In vivo Accuracy of CCD-based Radiography for the Estimation of Periapical Lesion Dimensions

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Summary

Objectives: *This clinical study was performed to compare the accuracy of endodontists' assessment of the sizes of periapical radiolucencies using electronic imaging with the RVG® 32000 intraoral radiographic system and Ektaspeed film.*

Methods: *Following Institutions Review Board approval and informed consent, presurgical images were made both with the RVG® 32000 and Ektaspeed film for periapical lesions in 12 consecutive patients requiring endodontic surgery. Actual lesion size was determined by making impressions with Ethicon® bone wax at the time of surgery. A panel of five endodontists reached consensus in estimation of the superior-inferior and mesio-distal dimensions of the periapical radiolucencies from the presurgical images, separately and independently for two modalities.*

Results: *Lesion dimension estimates were significantly different between images made with the RVG® 32000 Ektaspeed film. There was a much greater deviation from the measured actual values for estimates using film radiographs than for those for the RVG® 32000 images. Generally, there was an over-estimation of lesion size with film, and a slight under-estimation with RVG® 32000 images.*

Conclusions: *Digital intraoral imaging with the RVG® 32000 offers potential advantages over conventional radiography in permitting endodontists on average to more accurately estimate the size of periapical radiolucencies.*

Key words: *apicoectomy, dental radiography, dental granuloma, digital imaging, periapical cyst*

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Conventional intraoral radiography with direct-exposure emulsion silver halide film is used extensively by endodontists for the assessment of periradicular pathoses. There is a perception, however, that radiographic findings do not always reflect the actual destructive borders of such inflammatory processes as the periapical abscess, granuloma or cyst (1).

As early as 1961, Bender and Seltzer found that mechanically induced medullary defects in cadaver mandibles were not evident on traditional film radiographs when the defects were entirely within can-

cellous bone. The "lesions" only became evident radiographically when cortical bone was lost (2). Regan and Mitchell corroborated these findings with a radiographic survey of 57 human cadaver mandibles followed by careful dissection of 18 radiographically detected periapical radiolucencies (3), Other researchers have found similar results (4-7). Shwartz and Foster created defects in dried human skulls using burs and curettes (8). They concluded that even extensive destruction of cancellous bone was not seen on radiographs unless cortical bone was also involved.

Irrespective of involvement of cortical bone, angulation of the X-ray beam can either increase, decrease, or completely obscure dental periapical lesions (9-11). An increase in vertical angulation foreshortens the image of the tooth and decreases the apparent size of any periapical lesions (12). Wengraf demonstrated that a change in horizontal angulation of a little as 15° can completely obscure a periapical lesion (13). Radiographic evaluation of periapical lesions has also been reported to be unpredictable due to the large variations in perceptions and diagnostic abilities among observers. Goldman et al. found inter-observer agreement when viewing areas of rarefaction to be less than 50% (14). It was also found that intra-observer agreement over time was only 72-88% (15). In a similar study, Brynolf re-interpreted radiographs she had previously examined and agreed with herself only 70% of the time (16).

The purpose of this was to compare observer accuracy in the estimation of the size of periapical radiolucencies with E-speed direct emulsion intraoral radiographic film (Ektaspeed: Eastman Kodak, Rochester, NY) and thermal prints from images acquired with a CCD-based intraoral radiographic sensor (RVG® 32000: Trophy Radiologie, Vincennes, France). The null hypothesis was that the RVG® 32000 and Ektaspeed® film (Eastman Kodak, Rochester, NY) are equal in accuracy for determining the dimensions or periapical lesions.

Material and Methods

Population: Patients attending the postgraduate endodontic clinic at the University of Louisville School of Dentistry were invited to participate in the study if they possessed a tooth that required apical surgery (*i.e.* that had a symptomatic tooth with an area of rerefaction, a large periapical radiolucency, or post-treatment enlargement of an apical lesion). Approval for the study was obtained from the Human Subjects Committee, University of Louisville. Two consent forms were obtained form all participants; a written surgical informed consent, and a second informed consent to participate in the investigation as required by our Institutional Review Board. Twelve consecutive patients required rootend surgery participated in the investigation.

Imaging Techniques: All images were taken using a paralleling technique with a modified Precision® film holder (Masel, Philadelphia, PA) to stabilize either the film of the intraoral sensor (17,18). To ensure identical geometric projection angles for both imaging modalities, a bite registration was taken with Blue-Mousse® (Parkell, Farmington, NY) (19).

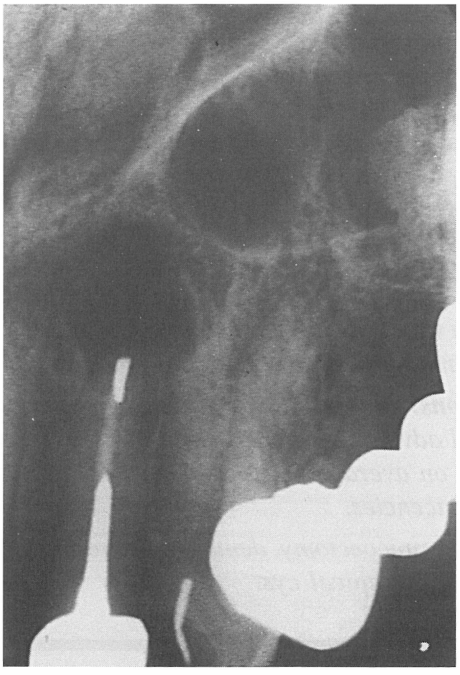

Figure 1. *Ektaspeed® film intraoral radiograph of tooth with associated periapical radiolucency. Dimensions were estimated by direct measurement with the film placed on a vievbox in a room with subdued ambient lighting*

Slika 1. *Intraoralna radiografija zuba filmom Ektaspeed® s odgovarajućim periapikalnim prosvjetljenjem. Dimenzije su bile procijenjene izravnim mjerenjem uz film stavljen u okvir za promatranje, u prostoriji s prigušenom rasvjetom*

Ektaspeed® was used as the radiographic film. The X-ray unit used was an Acuray® 017A (Belmont, Somerset, NJ), with a focal spot of 0.5 mm², 2.5 mm Al equivalence filtration, and a source-to--cone tip distance of 8 inches, operating at 70 kVp, 10 mA, with exposures of 15-24 impulses. An AT 2000® processor (Air Techniques, Inc, Hicksville, NY) set on a 5 minute cycle was used to process the films. A representative Ektaspeed radiograph from one of the cases is shown (Figure 1).

For CCD- based digital intraoral radiography, the RVG® 32000 was used. The X-ray unit was a Trophy Irix® with electronic timer (Trophy Radiologie, Vincennes, France) with a nominal focal spot size of 0.49 mm², 1.5 mm Al equivalence filtration, and a source-to-cone tip distance of 8 inches, operating at 70 kVp, 8 mA using the manufacturer's recommended exposure sequences for standard mode. A reprecentative RVG® image form one of the cases is shown (Figure 2).

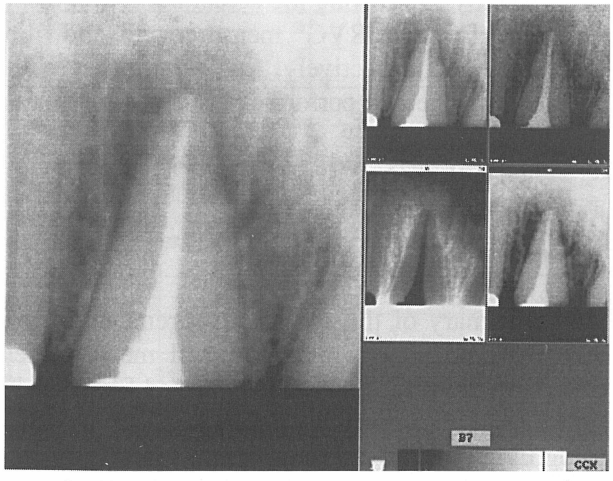

Figure 2. *RVG® 32000 thermal print image of tooth with associated periapical radiolucency. Dimensions of the lesions were estimated using direct measurements made from the small images to the left of the print*

Slika 2. *Slika zuba dobivena toplinskim tiskom od sustava RVG® 32000 s odgovarajućim periapikalnim prosvjetljenjem. Dimenzije oštećenja bile su procijenjene izravnim mjerenjem na malim slikama lijevo od otiska*

Surgical Phase: A bone was (Ethicon®, Somerset, NJ) impression of the bony defect was taken during the periapical surgery after the buccal window of bone was removed and direct access to the defect without undercuts was established (Figures 3 and 4). The bone wax was rolled into a small ball and placed in ice cold water prior to placement in the bony defect. This procedure helped facilitate a good wax impression and prevented the wax from softening and adhering to the bone. The wax was inserted into the defect with pressure so that it conformed to the shape of the defect. After removal, the greatest superior-inferior and mesio-distal measurements of the wax impression were recorded with a millimeter caliper gauge (Figure 5). The accuracy of the caliper gauge was ±.1 mm.

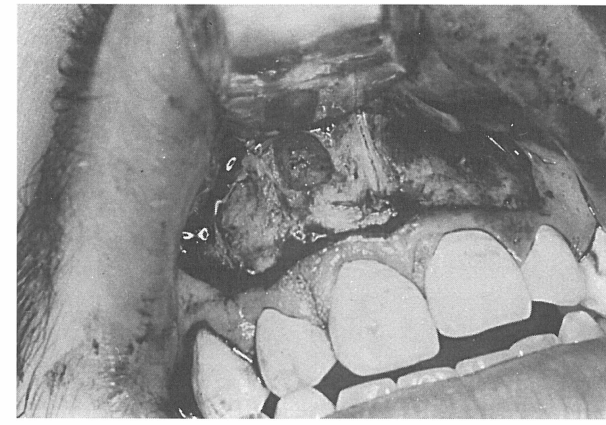

Figure 3. *Surgical access to the periapical lesion was achieved by removal of buccal plate to create a window in the bone*

Slika 3. *Kirurški pristup periapikalnom oštećenju bio je ostvaren skidanjem bukalnoga kortikalisa, da se izradi prozor u kosti*

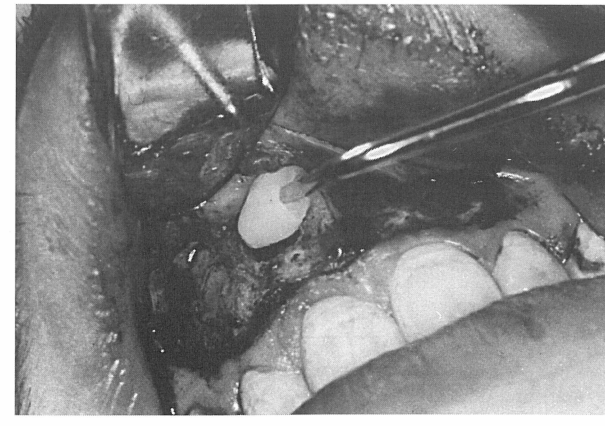

Figure 4. *Impressions using bone wax were used to establish to true morphology of the lesions*

Slika 4. *Stvarna morfologija oštećenja ustanovljena je utiskivanjem koštanoga voska*

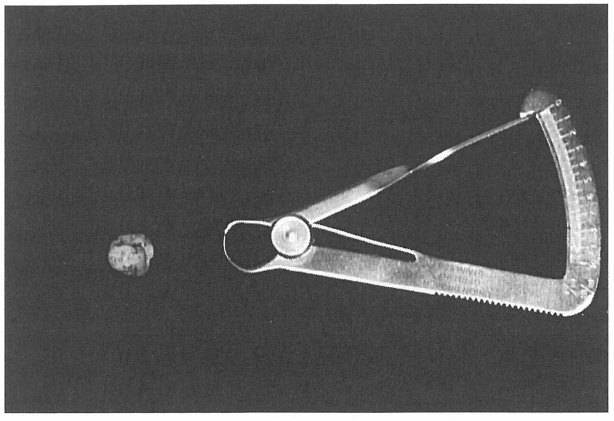

Figure 5. *Dimensions were measured form the bone wax using a vernier calliper. Orientation was established using a diagram carefully drawn at the time of surgery*

Slika 5. *Dimenzije su mjerene na voštanom otisku s pomoću prilagodljiva kalipera. Orijentacija je ustanovljena pozornim crtanjem dijagrama tijekom operacije*

Evaluation of Diagnostic Images: All dimensional estimates were made by a panel of five endodontists using a measurement guide (Figure 6) and standardized reading conditions. All radiographs were placed on a lighted viewbox in a dimly lit room. The mesio-distal and superior-inferior dimensions of the periapical radiolucencies were measured using a clear plastic mm ruler. RVG® images were viewed on thermal prints under reflected fluorescent light in a brightly lit room. The RVG® 32000 images were measured using the smaller images from the thermal prints (Figure 2) to avoid magnification variables and problems associated with the convexity of the monitor screen. Prior testing and calibration with an object of known length ensured that the smaller images on the thermal prints were dimensionally consistent and accurate to within .5 mm.

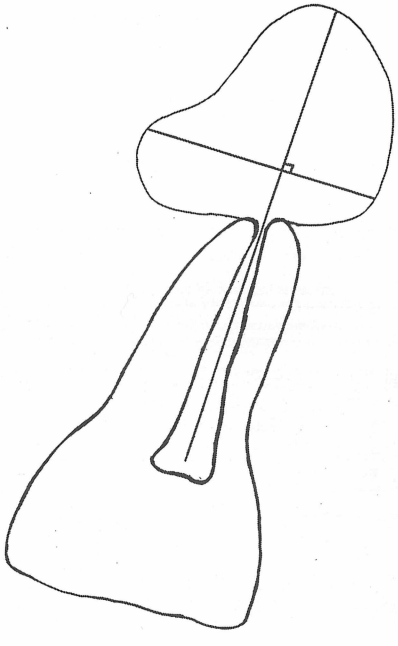

Figure 6. *Standard measurements made in estimation of superior-inferior and mesio-distal dimensions*

Slika 6. *Standardna mjerenja učinjena u procjeni superiornih - inferiornih i mezio-distalnih dimenzija*

Data Analysis: A paired *t-test* of the scores was employed so that each subject served as their control and reduce the effects of extraneous independent variables were reduced (20). The matched pair design of the experiment allowed for a greater reduction of total variability among replications, providing sufficient power with comparatively few subjects. The values for the image size differences were derived by subtracting the actual bone wax measurements from the RVG® measurements and film measurements, respectively. An *f-test* and regression analysis were also performed. The *à priori* α was set at 0.05.

Results

A summary of the actual measurements of the wax impressions and the estimated mean values from both the RVG® 32000 images and Ektaspeed® film images is shown in Table 1. Measurements using Ektaspeed® film were generally above the actual dimensions, whereas those using RVG 32000® thermal print images were slightly less than the actual dimensions and showed less variation in the degree of dimensional distortion.

Differences between the RVG® and film measurements were clearly demonstrated by linear regression for both modalities. The linear regression (Figure 7) for the actual superior-inferior dimensions and those estimated from the RVG® 32000 images resulted in a slope of y=-.132+.924x with a *Pearson R* value of .971, suggesting a very strong linear association between the RVG estimates and actual values. The R^2 of .943 for the RVG® accounted for 94% of the variance in the actual values in the su-

Table 1. *Actual vs estimated superior-inferior and mesio-distal dimension of the periapical lesions included in the study*

Tablica 1. *Stvarne dimenzije prema procijenjenim superiornim - inferiornim i mezio-distalnim dimenzijama periapikalnih oštećenja obuhvaćenih studijom*

CASE # SLUČAJ	Actual size (mm) Stvarna vel. (mm)	RVG 32000 (mm)	Ektaspeed (mm)
Sup-Inf dimension Sup-Inf dimenzija			
1	1.4	1.5	2.0
2	4.5	4.0	3.6
3	2.6	2.0	1.0
4	3.0	2.0	2.0
5	5.0	5.0	5.0
6	2.0	1.5	2.6
7	2.0	2.0	1.3
8	5.7	5.0	9.0
9	2.3	2.0	3.0
10	2.0	1.5	2.5
11	1.8	1.5	4.0
12	2.0	2.0	2.7
Mes-Dist dimension Mes-Dist dimenzija			
1	2.0	2.0	4.0
2	6.3	6.0	5.5
3	3.8	2.0	2.0
4	3.5	2.0	3.0
5	6.5	5.5	8.0
6	4.2	4.0	5.6
7	1.5	1.5	2.0
8	9.9	10.0	16.0
9	3.0	3.0	2.0
10	3.8	4.0	6.0
11	2.5	2.0	6.0
12	2.0	2.0	2.3

perior-inferior dimension. The linear regression (Figure 7) for Ektaspeed® radiographs versus the measured reality resulted in a slope of y=-.068 +1.156x. with a *Pearson R* valued of .767 suggesting a moderately strong linear association between the Ektaspeed estimates and actual values. The R^2 of .589 for Ektaspeed® radiographs acdounted for 59% of the variance in the actual values in the superior-inferior dimension.

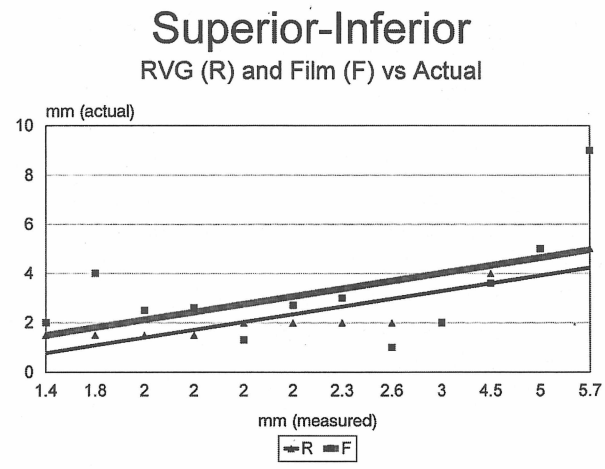

Figure 7. *Actual vs estimated superior-inferior dimensions of periapical radiolucencies for RVG® 32000 and Ektaspeed® radiographic images*

Slika 7. *Stvarne dimenzije u odnosu prema procijenjenim superiornim - inferiornim dimenzijama periapikalnih prosvjetljenja za slike prikupljene sustavom RVG® 32000 i radiografijom filmom Ektaspeed*

The linear regression (Figure 8) for the actual mesio-distal dimensions and those estimated from the RVG® 32000 images produced a slope of y=-.391+.994x, with a *Pearson R* value of .964, suggesting a very strong linear association between the RVG® estimates and actual values. The R^2 of .929

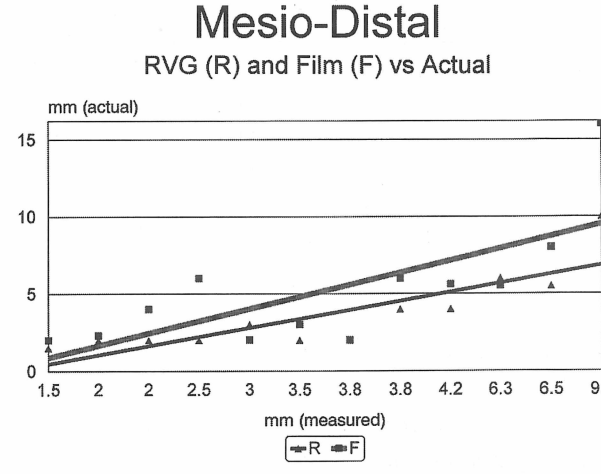

Figure 8. *Actual vs estimated mesio-distal dimensions of periapical radiolucencies for RVG® 32000 and Ektaspeed® radiographic images*

Slika 8. *Stvarne dimenzije prema odnosu na procijenjenim mezio-distalnim dimenzijama periapikalnih prosvjetljenja za slike prikupljene sustavom RVG® 32000 i radiografijom filmom Ektaspeed*

for the RVG® values accounted for 93% of the variance in the actual values for error in estimation of the mesio-distal dimension. The linear regression for Ektaspeed® film images produced a slope of y=-.622+1.425. The *Pearson R* value was 0.871, suggesting a strong linear association between the RVG® estimates and actual values. The Ektaspeed® R^2 accounted for 76% of the variance in the values for error in estimation of the mesio-distal dimension.

While the dimensional estimations made with the RVG® 32000 appeared more accurate than those made with Ektaspeed® radiographs, the paired *t-test* provided insufficient evidence to reject the null hypothesis when evaluating differences in the superior-inferior ($p \geq .100$) dimensional estimates between RVG® 32000 images and Ektaspeed® radiographs. The disparity, however, between the mesio-distal estimates was significant ($p=.022$). The mean RVG® superior- inferior measurement was 2.50 mm ±1.35 mm, while the actual mean value was 2.85 mm ±1.42 mm. Mesio-distal measurements averaged 3.67 mm ±2.49 mm with the RVG® 32000, whereas the actual mean value was 4.08 mm ±2.41 mm. For radiographic assessment with film, the mean mesio-distal and superior-inferior measurements were 5.20 mm ±3.95 mm and 3.22 mm ± 2.14 mm respectively.

An *f-test* of variability was performed to test sample differences between RVG® and Ektaspeed® film estimates minus actual values. For superior-inferior dimension, the estimate variance for the RVG® 32000 and film were .12 and 1.92, respectively. This difference was significant ($p<.05$). In the mesio-distal dimension, the RVG® 32000 estimate variance was 0.44, while that for film was 4.83 ($p<.05$). Estimated from the two modalities were therefore, significantly different.

Discussion

Any technology which complements the information gathered through conventional radiography has potential for use in endodontics. The instant image acquisition inherent with CCD-based imaging obviously provides a potential savings in time, in addition to obviating the need for a darkroom, processors, film and processing chemistry, and for the waste management of spent solutions high in silver content. Furthermore, CCD-based technology permits a dose savings over conventional intraoral film radiography (21,22). The major question, therefore, is whether CCD-based images are diagnostic. This study found that RVG® 32000 images were at least equal to Ektaspeed® film radiographs in estimation of the size of periapical lesions. It does not, however, provide any information about whether such lesions would be seen more readily by either modality, since the presence of a radiolucency was a selection criteria for the subjects included in the study.

Further investigations are needed to determine how the effectiveness CCD-based imaging and associated software packages compare with conventional film in the detection of subtle early density and contrast changes in bone resulting form periapical pathoses.

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Točnost *in vivo* radiografije temeljene na CCD (*), koja se koristila za procjenu dimenzija periapikalnog oštećenja

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Sažetak

Ciljevi: *Ova je klinička studija provedena da bi se usporedile točnosti procjena stomatologa o dimenzijama periapikalnih prosvjetljenja temeljenih na primjeni elektroničkoga slikanja uporabom sustava za intraoralnu radiografiju tipa RVG® 32000, te filma tipa Ektaspeed.*

Metode: *Držeći se dozvole Nadzornoga tijela Institucije i informacija o uvjetima, napravljene su bile predoperacijske slike periapikalnih oštećenja 12 redom pridošlih pacijenata kojima je bio potreban kirurški zahvat. Slike su napravljene na oba načina: sustavom RVG® 32000, i filmom Ektaspeed. Stvarna veličina oštećenja bila je ustanovljena izradom otisaka od koštanoga voska tipa Ethicon®, tijekom same operacije. Skupina od pet stomatologa postigla je konsenzus u procjeni superiornih - inferiornih i mezio-distalnih dimenzija periapikalnih prosvjetljenja ustanovljenih iz predoperacijskih slika, odvojeno i neovisno za dva modaliteta.*

Rezultati: *Procjene dimenzija oštećenja izrađene sustavom RVG® 32000 i filmom Ektaspeed znatno su se među se razlikovale. Odstupanje od stvarnih izmjerenih vrijednosti bilo je znatno veće za procjene temeljene na filmskim radiografijama od odstupanja procjena na temelju slika sustava RVG® 32000. Općenito uzevši, dimenzije oštećenja bile su na osnovi filmskih slika precijenjene, a malo podcijenjene na osnovi slika snimljenih sustavom RVG® 32000.*

Zaključci: *Digitalno intraoralno slikanje sustavom RVG® 32000 daje moguće prednosti pred konvencionalnom radiografijom time što stomatolozima omogućuje u prosjeku točnije procjene veličina periapikalnih prosvjetljenja.*

Ključne riječi: *apikoektomija, dentalna radiografija, dentalni granulom, digitalno slikanje, periapikalna cista.*

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(*) Optički pretvornik vrste CCD (Charge-cupled Device) za pretvorbu slike u naboj.

Konvencionalnu intraoralnu radiografiju s pomoću neposredno eksponiranih filmova s emulzijom od srebrnog halida stomatolozi rasprostranjeno upotrebljavaju za procjene periradikularnih patoloških promjena. No postoje spoznaje da radiografski nalazi ne pokazuju uvijek stvarne granice oštećenja takvih upalnih procesa kao što su difuzna ili ograničena periapikalna upala ili cista (1).

Već su godine 1961. Bender i Seltzer otkrili da su mehanički inducirani medularni defekti u donjim čeljustima mrtvaca bili potpuno unutar porozne kosti. "Ozljede" su postale radiografski vidljive samo nakon gubitka kortikalisa kosti (2). Regan i Mitchell potkrijepili su te nalaze radiografskim pregledom 57 donjih čeljusti mrtvih ljudi i popratili pažljivim istraživanjem 18 radiografički otkrivenih periapikalnih prosvjetljenja (3). Drugi istraživači došli su do sličnih rezultata (4-7). Schwartz i Foster kreirali su defekte u osušenim ljudskim lubanjama upotrebljavajući bušilice i kirurške strugalice (8). Oni su zaključili da na rendgenskim snimkama nisu bila vidljiva čak znatna oštećenja porozne kosti, ako nije bio zahvaćen i kortikalis kosti.

Bez obzira na zahvaćenost kortikalisa kosti, kut snopa X-zraka može povećati, smanjiti ili potpuno prikriti dentalna periapikalna oštećenja (9-11). Povećanje okomite angulacije uzrokuje perspektivni prikaz, dakle skraćenje slike zuba, i smanjuje prividnu veličinu nekog periapikalnog oštećenja (12). Wengraf je demonstrirao da promjene u vodoravnoj angulaciji od samo 15° mogu potpuno sakriti periapikalno oštećenje (13). Također je bilo izviješćeno da radiografsko vrjednovanje periapikalnih oštećenja može biti nepouzdano zbog velikih varijacija u sposobnostima zapažanja i dijagnosticiranja raznih promatrača. Goldman i suradnici ustanovili su da je međusobno slaganje promatrača prigodom promatranja područja sa smanjenom gustoćom manje od 50% (14). Također je ustanovljeno da su se promatrači složili u samo 72 - 88% slučajeva (15). U sličnoj studiji, Brynolf je reinterpretirala svoje prijašnje radiografije i složila se s vlastitim zaključcima u samo 70% slučajeva (16).

Svrha ove studije bila je usporediti točnost promatrača u procjeni veličina periapikalnih prosvjetljenje s pomoću neposredne intraoralne radiografije emulzijskim filmom tipa "E-speed" (Ektaspeed: Eastman Kodak, Rochester, NY) i s pomoću toplinski iscrtanih slika prikupljenih intraoralnim radiografskim osjetilom temeljenom na načelu CCD (RVG® 32000: Trophy Radiologie, Vincennes, France). Polazna hipoteza bila je da su sustav RVG® 32000 i film Ektaspeed® (Eastman Kodak, Rochester, NY) jednako točni kod određivanja dimenzija periapikalnih oštećenja.

Materijali i postupci

Populacija: Pacijenti liječeni u postdiplomskoj endodontičkoj klinici Stomatološkog fakulteta Sveučilišta grada Louisvillea bili su pozvani da sudjeluju u studiji, ako imaju zub kojemu je potrebna apikotomija (tj. imaju simptomatičan zub s područjem smanjene gustoće, veliku periapikalnu radiolucenciju ili povećanje apikalnog oštećenja nakon liječenja). Dozvolu za studiju izdao je Odbor za ljudska pitanja, Sveučilište grada Louisvillea. Od svih sudionika dobili smo dva pristanka: pismenu izjavu da su obaviješteni o kirurškome zahvatu, i drugi pristanak da sudjeluju u istraživanju, kao što zahtijeva Nadzorno tijelo naše institucije. U istraživanju je sudjelovalo dvanaest pridošlih pacijenata kojima je bio potreban kirurški zahvat u području korijena.

Tehnike snimanja: Sve su slike snimljene tehnikom koja osigurava usporednost. Za to je upotrebljen modificirani držač filma Precisio® (Masel, Philadelphia, PA) za stabiliziranje filma ili intraoralnog osjetila (17,18). Da se osiguraju identični geometrijski projekcijski kutovi za oba načina snimanja, uzeta je registracija čestice s pomoću Blue-Mousse® (Parkell, Farmington, NY) (19).

Za rendgensko snimanje bio je upotrijebljen film Ektaspeed®. Naprava za generiranje X-zraka bila je Acuray® 017A (Belmont, Somerset, NJ), s fokusnom točkom od 0,5 mm^2, 2,5 mm Al ekvivalentnim filtriranjem i razmakom izvor - vrh konusa od 8 palaca, radila je uz 70 kVp, 10 mA, s ekspozicijama od 15 do 24 impulsa. Za razvijanje filmova upotrebljen je procesor AT 2000® (Air Techniques, Inc, Hicksville, NY), postavljen na ciklus od 5 minuta. Reprezentativna snimka jednog od slučajeva, snimljena filmom Ektaspeed, prikazana je na Slici 1.

Za digitalno intraoralno radiografiranje temeljeno na načelu CCD upotrebljen je sustav RVG® 32000. Naprava za generiranje X-zraka bila je Trophy Irix® s elektroničkim vremenskim sklopom (Trophy Radiologie, Vincennes, France) s nazivnom

veličinom točke fokusa od 0,49 mm², 1,5 mm Al ekvivalentnim filtriranjem i razmakom izvor - vrh konusa od 8 palaca, radila je uz 70 kVp, 8 mA, a prema proizvođačevim preporukama o sekvencama eksponiranja za standardni način rada. Reprezentativna slika jednog od slučajeva, snimljena sustavom RVG®, prikazana je na Slici 2.

Kirurška faza: U tijeku periapikalne operacije, pošto je uklonjen bukalni kortikalis i bez podrezivanja uspostavljen neposredni pristup defektu, utisnut je koštani vosak (Ethicon®, Somerset, NJ) u koštani defekt (Slike 3, 4). Koštani je vosak bio prije toga izvaljan u kuglicu i stavljen u ledom ohlađenu vodu. Taj je postupak pomogao da se vosak dobro utiskuje i spriječio je da se omekša i lijepi na kost. Vosak se je utiskivao u defekt pritiskom prsta, tako da se prilagođavao obliku defekta. Pošto je vosak izvađen i premjeren milimetarskim kaliperom (mjerna sprava s krakovima, Slika 5), bilježene su najveće superiorne - inferiorne i mezio-distalne izmjere voštanog otiska. Točnost kalipera bila je ±0,1 mm.

Vrjednovanje dijagnostičkih slika: Sve dimenzionalne procjena učinila je skupina od pet stomatologa služeći se pritom vodičem za mjerenje (Slika 6) i standardiziranim uvjetima čitanja. Sve snimke bile su stavljene na osvijetljeni okvir za promatranje u prostoriji s prigušenim svjetlom. Mezio-distalne i superiorne - inferiorne dimenzije periapikalnih prosvjetljenja mjerile su se prozirnim plastičnim milimetarskim ravnalom. RVG® slike promatrale su se na toplinskim snimkama pod reflektiranom fluorescentnom rasvjetom u svjetloj prostoriji. Slike snimljene sustavom RVG® 32000 mjerile su se s pomoću manjih slika toplinskih snimaka (Slika 2) da se izbjegnu varijable povećavanja i poteškoće u svezi s konveksnošću ekrana monitora. Prethodno testiranje i kalibracija s objektom poznate dužine osigurali su da manje slike toplinskih snimaka budu dimenzionalno konzistentne i točne unutar 0,5 mm.

Raščlamba podataka: Upotrebljen je sparen *t-test* rezultata, tako da je svaki subjekt poslužio kao vlastita kontrolna vrijednost pa su učinci stranih neovisnih varijabla bili reducirani (20). Konstrukcija pokusa od prilagođenih parova omogućila je veću redukciju ukupne promjerljivosti u replikacijama, pružajući dovoljnu moć uz poredbeno malo subjekata. Vrijednosti razlika dimenzija slika izvedene su odbijanjem stvarnih izmjera na voštanom otisku, od izmjera na RVG® slikama i na filmskim snimkama. Također je provedena raščlamba regresije i *f-test*. Vrijednost *à priori* α bila je postavljena na 0,05.

Rezultati

Zbirni podatci rezultata mjerenja stvarnih dimenzija voštanih otisaka i procijenjene prosječne vrijednosti na temelju obaju snimanja, slika sustava RVG® 32000 i slika filmova Ektaspeed®, prikazani su u Tablici 1. Mjerenja obavljena uporabom filmova Ektaspeed® dala su rezultate općenito veće od stvarnih dimenzija, a mjerenja temeljena na slikama toplinskoga snimanja sustavom RVG 32000® dala su rezultate nešto manje od stvarnih dimenzija i pokazala su manje varijacija u stupnju dimenzionalnog izobličenja.

Razlike između mjerenja temeljenih na RVG® i na filmu bile su jasno demonstrirane primjenom linearne regresije za oba modaliteta. Linearna regresija (Slika 7) za stvarne superiorne - inferiorne dimenzije i one procijenjene na osnovi slika od sustava RVG® 32000 rezultira kosinom od y = - .132 + .924x, uz vrijednost *Pearson R* od .971, sugerirajući vrlo snažnu linearnu asocijaciju između RVG procjena i stvarnih vrijednosti. Vrijednost R^2 od .943 za RVG® uračunata je za 94% neslaganja stvarnih vrijednosti superiornih - inferiornih dimenzija. Linearna regresija (Slika 7) za radiografije Ektaspeed® nasuprot izmjerenom realitetu, rezultira kosinom od y = - .068 + 1,156x, uz vrijednost *Pearson R* od 0,767, sugerirajući umjereno snažnu asocijaciju između procjena na osnovi uporabe Ektaspeed filma i stvarnih vrijednosti. Vrijednost R^2 od .589 za Ektaspeed® radiografije uračunata je za 59% neslaganja stvarnih vrijednosti superiornih - inferiornih dimenzija.

Linearna regresija (Slika 8) za stvarne mezio-distalne dimenzije i one procijenjene na osnovi slika od sustava RVG® 32000, rezultira kosinom od y = - .391 + .994x, uz vrijednost *Pearson R* od .964, sugerirajući vrlo snažnu linearnu asocijaciju između RVG® procjena i stvarnih vrijednosti. Vrijednost R^2 od .929 za RVG® veličine uračunata je za 93% neslaganja stvarnih vrijednosti srednjih dimenzija. Linearna regresija za slike filma Ektaspeed®, proizvela je kosinu od y = - .622 + 1,425. Vrijednost *Pearson R* bila je .871, sugerirajući snažnu linearnu asocijaciju između procjena na osnovi uporabe RVG® i stvarnih vrijednosti. Vrijednost R2 za Ek-

taspeed® uračunata je za 76% neslaganja stvarnih vrijednosti u procjeni srednjih dimenzija.

Dok procjene dimenzija temeljene na RVG® 32000 izgledaju točnijima od procjena temeljenih na Ektaspeed® radiografijama, spareni *t-test* nije dao takve rezultate koji bi poništili početnu pretpostavku, kad se radi o vrjednovanju razlika u procjenama superiornih - inferiornih dimenzija ($p \geq 0,100$) temeljenih na slikama RVG® 32000 i radiografijama Ektaspeed®. No disparitet procjena mezio-distalnih dimenzija bio je značajan ($p = 0,022$). Srednja vrijednost superiornih - inferiornih dimenzija izmjerena s pomoću RVG® bila je 2,50 mm ± 1,35 mm, a stvarna je vrijednost bila 2,85 mm ± 1,42 mm. Prosjek mezio-distalnih dimenzija bio je 3,67 mm ± 2,49 mm ustanovljen s pomoću RVG® 32000, a stvarna srednja vrijednost bila je 4,08 mm ± 2,41 mm. Prosjek dimenzija izmjerena s pomoću radiografija filmom bio je 5,20 mm ± 3,95 mm u slučaju mezio-distalnih dimenzija i 3,22 mm ± 2,14 mm u slučaju superiornih - inferiornih.

Da bi se ispitale razlike uzoraka procjena temeljenih na RVG® i na filmu Ektaspeed®, minus stvarne vrijednosti, izvršen je *f-test* neslaganja. Neslaganje procjena superiornih - inferiornih dimenzija za RVG® 32000 bilo je 0,12, a za film 1,92. To je velika razlika ($p < 0,05$). Kod mezio-distalnih dimenzija neslaganje procjene bilo je 0,44, a za film je bilo 4,83 ($p < 0,05$). Proizlazi da su procjene spomenutih dimenzija temeljenih na dva modaliteta znatno različite.

Rasprava

Bilo koja tehnologija koja upotpunjuje informacije dobivene konvencionalnom radiografijom, ima potencijal za primjenu u stomatologiji. Prikupljanje slika bez kašnjenja, svojstveno slikanju na osnovi CCD, očito pruža potencijalnu uštedu vremena i dodatno uklanja potrebu za tamnom komorom, uređajima za razvijanje, kemikalijama za film i razvijanje te rukovanje otpadom iskorištenih rastopina s visokim sadržajem srebra. Osim toga, tehnologija temeljena na CCD omogućuje da se smanje doze zračenja u usporedbi s konvencionalnom intraoralnom radiografijom (21,22). Zbog toga je glavno pitanje: jesu li slike temeljene na CCD, dijagnostičke. Ova je studija otkrila da su slike snimljene sustavom RVG® 32000 najmanje ravnopravne radiografijama filmom Ektaspeed®, kad se radi o procjeni dimenzija periapikalnih oštećenja. Studija, međutim, nije dala nikakvu informaciju o tome bi li se takva oštećenja otkrivala pouzdanije kojim od dvaju načina, jer je radiolucencija bila kriterij za subjekte uključene u studiju.

Da bi se odredilo kako se učinkovitost slikanja temeljenog na tehnologiji CCD i pripadajućih paketa programske podrške uspoređuje s konvencionalnim filmom u ranom otkrivanju malih prosvjetljenja i promjena kontrasta kosti, koje su posljedica periapikalnih patoloških promjena, potrebna su daljnja istraživanja.