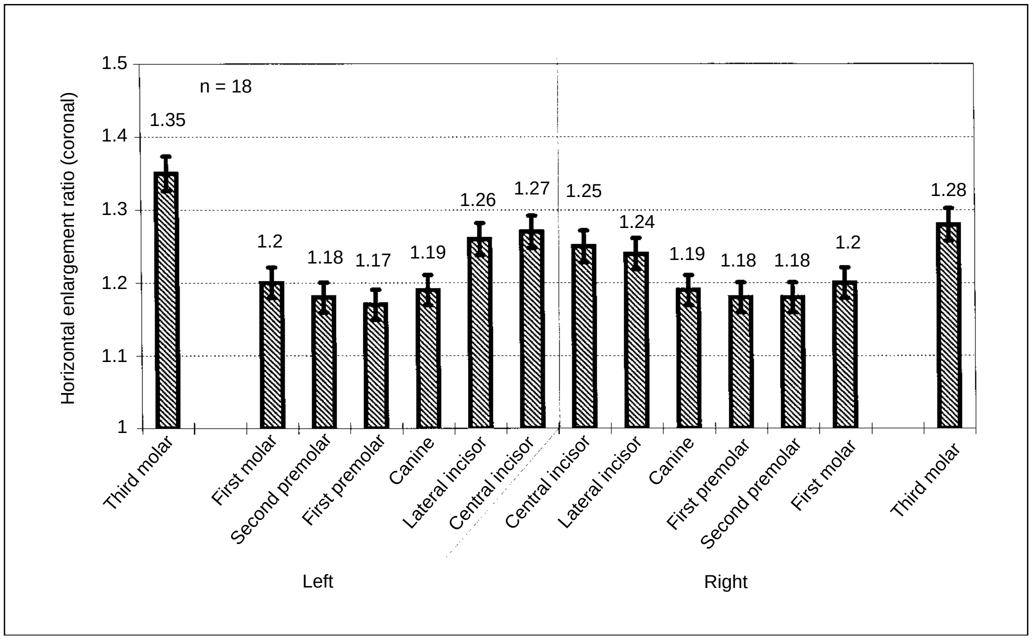


Fig 7 Graph showing mean horizontal enlargement at the coronal end of the implant in the maxilla. The perpendicular lines are spans of 5%.

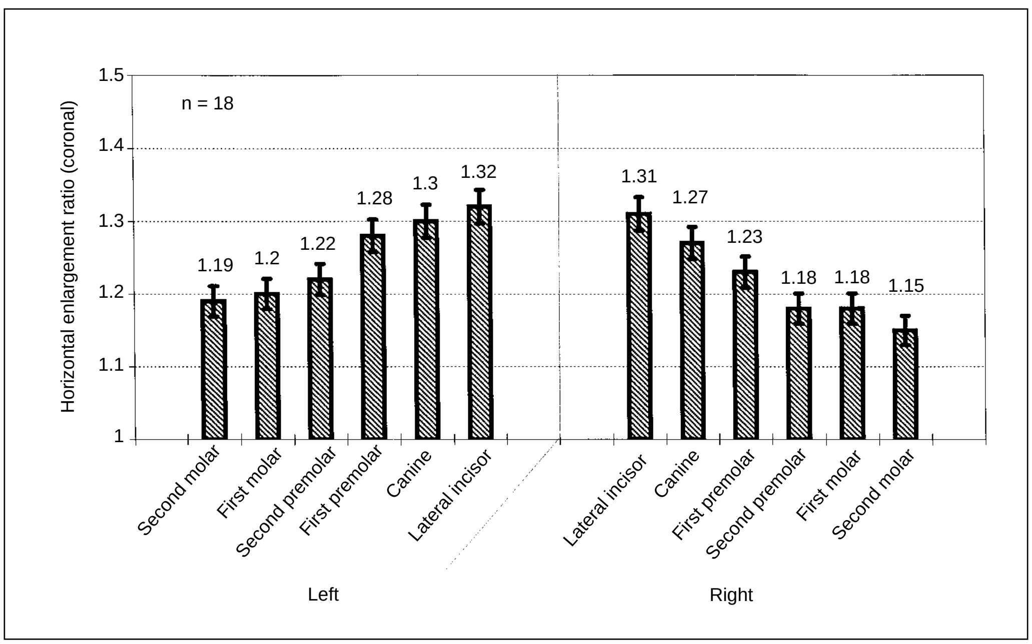


Fig 8 Graph showing mean horizontal enlargement at the coronal end of the implant in the mandible. The perpendicular lines are spans of 5%.

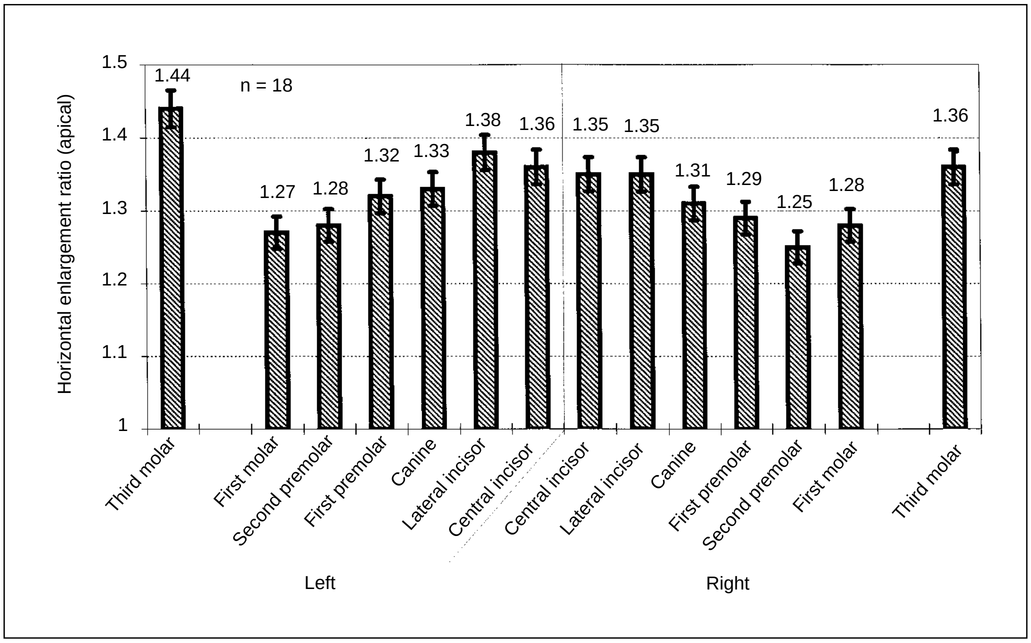


Fig 9 Graph showing mean horizontal enlargement at the apical end of the implant in the maxilla. The perpendicular lines are spans of 9%.

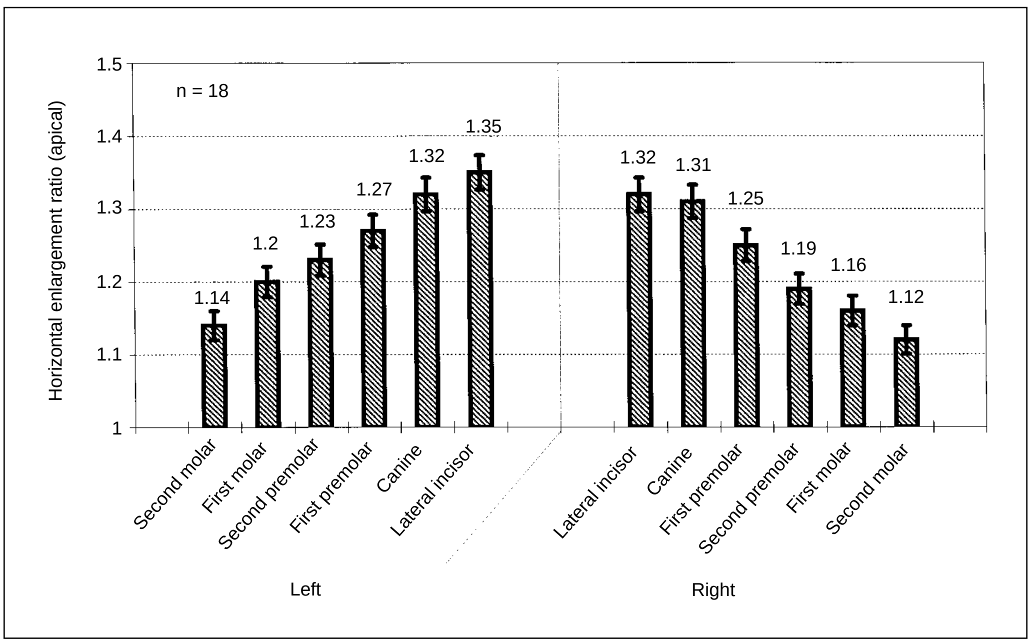


Fig 10 Graph showing mean horizontal enlargement at the apical end of the implant in the mandible. The perpendicular lines are spans of 9%.

Horizontal Enlargement Ratio at the Apical End of the Implant. Figures 9 and 10 show the area-dependent enlargement ratios at the apical end of the implants. In the anterior maxilla and mandible, all values at the apical end were above the values found at the coronal end. In the maxilla, at the apical end, they varied between 1.31 and 1.38, while in the mandible the variation was between 1.31 and 1.35. In the lateral area of the maxilla, the values were between 1.25 and 1.44. In the molar region of the mandible the enlargement was lower than at the coronal end, with the exception of both first molars, where the enlargements were the same at the apical and the coronal ends.

Discussion

Reproducibility of the Measurements on the Radiograph. On the basis of 2-dimensional representations of 3-dimensional objects, it is generally admitted that radiographs provide limited quantitative information. The result is that calculations are generally made with an inaccuracy of 1 mm.[10–12] In contrast to this, the maximum measurement differences of 0.4 mm in the vertical and horizontal dimension recorded in the present study can be ignored. The implant-specific reference positions selected in the present study can obviously be better identified than the characteristics of natural teeth or bony structures. The delineation of radiopaque implant structures against neighboring bone is quite successful. In a previous study, the apical border of the coronal end of Frialit-2 implants has already proven a reliable reference point.[13]

In the present study, the extreme values of the comparative measurements differ only slightly from the mean values. This enables one to conclude that even data involving implants measured only once may provide helpful information.

Area-Dependent Enlargement Ratio. *Vertical Enlargement Ratio.* As seen in Figs 5 to 10, the vertical enlargement ratios in the maxilla and the mandible vary only slightly around a mean value. This is confirmed by the Sämfors and Welander study.[14] The drop in the vertical enlargement ratio in the regions of both maxillary lateral incisors and both mandibular second molars can be explained by the stronger inclination of the implants in the buccolingual direction. However, the dependency of vertical enlargement on the depth of the object, as noted by McDavid et al,[15] also contributes to the lower vertical enlargement ratio.

Considering the enlargement ratios in the vertical dimension and comparing them with the standard of transparent templates usually used in preimplant diagnosis, it clearly appears that the basic enlargement ratio of 1.25 is exceeded in the majority of maxillary and mandibular regions and only rarely not reached. This value of 1.25 was exceeded or not attained at the rate of only 0.04 or 3.2% by enlargement ratios of 1.29 or 1.21 as determined in this investigation. The consequence of this is that by applying a mean ratio of 1.25, the existing bone volume in the regions of both maxillary lateral incisors and both mandibular second molars is only slightly underrated, and in other regions slightly overestimated. An average enlargement ratio of 1.3 is therefore a more certain value for the measurement of orthograde images in the vertical dimension.

Horizontal Enlargement Ratio. The observations made by Tronje et al,[9] Zach et al,[16] and also by Sjöblom and Welander,[17] according to which horizontal enlargement ratio is greater in the anterior maxillary area, are also supported by these results. In the whole maxilla, the horizontal enlargement ratio was greater at the apical end of the implant than at its coronal end. In the mandibular anterior area it was mostly higher, whereas in the lateral area it was less than or equal to the enlargement at the coronal end. The differing horizontal enlargement at these 2 ends is related to the fact that, because of the buccolingual inclination of the implants, the apical end in the maxilla is further away from the film. This fact has already been demonstrated by Setz et al[18] in a clinical study carried out on IMZ implants and has been mathematically represented by Tronje et al.[9] An additional explanation is certainly also provided by the study carried out by Hayakawa et al,[6] which demonstrates that objects located further away from the film are more distorted than those positioned closer to the film.

When comparing the area-dependent horizontal enlargement ratios on both ends of the implant with the corresponding perpendicular ones, attention is attracted by a larger range of variation in the values. At the same time, it is clearly visible that, although they are at an orthograde setting, the implants appear distorted on the panoramic tomograph. The horizontal ratios in the lateral tooth area, with the exception of the maxillary tuberosity, clearly decrease, compared with the values in the anterior and in the third molar region. When comparing the corresponding regions in the maxilla and mandible, whose enlargement ratios do not precisely coincide, it should always be considered that the alveolar extension has no absolutely symmetric shape, that it can be more or less heavily modified by resorption, and that a technical or system-conditioned asymmetric enlargement of the right or left maxillary section can take place, as has been shown by McDavid et al.[19]

A comparison with similar studies carried out by Szabo et al[3] or Setz et al,[18] who in their image evaluations tried to take into account the enlargement ratio conditioned by radiographic technique for the preimplant diagnosis, seems difficult, although there are high consistencies in the vertical dimension with the present results. Indications concerning the length and the diameter of the measured implants are lacking in both of these studies. But these two parameters have a major influence, particularly on the horizontal enlargement ratio, as has been demonstrated by Hayakawa et al.[6]

The high value conceded in the present study to patient positioning, which is a major parameter in producing optimal panoramic tomographs, is also emphasized in the studies of many authors, such as Tronje et al,[9] McDavid et al,[15] Treasure et al,[20] Schopf,[21] Szabo et al,[3] and Setz et al.[18] A comparison with studies carried out on the quantification of the enlargement ratio by Thanyakarn et al,[22] Larheim et al,[23] Selle and Schneuzer,[24] and Schopf[21] seems problematic, since factors such as root curvature, axis inclination, tooth position, tooth dimension, and correct patient positioning influence the enlargement ratio.

Conclusions

Significance of the Results for Preimplant Diagnosis. Panoramic tomographs may be well suited to preimplant diagnosis, particularly in the vertical dimension. An enlargement of 1.3 in the perpendicular and of 1.35 in the horizontal line is proposed for transparent templates used for implantation planning.

Significance of the Results for Follow-up Examinations. Panoramic tomographs are generally taken on implant-treated patients immediately after surgery, after prosthetic restoration, and then usually at annual intervals, so that whole measurement series exist for the same patient for comparison. Since the peri-implant bone defect was located directly at the implant and exposed to the same enlargement and distortion effects, it was possible to transfer the area-dependent enlargement ratio at the implant on the peri-implant translucency. Thus panoramic tomographs would seem to be well suited for check-ups of progress and success, particularly in edentulous patients. Periapical radiographs provide a more accurate record, assuming that they are well positioned using the paralleling technique. However, where multiple implants exist, the amount of radiation to the patient is less with panoramic tomographs.

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