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ORIGINAL SCIENTIFIC ARTICLE

Quality of bitewing radiographs in children in relation to the type of film holder used

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Abstract
Aim To assess the frequency of use with young uncooperative children of the bitewing radiograph film holders: KWIK-BITE, Snap-a-ray, and a Sticky tape, and to compare the quality of bitewing radiographs achieved with these types of film holders.
Study design This retrospective study assessed 298 pairs of bitewing radiographs of children aged 3–14 years. The radiographs were evaluated according to age, type of behavioural management approach used, extent and degree of overlapping surfaces, visibility of the alveolar bone, and the presence of folds, cone-cut and elongated teeth.
Results Snap-a-ray was used more frequently in younger children ($p < 0.001$), less cooperative children ($p < 0.001$), and in those who were treated under sedation ($p < 0.001$). The KWIK-BITE holder was used more frequently in older children ($p < 0.001$), cooperative children ($p = 0.001$), and in those under general anaesthesia ($p < 0.001$). About 76.5 % of the radiographs contained technical errors. The degree of overlapping surfaces in radiographs was not correlated with the type of film holder used, but rather with the degree of children's cooperation.
Conclusions The Snap-a-ray film holder was used more frequently in young uncooperative children; nevertheless, its use was not associated with an increased frequency or degree of overlapping surfaces.

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Introduction

According to self-reports of dentists, the most prevalent errors in paediatric dentistry relate to performance of intra-oral radiographs (Ashkenazi et al. 2011). This is despite the fact that bitewing radiographs are considered the most efficient, accurate and common tool for diagnosis of proximal caries (McDonald 1983; Nysther and Hansen 1983; Harrison and Richardson 1989). Optimal bitewing radiographs are in fact rarely achieved, due to technical errors such as: incorrect placement of the film or the cone of the radiograph machine and poor development of the film (Haugejorden 1974; Nysther and Hansen 1983). Nysther and Hansen found that only 4.6 % of 2,406 bitewing radiographs were accurate, and in the others, there was at least one technical error.

One of the most common negative consequences of the technical errors made with bitewing radiographs is overlapping of the proximal surfaces. Haugejorden (1974) found overlapping of surfaces in 81 % of 791 radiographs of patients older than 16 years, although in 65 % of them, the magnitude of the overlapping was small. Pitts et al. (1989) reported overlapping of proximal surfaces in 31–39 % of bitewing radiographs of 280 children aged 11–15 years. In another study, the quality of bitewing radiographs was shown to be particularly poor in uncooperative children (Nysther and Hansen 1983).

One way to increase the quality of bitewing radiographs is to use film holders. This is true for regular as well as for phosphoric plates in digital radiography (following grinding of the sharp edges of the holders). Film holders can

assist dentists in correctly placing the film and the cone, in preventing the film from folding, and in helping the standardisation of radiographs for follow-up purposes (Nysther and Hansen 1983). However, McDonald (1983) reported that even with a film holder (Rinn XCP or BRT technique) it was hard to take a bitewing radiograph without overlapping, and sometimes it was even impossible. Similarly, in a study of 1,014 bitewing radiographs in 338 children aged 5–11 years, Harrison and Richardson (1989) did not find that the use of a film holder improved radiograph quality.

Currently, the most commonly used film holders include commercial Sticky tape, the Snap-a-ray film holder (Rinn Corporation, Elgin, IL, USA) and the KWIK-BITE film holder (Hawe-Neos Dental, Bioggio, Switzerland). Our assumption was that dentists usually select the most comfortable film holder for young uncooperative children. The aims of the present study were, therefore, to investigate which film holder was more frequently used at a post-graduate clinic when treating young uncooperative children, and to compare the quality of bitewing radiographs achieved with different types of film holders.

Materials and methods

Study population

This was a retrospective study of children who received routine dental treatment, including the taking of bitewing radiographs, at the Department of Paediatric Dentistry of Tel Aviv University, Israel. The children were examined and treated by 26 post-graduate students. The post-graduate students selected film holders without any recommended departmental guidelines. The Ethics Committee of Tel Aviv University approved the study.

Data collection and analysis

A structured form was developed to record clinical data accessed from patients' records: age, gender, children's level of cooperation according to Frankl's Behaviour Rating Scale (Frankl et al. 1962), and the behavioural management approach applied during X-ray (behavioural modification only or behavioural modification in conjunction with nitrous oxide or with sedation, or under general anaesthesia).

All bitewing radiographs were evaluated by one dentist (HDH) using a back light and a magnifying glass (3×). The data accessed from the radiographs included: film size, film placement (vertical or horizontal), number of full crowns shown in one film (in mesio-distal diameter), number and percentage of overlapping surfaces, degree of overlapping (none, mild = half of the enamel width, severe = full enamel width and into dentine), presence of folds in the film, existence of cone-cut, existence of elongated teeth; and the lack of visibility of upper or lower tooth crowns, or of alveolar bone crest in both jaws. Signs of defective development were also recorded; however, in evaluating the effect of different film holders on the quality of bitewing radiographs, this variable was excluded. Radiograph quality (Q) was defined as the percentage of parameters that had a null value (no shortcoming).

The quality of the bitewings was calculated as the ratio of errors out of a total of 8 possible errors (presence of overlapping, degree of overlapping [none, mild = half error, severe = full error], elongated teeth, cone-cut, folds, lack of visibility of upper or lower tooth crowns, or of alveolar bone crest in both jaws and developmental defects). Accordingly, radiographs with 0–8 errors received scores of 100, 87.5, 75, 62.5, 50, 37.5, 25, 12.5 and 0 points, respectively. However, for evaluating the effect of the film holders on the quality of the bitewings, only 7 errors were calculated (we excluded developmental defects that were not related to the type of the film holder). Accordingly, radiographs with 0–7 errors received scores of 100, 85.7, 71.4, 57.1, 42.9, 28.6, 14.3 and 0 points, respectively.

Intra-examiner reliability

In a pilot study, 10 pairs of bitewing radiographs were evaluated by one examiner (HA) and again one week later. The mean intra-examiner reliability for scoring the errors was 82 % (Kappa = 0.822).

Statistical analysis

The Chi square test was used to evaluate relationships between types of film holders and levels of children's cooperation according to Frankl's scale, the behavioural management approach used, film size, film placement, the degree of overlapping, the presence of folds in the film, defective development, existence of cone-cut, existence of elongated teeth and visibility of alveolar crest bone. The ANOVA test was used to evaluate relationships between types of film holders and children's age, radiograph quality grade and the treating dentist. The *t* test was used to evaluate the relationship between film holders and film size, or the number of teeth entirely visible on the radiograph. A stepwise multiple regression was used to determine the main factors that were associated with radiograph quality grade. The data were analysed by SPSS 10.0 (SPSS, Inc., Chicago, IL, USA).

Table 1 The use of film holders according to age, Frankl's scale and the behavioural modification approach used during treatment

	Age (years)			Total	Cooperation according to Frankl's score				Total	Behaviour management approach				Total
	3–5	6–9	10–14		4 ++ (%)	3 + (%)	2 – (%)	1 – – (%)		BMT (%)	N_2O (%)	SeD (%)	GA (%)	
KWIK-BITE	21 (19)	36 (30.25)	42 (60.9)	99 (33.2)	57 (93.4)	2 (3.3)	1 (1.6)	1 (1.6)	61 (32.5)	62 (37.8)	7 (14.9)	2 (8.3)	28 (44.4)	99 (33.2)
Snap-a-ray	52 (47.3)	36 (30.25)	11 (15.9)	99 (33.2)	40 (59.7)	13 (19.4)	7 (10.4)	7 (10.4)	67 (35.6)	45 (27.4)	23 (48.9)	16 (66.7)	15 (23.8)	99 (33.2)
Tape	37 (33.6)	47 (39.5)	16 (23.2)	100 (33.6)	47 (78.3)	10 (16.7)	2 (3.3)	1 (1.7)	60 (31.9)	57 (34.8)	17 (36.2)	6 (25)	20 (31.8)	100 (33.6)
Total	110 (36.9)	119 (39.9)	69 (23.2)	298 (100)	144 (76.6)	25 (13.3)	10 (5.3)	9 (4.8)	188[a]	164 (55)	47 (15.8)	24 (8.1)	63 (21.1)	298 (100)

BMT behavioural modification only, *N_2O* behavioural modification in conjunction with nitrous oxide, *SeD* behavioural modification in conjunction with sedation, *GA* behavioural modification in conjunction with general anaesthesia

[a] Cooperation according to Frankl's score was available only for 188 children

Results

Study population

The study population included 298 children (mean age 7.1 ± 2.7 years, range 3–14 years). Of these, 158 (53 %) were boys. Data regarding cooperation level were available for only 188 children. The use of film holders according to age and the behavioural management approach applied during X-ray (behavioural modification only or behavioural modification in conjunction with nitrous oxide, with sedation or under general anaesthesia) are presented in Table 1. A statistically significant relationship was found between the level of children's cooperation, as assessed by the Frankl score, and the behavioural management approach applied ($p < 0.0001$).

Types of film holders used (Fig. 1)

Of the evaluated radiographs, 100 were taken using a Sticky tape to hold the film, 99 using a KWIK-BITE (Hawe-Neos Dental Bioggio, Switzerland) and 99 using a Snap-a-ray film holder (Dentsply RINN, USA). All bite-wing radiographs were taken using a long cone.

Relationship between type of film holder, size of film and children's age

The KWIK-BITE holder was used more frequently in older children (mean age 8.5 years vs. 6.1 and 6.7 years for Snap-a-ray and Sticky tape groups, respectively, $p = 0.0001$), in children who were classified as fully

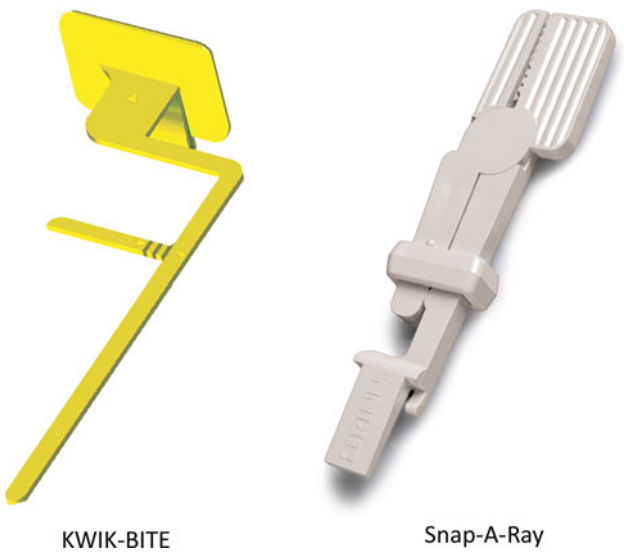


Fig. 1 Types of film holders used. KWIK-BITE (Hawe-Neos Dental Bioggio, Switzerland), a Snap-a-ray film holder (Dentsply RINN, USA)

cooperative during dental treatment (Frankl's score grade 4) [93 % (57/61) vs. 59.7 and 78.3 % in the Snap-a-ray and Sticky tape groups, respectively] and who were treated by behavioural modification techniques or by general anaesthesia (82.2 vs. 51.2 % and 66.6 %, in Snap-a-ray and Sticky tape groups, respectively, $p = 0.0001$). The KWIK-BITE holder was also used more frequently in conjunction with larger sized films as compared to the Snap-a-ray or Sticky tape groups (68 vs. 33 % and 36 %, respectively $p = 0.0001$).

The Snap-a-ray film holder was used more frequently in younger children (mean age 6.1 years), in children with poor cooperation, 20.9 % of the children were classified as Frankl score = 1 or 2 vs. 3.3 % in KWIK-BITE and 5 % in Snap-a-ray groups, respectively ($p = 0.001$), and in children who were treated under nitrous oxide analgesia or conscious sedation (39.4 vs. 9 % in KWIK-BITE and 23 % in Sticky tape groups, $p = 0.0001$). The Snap-a-ray film holder was used in conjunction with a small size film (67 vs. 32 % in KWIK-BITE and 64 % in Sticky tape, $p = 0.0001$).

A Sticky tape was used more frequently in children with early mixed dentition (mean age 6.7 years; 64 %; $p < 0.001$), in children who showed partial cooperation, 16.7 % of the children were classified with Frankl's score = 3, vs. 3.3 and 19.4 % in KWIK-BITE and Snap-a-ray groups, respectively ($p < 0.001$), and in those who were treated solely by behavioural modification techniques (without analgesia or sedation: 57 vs. 62.6 % in KWIK-BITE and 45.5 % in Snap-a-ray groups). A Sticky tape was used more frequently in conjunction with a small size film (64 vs. 32 % in KWIK-BITE and 67 % in Snap-a-ray groups, $p = 0.0001$).

Associations between the type of film holder used and technical errors

The frequency of technical errors was very high (Table 2). Only 140 (23.5 %) bitewing radiographs were free of any errors. None of the radiographs presented more than 6 technical errors. No statistically significant difference was found between percentages of technical errors in the right or left sides (77.2 vs. 75.8 %, respectively).

Proximal surfaces overlapped in 58.2 % of the radiographs. The mean number of overlapped surfaces per film was 19.1 % (18.9 % on the right and 19.4 % on the left sides). In 16 (2.7 %) of the bitewing radiographs, all the teeth in the radiographs showed overlapping. In 83 (13.85 %), at least 50 % of the teeth overlapped. No overlapping was found in 279 (46.8 %) of the bitewing radiographs.

The frequency or degree of the overlapping was not related to the type of film holder ($p = 0.649$) or to the type of behavioural modification approach used during treatment ($p = 0.246$). The frequency of overlapping increased with increasing contact points in the film ($p = 0.01$). The frequency of overlapping on the left side was significantly correlated with the operating dentist ($p = 0.006$). This was not observed for the right side ($p = 0.36$).

With regard to the location of the overlapping, the highest frequency of overlapping was found in the proximal surfaces of the primary second molar and permanent first molar: 36.9 %, and in the proximal surfaces of the primary first and second molars: 34.4 %. In 39.9 % of the bitewing radiographs, the level of overlapping was mild, and in 14.6 %, severe. Uneven distribution of the film between lower and upper arch teeth was found in 34.3, 26 and 11.1 % of the bitewing radiographs that were taken with the KWIK-BITE holder, the Sticky tape, and the Snap-a-ray film holder, respectively ($p = 0.001$).

A statistically significant relationship was found between the type of film holder used and the visibility of the alveolar bone crest in the bitewing radiographs, $p < 0.001$. The highest degree of visibility in both arches (97.5 %) was found when the KWIK-BITE was used. When the Snap-a-ray film holder was used, the visibility in both arches decreased to 74 % of the radiographs.

Fold marks were found in 8.2 % of the bitewing radiographs. The KWIK-BITE was associated with the lowest frequency of fold marks (2 %), as compared to the Sticky tape (10.55 %) and to the Snap-a-ray film holder (12.05 %, $p = 0.0165$).

Table 2 Distribution of bitewing radiographs according to quality grade including developmental defects (total of 8 possible errors)

Quality grade	Distribution		
	Left side (%)	Right side (%)	Total (%)
Good quality	36.9	36.9	36.9
87.5–100			
(0–1 technical problems)			
Moderate quality	51.0	53.1	52.0
50–75			
(2–4 technical problems)			
Low quality	12.1	10.0	11.0
25–37.5			
(5–6 technical problems)			
Very low quality	0	0	0
0–12.5			
(7–8 technical problems)			

Table 3 Linear regression analysis of the quality of bitewings radiographs in relation to film holder type, behavioural modification approach, film size, child's gender and direction of placing the film (in this analysis, developmental mistakes were excluded)

Variable	Quality grade—right	Quality grade—left	Total quality grade
Type of film holder			
Sticky tape[a]	76.1	73.7	75
KWIK-BITE[b]	81.2	82.6	81.9
Snap-a-ray[c]	74.4	74.3	74.4
p value	0.015	0.001	0.027
Tukey	b > c; c = a; a = b	b > a, c	b > a, c
Behavioural modification approaches			
Behavioural modification techniques only[c]	77.1	76.2	76.7
Nitrous oxide[a]	71.7	69.9	71.1
Sedation[b]	73.8	80.3	77
General anaesthesia[d]	82.9	82.5	82.7
p value	0.005	0.004	<0.001
Tukey	d > a; a = b, c; c = d	d > a; a = c; b, c = d	d > a; a = b, c; d = b, c
Film size			
Large	78.9	79.4	77.3
Small	76	75	75.5
p value	0.160	0.046	
Child's sex			
Boy	76.5	77.4	77.5
Girl	78.2	76.5	77.3
p value	0.416	0.673	0.76
Direction of placing the film			
Vertical	80.2	76.5	78.3
Horizontal	76.7	78.4	77.5
p value	0.198	0.523	0.11

BMT behavioural modification only, N_2O behavioural modification in conjunction with nitrous oxide, *SeD* behavioural modification in conjunction with sedation, *GA* behavioural modification in conjunction with general anaesthesia

Cone-cuts were found in 2.5 % of the bitewing radiographs. No statistically significant relationship was found between the presence of cone-cuts and the type of film holder used ($p = 0.6$).

Elongated crowns were found in 6.4 % of the bitewing radiographs. Elongated crowns were more prevalent when Sticky tape was used (10 %) as compared to Snap-a-ray or KWIK-BITE film holders (6.1 and 0.5 %, respectively, $p = 0.003$).

Logistic regression analysis for determination of the primary factors that contribute to the quality of the bitewings (Table 3)

Since the type of film holder used was associated with children's age, as well as with the behavioural management approach, a stepwise multiple analysis was performed to determine the variables that were independently associated with the quality of the bitewing radiographs (Table 3). Use of the KWIK-BITE holder was associated with bitewing radiographs with higher quality score, while the quality score of bitewing radiographs taken by a Sticky tape or by Snap-a-ray was comparable. In a stepwise linear regression analysis, the quality of radiograph was positively correlated with children's cooperation according to Frankl's scale ($p = 0.018$). Bitewing radiographs of children treated by nitrous oxide were of lower quality than those taken in children treated by other behavioural methods ($p = 0.001$), and the highest quality of radiographs was achieved in children treated under general anaesthesia ($p = 0.001$).

Radiograph processing errors

Shortcomings in the film developmental process were found in 22 % of the bitewing radiographs. The most prevalent shortcoming was fixer-staining (9.4 %), followed by dark (overdeveloped or overexposed) film (4.7 %).

Discussion

Achieving high quality bitewing radiographs is a difficult task, especially in young and uncooperative children. Nevertheless, it is very important for correct diagnosis and treatment, and for minimising children's exposure to unnecessary radiation.

The aims of the present study were to discover which of the film holders currently used in dentistry was most commonly used in young and uncooperative children (this might indirectly indicate the most comfortable film holder for children), and to determine whether this type of film holder was associated with a higher rate of technical errors.

In the present study, the film holder most frequently used with young and uncooperative children was the Snap-a-ray type; the KWIK-BITE was most frequently used with older cooperative children. Preference for the Snap-a-ray type was probably due to its thick bite-plane, which decreases the pressure exerted by the film onto the oral mucosa, and the fact that it enables the dentist to adjust the mesio-distal length of the film to the length of the dental arch by folding the film. A disadvantage of this film holder was assumed to be increased risk of, and degree of, overlapping.

The main reason for preferring the KWIK-BITE film holder over the other film holders when treating cooperative children might be its additional branch guidance, which allows fast, and presumably correct, placement of the X-ray cone, thus minimising the frequency and degree of overlapping. However, we did not find a statistically significant difference in the frequency or the degree of overlapping and/or cone-cuts among the different film holders. We note, however, that the KWIK-BITE enhances visibility of the alveolar crest bone and even distribution of upper and lower arches. This is especially important for adolescents with a risk or suspicion of periodontal disease, for whom the visibility of alveolar bone crest is crucial.

To compare the total quality of bitewing radiographs in relation to the film holder used, we developed a quality index. Scores were based on the number of technical errors that appeared for each radiograph. We evaluated seven potential errors that may be related to the film holder. Errors related to the development of the film were, therefore, not included. This contrasts with previously published studies in which only one or two errors were evaluated (McDonald 1983; Nysther and Hansen 1983; Harrison and Richardson 1989). Accordingly, we found that mean quality scores for bitewing radiographs taken with KWIK-BITE film holders were the highest (81.9 points vs. 74.4 points by Snap-a-ray and 75 points with Sticky tape).

This study shows high frequency of technical errors related to bitewing radiographs in children, regardless of the type of film holder used. In 76.5 % of the radiographs, at least one error was detected. The high prevalence of technical errors related to bitewing radiographs concurs with results of previous studies (Haugejorden 1974; Murray and Shaw 1975; Sewerin 1981; Lervik and Cowley 1982; Pitts et al. 1989). The percentage of surface overlapping observed in the current study was high, but not as high as reported in previous studies (Haugejorden 1974; Murray and Shaw 1975). McDonald (1983) reported comparable results for the frequency of overlapping in bitewing radiographs taken with the XCP holder (59 %). Considerably higher frequency (81 %) of overlapping was reported by Haugejorden (1974) in a study of adults. The greater number of contact areas in adults as compared with children may increase the risk of overlapping. Further, in dental schools, as well as in post-graduate departments, lower quality of radiographs usually necessitates additional exposure to achieve higher quality. Since the present study was performed retrospectively, no data were available regarding the number of repeated exposures due to faulty radiographs.

Conclusions

Snap-a-ray was preferred for use in younger uncooperative children who were treated under conscious sedation, while KWIK-BITE was preferred for use with older cooperative children or with children under general anaesthesia. The type of film holder did not affect the frequency or the degree of overlapping surfaces in the bitewing radiographs. The number of technical errors in bitewing radiographs taken by post-graduate students was high. The development of a new film holder that includes the advantage of KWIK-BITE, namely, additional branch guidance for fast and correct adjustment of the X-ray beam, together with the advantage of Snap-a-ray, namely, thick bite-plane, could be beneficial. In addition, a new medium film size could help in the treatment of uncooperative children.

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