

## DIAGNOSTIC IMAGE QUALITY OF DIGITAL PANORAMIC RADIOGRAPHY OF PEDIATRIC PATIENTS

**Canan Uzun, DDS, PhD**

Assistant Professor, Department of Dentomaxillofacial Radiology,  
Faculty of Dentistry, University of Health Sciences,  
Istanbul, Turkey

**Paul F. van der Stelt, DDS, PhD**

Professor, Department of Dentomaxillofacial Radiology,  
Academic Centre for Dentistry  
Amsterdam, Netherlands

**Ayşe Pinar Sumer, DDS, PhD**

Professor, Department of Dentomaxillofacial Radiology,  
Faculty of Dentistry, Ondokuz Mayıs University,  
Samsun, Turkey

**Samet Hasan Abacı**

Research Associate, Biometry and Genetics Unit,  
Faculty of Agriculture, Ondokuz Mayıs University,  
Samsun, Turkey

### ABSTRACT

**Background and Aim:** Panoramic radiography is an important diagnostic tool in oral health care. This study aimed to evaluate the quality of panoramic images (PIs) of children aged 3 to 12 and to define the correlation between age and frequency of patient positioning and specific operating errors.

**Materials and Methods:** 650 PIs of pediatric patients (276 female and 374 male) were divided into 5 subgroups according to the patients age (3-4, 5-6, 7-8, 9-10, 11-12,  $n_{\text{subgroup}}=130$ ). The frequency of patient positioning and operating errors was determined. 15 operating errors were distinguished among which: patient too far forward or backward, head turned or tilted, chin tipped too high or too low, chin not on the chin rest, incorrect tongue position/lips open, bite guide not used and patient movement during exposure. Additionally, PIs were categorized into three groups: excellent, diagnostically acceptable and diagnostically unacceptable. For each unacceptable PI the inadequate region was noted.

**Results:** Eight types of errors occurred significantly more often as the child was younger ( $p<0.05$ , chi-square trend test); only patient positioned too far back showed an increase with age ( $p<0.001$ ). Only 3.7% of the PIs were excellent, 60.5% were diagnostically acceptable and 35.8% were diagnostically unacceptable. In the diagnostically unacceptable PIs the anterior region of the jaws was mostly affected.

**Conclusion:** Positioning errors occurred rather frequently when taking PIs in children. For improving the radiographic quality and reducing the number of retakes, attention to PI errors with type and frequencies may contribute possible solutions.

Clin Dent Res 2018; 42(3): 111-119

### Correspondence

**Canan Uzun DDS, PhD**

Department of Dentomaxillofacial Radiology, Faculty of Dentistry,  
University of Health Sciences, Istanbul, Turkey  
Phone: +90 216 418 96 16  
Fax: +90 216 418 96 20  
E-mail: canan.uzun@sbu.edu.tr

**Keywords:** Panoramic radiography, patient positioning,  
pediatric dentistry, quality control

Submitted for Publication: 02.21.2018

Accepted for Publication : 11.29.2018

## PEDİYATRİK HASTALARIN DİJİTAL PANORAMİK RAYOGRAFİLERİNİN DİYAGNOSTİK GÖRÜNTÜ KALİTESİ

**Canan Uzun**

Dr. Öğr. Üyesi, Sağlık Bilimleri Üniversitesi, Diş Hekimliği Fakültesi,  
Ağız, Diş ve Çene Radyolojisi Anabilim Dalı,  
İstanbul, Türkiye

**Paul F. van der Stelt**

Prof. Dr., Diş Hekimliği Akademik Merkezi, Dentomaksillofasiyal  
Radyoloji Anabilim Dalı,  
Amsterdam (ACTA), Hollanda

**Ayşe Pınar Sumer**

Prof. Dr., Ondokuz Mayıs Üniversitesi, Diş Hekimliği Fakültesi,  
Ağız, Diş ve Çene Radyolojisi Anabilim Dalı,  
Samsun, Türkiye

**Samet Hasan Abacı**

Araştırma Görevlisi, Ondokuz Mayıs Üniversitesi,  
Ziraat Fakültesi, Biyometri ve Genetik Anabilim Dalı,  
Samsun, Türkiye

### ÖZ

**Amaç:** Panoramik radyografi ağız sağlığı hizmetlerinde önemli bir tanı aracıdır. Bu çalışmada yaşları 3 ile 12 arasındaki çocukların panoramik görüntülerinin kalitesinin değerlendirilmesi ve yaş ile hasta pozisyonlandırma ve belirli operatör hatalarının sıklığı arasındaki ilişkiyi tanımlamak amaçlanmıştır.

**Gereç ve Yöntem:** Pediyatrik hastalara ait 650 panoramik görüntü (PG) (276 kız ve 374 erkek), hastaların yaşlarına göre 5 alt gruba ayrıldı (3-4, 5-6, 7-8, 9-10, 11-12,  $n_{alt\ grup}=130$ ). Hasta konumlandırma ve operatör hataları sıklığı belirlendi. Hasta çok ileride veya geride, baş çevrilmiş veya eğik, çene çok yukarı kaldırılmış veya çok aşağıya eğilmiş, çene çene desteğinde değil, yanlış dil pozisyonu/dudaklar açık, ısırma kılavuzu kullanılmamış ve çekim sırasında hasta hareketi'nin arasında olduğu 15 operatör hatası seçildi. İlave, PG'ler üç gruba ayrıldı: mükemmel, diyagnostik olarak kabul edilebilir ve diyagnostik olarak kabul edilemez. Her kabul edilemez PG için yetersiz bölge not edildi.

**Bulgular:** Çocuk küçüldükçe sekiz tür hata anlamlı derecede daha sık meydana geldi ( $p<0.05$ , ki-kare trend test); sadece hastanın çok geride pozisyonlaması yaşla birlikte artış gösterdi ( $p<0.001$ ). PG'lerin sadece %3.7'si mükemmeldi, %60.5'i diyagnostik olarak kabul edilebilir ve %35.8'i diyagnostik olarak kabul edilemezdi. Diyagnostik olarak kabul edilemez PG'de çenelerin anterior bölgesi en fazla etkilenen bölge oldu.

**Sonuç:** PG alınırken pozisyonlandırma hataları çocuklarda oldukça sık görüldü. Radyografik kalitenin artırılması ve tekrar çekimlerin sayısının azaltılması için PG hatalarının türleri ve sıklıklarına dikkat edilmesi olası çözümlere katkıda bulunabilir.

Clin Dent Res 2018; 42(3): 111-119

**Anahtar Kelimeler:** Çocuk diş hekimliği, hasta pozisyonu, kalite kontrolü, panoramik radyografi

Yayın Başvuru Tarihi : 21.02.2018

Yayına Kabul Tarihi : 29.11.2018

**Sorumlu Yazar**

**Canan Uzun**

Sağlık Bilimleri Üniversitesi, Diş Hekimliği Fakültesi,  
Ağız, Diş ve Çene Radyolojisi Anabilim Dalı, İstanbul, Türkiye

Telefon: +90 216 418 96 16

Faks: +90 216 418 96 20

E-mail: canan.uzun@sbu.edu.tr

## INTRODUCTION

Dental radiographs play an important role in the oral health care of children and adolescents in the diagnosis of oral diseases, the monitoring of dentomaxillofacial development and the follow up of therapies.<sup>1</sup> Early diagnosis with the aid of X-rays at a younger age makes it possible to detect abnormalities before they become more complicated to handle, which will increase the chance of success in the treatment of children.<sup>2</sup> However, because of the higher sensitivity of children for the effects of radiation, radiographs should be taken only when it will influence the treatment decision and maximum effort should be used to minimize the patients' radiation dose.<sup>1,3</sup>

With the increase of healthcare demand and better access to healthcare, the prescription of dental radiographic examinations is increasing. Panoramic radiography is one of the most frequently used radiographic examinations in dental practice; especially in young patients.<sup>4</sup>

Panoramic images (PIs) provide many benefits to the clinician, especially when it is not possible to image the essential regions with intraoral radiographs or in case of examination of larger lesions of the jaws. The PI is a rather complicated projection of the maxillofacial structures. As a result, image distortion is common due to the imaging geometry of panoramic radiography and can be worsened as a result of technical errors during exposure. The clinician, therefore, must have adequate knowledge of the anatomy and abnormalities and how they show in a PI, because of its complex projection with multiple superimpositions consisting of hard and soft tissue structures.<sup>5</sup>

The diagnostic value of PIs certainly depends on the amount and accuracy of the information obtained from the examination. To increase the diagnostic quality of the image good operator skills, good communication with the patient and spending enough time to patient positioning are essential.<sup>6</sup> In children patient posing in panoramic imaging can be a challenge.

The aim of this study was to evaluate the image quality of PIs of children aged 3 to 12 and define the frequency of patient positioning and other exposure errors in relation to the age of the patient.

## MATERIALS AND METHODS

In this retrospective study the digital archive of a university clinic of dentomaxillofacial radiology was used. All parents

gave their approval to use the data of their children for scientific purposes and clinical research and ethics board of the university reviewed and approved the study. The PIs were divided into 5 subgroups according to the patient's age: group 1 included PIs of 3 and 4 years-old patients, group 2: 5 and 6 years-old, group 3: 7 and 8 years-old, group 4: 9 and 10 years-old, and group 5: 11 and 12 years-old patients. PIs taken between January 2015 until July 2015 were selected at random from the list, until a total of 130 PIs for each group was reached. Only for group 1 images were selected from January 2014 until July 2015 because PIs in this age group are taken less frequently. Thus all subgroups had similar numbers of PIs (n=130).

All PIs were taken with the same radiographic equipment (Orthophos XG, Sirona Dental Systems GmbH, Bensheim, Germany), operating at 62 kVp and 8 mA according to the manufacturer's instructions (child-imaging mode). The exposure time was 14.1 seconds. PIs were evaluated under identical conditions, on a 20 inch, 24 bit color mode computer monitor (Dome GX2MP; manufacturer; location), with 1200x1600 pixel resolution in a room with subdued lighting by a PhD student with 4 year's experience in dentomaxillofacial Radiology under the supervision of a dentomaxillofacial radiology specialist with 20 year's experience. The observer evaluated all the PIs once and a sub-sample, consisting of 25% of all PIs (i.e. 162 PIs) for a second time after two weeks.

The frequency of positioning errors and other errors were defined according to criteria described by Langland et al.<sup>7</sup> and the criteria for panoramic imaging published in the European Guidelines on the safe use of radiation.<sup>8</sup> These criteria are shown in table 1.

In addition to the errors related to patient positioning and other exposure mistakes, the PIs were categorized into three groups according to their image quality: 1) excellent, 2) diagnostically acceptable, and 3) diagnostically unacceptable. A PI was selected as excellent when it was completely free from any errors. It was categorized as diagnostically acceptable when the PI showed some errors but still provided adequate diagnostic information. The PI was defined as unacceptable when it had one of the following characteristics.<sup>9</sup> 1) teeth are not visible including the periodontal ligament. 2) pathology cannot be excluded by the PI. 3) other intraoral radiographs or retake of the PI is required to obtain adequate diagnostic information.

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**Table 1.** Positioning errors and artifacts of PI with the frequencies. Types of errors adapted from Langland et al.<sup>7</sup>

| Type of Error                                                     | Effects on image quality                                                                                                                                                                   | Frequency   |
|-------------------------------------------------------------------|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|
| The patient was positioned too far forward                        | Blurring and narrowing of anterior teeth, cervical spine superimposed on the ramus.                                                                                                        | 108 (16.6%) |
| The patient was positioned too far backwards                      | Blurring and widening of anterior teeth, ghost image of rami superimposed on the posterior molars and rami, condyles close to lateral edge of the image.                                   | 122 (18.8%) |
| The patient's head was turned                                     | Especially teeth and ramus right and left unequally magnified and severe overlap on contact points in premolar area.                                                                       | 256 (39.4%) |
| The patient's head was tilted                                     | Mandible appears tilted on image, unequal distance between mandible and chin rest on the right and left side with condylar asymmetry.                                                      | 146 (22.5%) |
| The patient's chin was tipped too low                             | Curve of occlusal plane goes up, roots of the lower incisors are cut-off, mandible widens vertically in the anterior region with unclear trabecular pattern.                               | 31 (4.8%)   |
| The patient's chin was tipped too high                            | Occlusal plane curvature flattens or curves downwards, upper incisors blurred, hard palate shadow occurs wider and superimposes on roots of upper incisors, intercondylar distance larger. | 114 (17.5%) |
| The patient's chin was not on the chin rest                       | Sinus cannot be seen on the image, top of the condyles are cut off.                                                                                                                        | 324 (49.8%) |
| The patient was in slumped position                               | Ghost image of the cervical spine superimposes on the anterior region.                                                                                                                     | 48 (7.4%)   |
| The patient's tongue was not against the palate or lips were open | Radiolucency occurs on apices of the upper incisors due to palatoglossal air space or relative radiolucency appears on the coronal portion of both upper and lower incisors.               | 330 (50.8%) |
| The bite guide has not been used                                  | Overlap occurs of the incisal edge of upper and lower teeth.                                                                                                                               | 34 (5.2%)   |
| The patient did wore appliances and/or jewellery                  | Metal artifacts and/or radiopaque projections of the objects occur.                                                                                                                        | 19 (2.9%)   |
| An apron/thyroid shield artifact has happened                     | Radiopaque area occurs in the middle of the image.                                                                                                                                         | 1 (0.2%)    |
| PI has been overexposed                                           | Image is too light.                                                                                                                                                                        | 34 (5.2 %)  |
| PI has been underexposed                                          | Image is too dark.                                                                                                                                                                         | 0 (0%)      |
| Patient moved during the exposure                                 | Blurring of image, interior border of the mandible is wavy.                                                                                                                                | 131 (20.2%) |

Because we did not consider the diagnostic justification of each examination, the definition of diagnostic quality in this study is based on the assumption that the PI was intended to assess potential dental anomalies.

For each unacceptable PI the inadequate region was noted according to the study performed by Peretz et al.<sup>9</sup> using the following format:

- a) Upper incisors blurred/shortened/unclear.
- b) Lower incisors blurred/shortened/unclear.

- c) Both upper and lower incisors blurred/shortened/unclear.
- d) The whole PI or large parts of it blurred or unclear.

In our study, we added one more:

- e) One posterior side of PI blurred or unclear.

Two categories were distinguished for patient movement: total (head) movement and local movement. And for each of these movements a distinction was made between momentary or continuous.<sup>10</sup>

The data were statistically analyzed using SPSS (Statistical

Package for the Social Sciences) version IBM SPSS Statistics 22.0 software. The Pearson chi-square test and the chi-square trend test were used for the statistical analyses.

## RESULTS

Of the total number of 650 PIs, 276 (42.5%) belonged to female and 374 (57.5%) to male pediatric patients. The frequency of the errors is shown in table 1. The most common positioning error was that the patient's tongue had not been placed against the palate or the lips had been open during the exposure. This was observed in half of the PIs. No underexposed PIs were present and an apron or thyroid shield artifact was the least common error with 1 record.

Only 3.7% of the PIs were excellent (error free) among the total of 650 PIs, 60.5% were diagnostically acceptable and 35.8% of them were diagnostically unacceptable. Table 2 shows the diagnostic quality of the PIs for each of the age groups.

The distribution of the insufficient areas among the 233 (35.8%) diagnostically unacceptable PIs is shown in figure 1. The image of the anterior region of the jaws turned out to be the most sensitive region for the presence of errors in PIs.

131 (20.2%) PIs showed patient movement, of which 114 (87.0%) were categorized as total (head) movement and the remaining 17 (13.0%) of them as local movement. According to the duration of the movement, 75 (57.3%) PIs showed momentary patient movement and the remaining

56 (42.7%) PIs had continuous patient movement during the whole exposure.

Among the 650 (100%) PI examinations, only 22 (3.4%) were without any error, 95 (14.6%) showed one error, 201 (30.9%) PIs had two errors, 184 (28.3%) PIs showed three errors, 100 (15.4%) PIs contained four errors, 40 (6.2%) PIs had five errors, 7 (1.1%) PIs showed six errors and only 1 (0.2%) had seven errors. There was no PI with more than seven errors in the study sample. For each of the groups the distribution of the PIs according to the number of the errors they contained is shown in figure 2.

The frequency of errors and the statistically significant differences between the 5 groups are shown in table 3. The error of the patient being positioned too far back was found to increase with age ( $p < 0.001$ , chi-square trend test). The presence of other errors decreased with age ( $p < 0.05$ , chi-square trend test).

The intraobserver agreement was found to be excellent by kappa statistics (0.81-1.00).

## DISCUSSION

PI is often used for primary evaluations in dental practice to provide comprehensive information about the dentomaxillofacial region, including erupted and unerupted teeth, developing teeth germs, upper and lower jaw bones, sinuses, temporomandibular joints and various possible dental abnormalities of the jaws. Pediatric dentists prefer to use PI because the PI covers a large region and is well tolerated by children.<sup>11</sup> However, routine radiographic

**Table 2.** Diagnostic image quality assessment of PIs for each of the age groups.

| Group | excellent | diagnostically acceptable | diagnostically unacceptable |
|-------|-----------|---------------------------|-----------------------------|
| 1     | 0 (0.0%)  | 60 (46.2%)                | 70 (53.8%)                  |
| 2     | 2 (1.5%)  | 76 (58.5%)                | 52 (40.0%)                  |
| 3     | 6 (4.6%)  | 87 (66.9%)                | 37 (28.5%)                  |
| 4     | 7 (5.4%)  | 81 (62.3%)                | 42 (32.3)                   |
| 5     | 9 (6.9%)  | 89 (68.5%)                | 32 (24.6%)                  |
| Total | 24 (3.7%) | 393 (60.5%)               | 233(35.8%)                  |

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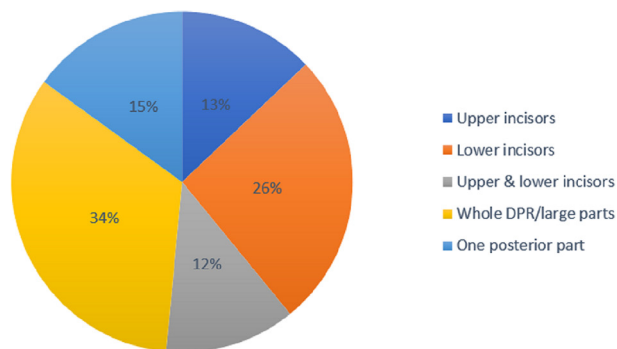


**Figure 1.** The proportion of affected areas in diagnostically unacceptable PIs.

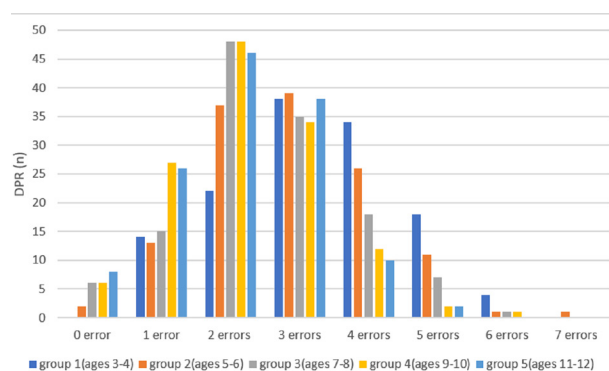


**Figure 2.** The distribution of PIs among the age groups according to frequency of errors.

examination of patients is being questioned because of the cumulative nature of the detrimental effects of radiation exposure, which is even more critical in young patients. The procedure for panoramic radiography should be performed properly in order to obtain an acceptable diagnostic image quality and to avoid the need for retakes. The panoramic radiographic errors and artefacts are very well known. However, most of radiologic studies have concentrated on patients with permanent dentition.<sup>6,12</sup> There are few studies that have determined the image errors specific to children's PI.<sup>9,13</sup> Therefore, we investigated PI of children with primary and mix dentition. The results of our study demonstrate a high frequency of errors in most of radiographs examined. Only 20 PIs were found excellent (error free) among the total of 650 PIs. Peretz et al.<sup>9</sup> examined 289 digital radiographs of mixed and permanent dentitions and found only two radiographs in each group contained no

errors. In Granlund et al.<sup>13</sup> study only 4 per cent of 1287 panoramic radiographs of young orthodontic patients were subjectively evaluated to be without positioning errors.

Although perceived to be an easy technique, a study revealed that 33% of dental panoramic radiographs performed in dental practices were diagnostically unacceptable.<sup>14</sup> Mayil et al.<sup>15</sup> evaluated 150 panoramic radiographs and reported that 72% of the images had an acceptable or optimal quality. In Brezdenn & Brooks's study,<sup>16</sup> 91 panoramic dental radiographs were found inadequate among 500 radiographs. Nearly 40% of the radiographs were found to be non-diagnostic in the study by Peretz et al.<sup>9</sup> In the present study, 35.8 percent of the 650 PIs were found to be diagnostically unacceptable. It would be considered that errors such as movement and positioning would have occurred at a higher rate in young patients. However, Peretz et al.<sup>9</sup> found that errors were higher among the older patients with permanent dentition. In the present study, only the error of the patient being positioned too far back was found to increase with age. The other errors tend to decrease with age showing that successful and diagnostically useful PIs are more difficult especially in 3-6 year old children.

The European Guidelines for safe use of Radiation in Dental practice prescribe that not more than 10% of the images should be inadequate.<sup>8</sup> It is clear that especially in the younger age groups a lower performance obtained that what is stated.

Patient positioning errors are the most frequent error type for PI.<sup>9,12,15,16,17</sup> The most common error in the present study was that the tongue was not placed in contact with the hard palate during exposure, a result also in concordance with the findings of Granlund et al.<sup>13</sup>, Dhillon et al.<sup>6</sup>, Aydın & Aybar<sup>17</sup> and Peretz et al.<sup>9</sup> Incorrect tongue position could diminish the diagnostic ability in this region and cause false diagnosis of apical periodontitis and cysts.<sup>9,13</sup> Another common error was that the patient's head was not symmetrically positioned. This systematic error was also reported as a common error seen in 577 of the 1287 dental radiographs examined.<sup>13</sup> Positioning the patient too far forward or too far backward was a frequent error in the analyzed group in the present study. The antero-posterior positioning errors were the most common faults which directly contributed to failure of the radiographs.<sup>14</sup> In a study by Dhillon et al.,<sup>6</sup> backward positioning of the patient (30%)

**Table 3.** Errors showing significant correlation with the age. All errors are more frequent in younger children except "patient too far back", which is more frequent with higher age.

| Error                               |     | Group 1    | Group 2    | Group 3    | Group 4    | Group 5    | X <sup>2</sup> | P*     |
|-------------------------------------|-----|------------|------------|------------|------------|------------|----------------|--------|
| Patient too far forward             | Yes | 39 (%30.0) | 23 (%17.7) | 15 (%11.5) | 9 (%6.9)   | 22 (%16.9) | 28.16          | <0.001 |
|                                     | No  | 91(70.0%)  | 107(82.3%) | 115(88.5%) | 121(93.1%) | 108(83.1%) |                |        |
| Patient too far back                | Yes | 9(6.9%)    | 19(14.6%)  | 26(20.0%)  | 36(27.7%)  | 32(24.6%)  | 23.26          | <0.001 |
|                                     | No  | 121(93.1%) | 111(85.4%) | 104(80.0%) | 94(72.3%)  | 98(75.4%)  |                |        |
| Head turned                         | Yes | 69(53.1%)  | 57(43.8%)  | 54(41.5%)  | 48(36.9%)  | 28(21.5%)  | 29.21          | <0.001 |
|                                     | No  | 61(46.9%)  | 73(56.2%)  | 76(58.5%)  | 82(63.1%)  | 102(78.5%) |                |        |
| Head tilted                         | Yes | 42(32.3%)  | 40(30.8%)  | 25(19.2%)  | 22(16.9%)  | 17(13.1%)  | 22.03          | <0.001 |
|                                     | No  | 88(67.7%)  | 90(69.2%)  | 105(80.8%) | 108(83.1%) | 113(86.9%) |                |        |
| Chin is tipped too high             | Yes | 28(21.5%)  | 28(21.5%)  | 22(16.9%)  | 19(14.6%)  | 17(13.1%)  | 5.46           | 0.02   |
|                                     | No  | 102(78.5%) | 102(78.5%) | 108(83.1%) | 111(85.4%) | 113(86.9%) |                |        |
| Chin not on the chin rest           | Yes | 79(60.8%)  | 68(52.3%)  | 54(41.5%)  | 58(44.6%)  | 65(50.0%)  | 11.53          | 0.03   |
|                                     | No  | 51(39.2%)  | 62(47.7%)  | 76(58.5%)  | 72(55.4%)  | 65(50.0%)  |                |        |
| Incorrect tongue position/lips open | Yes | 79(60.8%)  | 76(58.5%)  | 64(49.2%)  | 53(40.8%)  | 58(44.6%)  | 15.57          | <0.001 |
|                                     | No  | 51(39.2%)  | 54(41.5%)  | 66(50.8%)  | 77(59.2%)  | 72(55.4%)  |                |        |
| Bite guide not used                 | Yes | 11(8.5%)   | 8(6.2%)    | 15(11.5%)  | 0(0%)      | 0(0%)      | 27.74          | <0.001 |
|                                     | No  | 119(91.5%) | 122(93.8%) | 115(88.5%) | 130(100%)  | 130(100%)  |                |        |
| Patient movement during exposure    | Yes | 45(34.6%)  | 34(26.2%)  | 24(18.5%)  | 15(11.5%)  | 13(10.0%)  | 34.36          | <0.001 |
|                                     | No  | 85(65.4%)  | 96(73.8%)  | 106(81.5%) | 115(88.5%) | 117(90.0%) |                |        |

\*chi-square trend test

was more prevalent than forward positioning (18.3%). Peretz et al.<sup>9</sup> reported that the position of the patient too far forward was more prevalent among a younger group and this error might originate from the smaller size of the head in the younger age group.

Children and adolescents may not remain quiet and motionless during the panoramic procedures<sup>9</sup> and movement errors could be more prevalent among the younger group. In the present study, 20% of the PIs were found to have movement errors that compromised the image quality. The

exposure time offered by the machine when used in child mode was 14.1 seconds. This time is still rather long for young children and it was obviously the reason for this high failure rate.

The distribution of errors in the results of our study reveals that four or more errors were not prevalent among the radiographs of the children a contrast to the study by Peretz et al.<sup>9</sup> where three or more errors in PIs more frequent in the mixed dentition group compared to older group. On the other hand, most radiographs that exhibited positioning errors

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usually had more than a single error as in studies by Peretz<sup>9</sup> and also Dhillon<sup>6</sup>. However, the severity of errors was more important than the number of errors in the determination of diagnostic quality.<sup>16</sup>

The least accurate areas for proper diagnosis in the PIs in the present study were upper and lower anterior regions. This is in accordance with the common findings for these aspects.<sup>9,18</sup> Therefore, additional periapical radiographs of the anterior region are often required.

Our study has some limitations; the sample size was small, the clinical situation of children was not considered while assessing a radiograph (physical stature, facial asymmetry or inability to follow instructions), the results were obtained in a single clinic and all images have been evaluated by one examiner (even under the supervision of an experienced dentomaxillofacial radiology specialist). Nevertheless, it can be assumed that the outcome can be generalized and used to optimize the prescription of PIs in children in general.

### CONCLUSION

PIs are difficult to take without positioning errors. Furthermore, the widespread use of panoramic imaging in children makes it necessary to obtain more insight into image errors with clarification of the frequencies, type of errors and therefore possible solutions. This is important for improving the radiographic quality and reducing the number of retakes. For improving the radiographic quality and reducing the number of retakes, attention to PI errors with type and frequencies could help to improve the image quality and thus obtain a better diagnostic situation.

### ACKNOWLEDGEMENT

We thank Nick Weightman for providing useful advice about grammar and linguistic aspect of the manuscript.

### CONFLICT OF INTEREST

The authors declare that they have no conflict of interest.

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