Original Article

A comparative study between currently used methods and Small Volume-Cone Beam Tomography for surgical placement of mini implants

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ABSTRACT

Objective: To compare the outcome of mini implant placement by four different methods: blind placement, a single periapical radiograph (PA), a single panoramic radiograph, and a small-volume cone-beam computed tomography (SV-CBCT). Our hypothesis was that SV-CBCT, with its high resolution, low radiation dose, and three-dimensional depiction of area of interest would yield superior diagnostic information in assessing the potential anchorage site compared to currently used methods that often result in undesired root perforations.

Materials and Methods: Potential mini implant sites of 20 dentate or partially dentate human skulls were imaged using three different imaging modalities: PA, panoramic radiograph, and SV-CBCT. Mini implants were placed in 10 maxillary and 10 mandibular randomized sites blindly and using each of the three imaging modalities. Large-volume CBCT scans done postoperatively were used to detect root perforation. Two oral radiologists analyzed the images for perforation of root structures at each site.

Results: There was significantly (P < .05) less root perforation with SV-CBCT when compared with other imaging modalities. Fifty-five percent of mini implants placed blindly, 60% of mini implants placed using PA, and 50% of mini implants placed using a panoramic radiograph perforated a root structure, whereas only 5% of mini implants placed using SV-CBCT perforated a root structure.

Conclusions: Preoperative evaluation of potential mini implant insertion sites using SV-CBCT aids in predictable placement and results in the least amount of root perforation. (*Angle Orthod.* 2015;85:446–453.)

KEY WORDS: SV-CBCT; Mini implants

INTRODUCTION

Mini implants have gained enormous popularity in the orthodontic community because of their ease of placement and removal, low cost, and minimal/no

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need of patient compliance.^{1,2} Mini implants are being considered an absolute source of skeletal orthodontic anchorage.^{1,2} However, the clinical application of a mini implant does not guarantee treatment success, and its stability is essential before it can be used for different treatment modalities.^{3,4}

A critical step that determines the success of the mini implant is the atraumatic surgical placement of the mini implant. Several critical anatomic structures are present in the vicinity of the common sites for mini implant placement.^{5,6} Important factors that should be considered for placement of mini implants are soft tissue status, anatomy of the tooth and bone and, more importantly, interradicular distance, location of the inferior alveolar nerve, buccal and lingual/palatal bone thickness, and sinus morphology.^{5–7} Therefore, careful clinical and radiographic evaluation of the potential mini implant placement site is very important.

Root resorption, local bony or soft tissue infections, maxillary sinus perforations, bone loss at furcation, and ankylosis have been reported in the literature with

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Figure 1. Periapical radiographs of the mini implant placement site.

the placement of mini implants.^{8–10} Moreover, contact with the root of a tooth can lead to mobility and ultimately failure of the mini implant. Orthodontic literature reports 0.47% to 43.3% of root perforation in patients associated with mini implant placement.^{5,6} Although some studies have pointed out these critical issues with mini implant placement, the current trend seems to be either blind placement of the mini implant or the use of a periapical (PA) radiograph of the potential anchorage site.^{11,12} However, neither of these methods offers adequate information for predictable placing of mini implants without causing any potential damage to the critical structures in the vicinity.

Three-dimensional (3D) imaging is an important diagnostic tool in the assessment of potential sites for mini implant placement and can contribute significantly in predictable placement of mini implants. Moreover, two-dimensional imaging does not offer adequate information regarding the interradicular space, root morphology, thickness of cortical bone, and the position of the inferior alveolar nerve.11,12 Threedimensional imaging of the potential placement site can help with preoperative planning and preparation; however, conventional 3D imaging using multi-slice computed tomography (CTs) delivers a large radiation dose, which has discouraged orthodontists from routinely using this imaging technique.7 The development of cone-beam computed tomography (CBCT) has changed the imaging paradigm to an extent, but the radiation dose delivered by large-volume CBCTs, although significantly less than multi-slice CT, is still not considered justified for the task at hand.13 The evolution of small-volume CBCT (SV-CBCT) offers 3D views of the area of interest in all three orthogonal planes and provides excellent submillimeter resolution with an additional benefit of a drastic reduction in radiation dose. Moreover, SV-CBCT aids in marking the inferior alveolar nerve canal and helps in transferring the location of the nerve into cross-sectional views for precise placement of mini implants.

Since SV-CBCT is a relatively new entrant into dentistry/orthodontics, imaging protocols for mini implant placement have not been established yet.⁸ Development of such protocols should mandate the optimum image resolution and lowest radiation dose that will improve the success of mini implant placement. Our study aims to provide essential information to develop scientifically justified imaging protocols for mini implant placement.

MATERIALS AND METHODS

Twenty dentate or partially dentate dry human skulls were used in this study. All 20 skulls selected had both first and second molars in the maxillary and the mandibular arch. Skulls were excluded from the study if there was significant bone loss (midroot or greater) in the areas of mini implant placement. Metallic springs and screws on the skulls were removed to prevent metallic streak artifacts during imaging.

Image Acquisition

Panoramic, periapical, and SV-CBCT imaging were done before the mini implant placement for each quadrant (maxillary left, maxillary right, mandibular left, and mandibular right) of the 20 skulls.

Periapical radiographs were acquired using Progeny-dental wall mounted X-ray unit with exposure parameters of 70 kvp and 7 mA and a size-2 film using the parallel angle technique for image capture (Figure 1). Panoramic images were acquired using Sirona Orthophos XG digital panoramic machine with exposure parameters of 60 kvp and 7 mA. The images were viewed using DIMAXIS image viewing software (Planmeca, Roselle, III) (Figure 2). SV-CBCT images were acquired using Kodak-9000 (Kodak Dental Systems, Rochester, NY) with the exposure parameters of 70 kvp and 10 mA, 50 mm \times 38 mm field of view (approximately 3–4 teeth), voxel size of 76 µm, and exposure time of 10.8 seconds (Figure 3).



Figure 2. Panoramic radiograph of the skull.

Following acquisition, 3D image volumes were reconstructed using the Dental CT software provided by the manufacturer (Dental CT Software, Kodak Dental Systems, Rochester, NY, USA). Images were viewed using the Kodak 3.0 DICOM viewer (Figure 3).

Implant Placement

Prior to mini implant placement, to simulate the soft tissue depth, Play-Doh(1–2 mm) was placed from the alveolar crest extending apically to cover the roots of the teeth in each of the four quadrants (Figure 4). The placement of Play-Doh also allowed us to simulate a bleeding point for the placement of mini implants (Figure 5). Mini implants were placed in each quadrant using three different imaging techniques: (1) blind placement—radiographs were not used as an aid in placing the mini implants, (2) periapical radiograph single PA was acquired before the placement of the mini implant, (3) panoramic radiograph—single panoramic radiograph was acquired before the placement of the mini implant, and (4) SV-CBCT—single SV-CBCT was taken before mini implant insertion.

Blind placement method. Radiographic imaging of the potential anchorage site was not done prior to mini implant placement. Root structure locations were estimated based on the long axis of the crowns of the teeth and the contour of the root structure visualized through the Play-Doh. Using a periodontal probe, we simulated a "bleeding point" to estimate the midpoint between adjacent teeth.

PA radiograph method. A single PA radiograph was acquired and interradicular distance was measured at the midroot height and a central location was estimated. This information was translated to the Play-Doh at the mini implant placement site using a periodontal probe.

Single panoramic radiograph method. A single panoramic radiograph was used to assess the potential



Figure 3. SV-CBCT of the mini implant placement site.



Figure 4. Play-Doh on the maxilla and the mandible.

anchorage site prior to mini implant placement. Similar to the PA radiograph method, the interradicular distance was measured at the midroot height and a central location was estimated. The magnification caused by panoramic radiography was considered before estimating the final placement site. After compensating for the magnification of approximately 20%, a bleeding point was simulated using a periodontal probe.

Single SV-CBCT method. A single SV-CBCT acquisition was used to assess the potential anchorage site prior to mini implant placement. Postprocessing reconstruction was done to evaluate the area of interest in three dimensions. A simulated periapical projection was created using the arch-creating tool on the Kodak DICOM viewer. To create the periapical projection, the curve was drawn at the level of midroot and at the buccolingual center of the alveolar ridge on axial section. The potential mini implant placement site was assessed using simulated periapical projection and corresponding cross-sectional images. The mandibular canal was tracked using the nerve-marking tool. Using the measurement tool in the Kodak DICOM viewer, the exact midroot location and interradicular space at midroot was found. In the axial view, the interradicular space was remeasured and potential



Figure 5. Bleeding point simulation on the Play-Doh.

mini implant placement site was determined. The path of insertion was determined based on the axial view and measurement from the buccal cortical plate to the lingual cortical plate.

Each placement method was randomly assigned to 10 maxillary sites and 10 mandibular sites (20 sites imes4 methods = 80 potential sites). Mini implants were placed approximately midroot between the first and second molars in the mandibular arch and between the first molar and second premolars in the maxillary arch. We chose the above sites as they are recommended as the safest sites (Figure 6) for buccal mini implant placement in the posterior region of the maxilla and mandible.14-16 When placing a mini implant, a round bur (0.9-mm diameter) was used to make a small indentation on the bony surface. Next, the pilot hole was made using a tapered fissure bur with the highspeed contra-angle hand piece. All mini implants were made from titanium alloy Ti6Al4V grade 5. The 10-mm long mini implants were self-tapping. Mini implants both in the maxilla and mandibles were placed by a single examiner.

Each skull was imaged postoperatively on a Hitachi CB MercuRay CBCT scanner (Twinsburg, OH, USA) with exposure parameters of 120 kV and 15 mA with a 9-inch field of view and a voxel size of 0.3 mm. The images were acquired and reconstructed by using CB works 3.0 (Cybermed, Irvine, Calif) (Figure 7).

Two oral radiologists independently analyzed the large-volume- (LV) CBCT. The radiologists were blinded to the preoperative imaging methods used to place the mini implants in each quadrant. The images Downloaded from https://prime-pdf-watermark.prime-prod.pubfactory.com/ at 2025-05-14 via free access



Figure 6. Mini implant in the safe zones in maxilla and mandible.

were displayed on the image viewing workstation powered by a HP Pavillion ZE 2000 computer and 22-inch dual monitor display with a 1600×1050 and 1.8-megapixel resolution. The viewing conditions (room lighting and display monitor settings) were standardized. The examiners were allowed to manipulate the images and were given access to the histogram to adjust the brightness, contrast, and magnification and use the secondary reconstruction tools in the software program. They were asked to record perforation of root structures by the mini implant. The examiners scored the images on separate sessions, at least 2 weeks apart. The order of the imaging exams provided for evaluation were randomly changed and presented to the examiners at the evaluation sessions.

Statistical Analysis

Descriptive statistics with counts of root perforation for each of the four placement methods were calculated. Percentages of root perforation for each method were also calculated. Chi-square test was performed to see the relationship between mini implant placement with three different imaging modalities. Interrater reliability was performed to see the root perforation based on LV-CBCT images using Cohen kappa. Weighted kappa values for interrater variability were computed and interpreted using previously reported criteria: 0.81 (very good), 0.61-0.80 (good), 0.41-0.60 (moderate), 0.21-0.40 (fair), and 0.20 (poor agreement). P value less than .05 was considered statistically significant. All of the statistics were performed using SPSS version 21.0 (IBM SPSS Statistics for Windows, version 21.0, Armonk, NY).

RESULTS

Descriptive statistics showed that total root perforation for the blind method was 11 out of 20 (55%); for PA it was 12 out of 20 (60%); for panoramic radiography, it was 10 out of 20 mini implants placed (50%); and for SV-CBCT it was 1 out of 20 (5%) (Figure 8; Table 1). Moreover, 45% of mini implants placed blindly did not perforate a root structure; similarly, 40% of mini implants were placed using PA, 50% of mini implants using panoramic, and 95% of mini implants using SV-CBCT did not perforate a root structure (Figure 8).

Chi-square test results showed statistically significant relation between the different mini implant placement methods and the postoperative outcome,



Figure 7. Large-volume CBCT after the mini implant placement.



Figure 8. Depicting root perforation with different placement methods.

ie, root perforation (P < .004) for both oral maxillofacial radiologists (Tables 2, 3 and 4).

Interobserver agreement values were compared using Cohen kappa test and showed very good interrater agreement ($\kappa = 0.88$).

DISCUSSION

A critical step that determines the success of mini implants is their surgical placement without damaging adjacent critical structures. Root resorption is a common sequela of root perforation with a mini implant. Even with the data on root resorption and clinical success, the contemporary method for mini implant placement seems to be blind placement or by using a single PA of the potential anchorage site. Our study has shown that SV-CBCT is superior in limiting root perforations when compared to other placement methods.

Radiologic imaging is an essential diagnostic tool to assess interradicular space, root morphology, location of the inferior alveolar nerve, buccal and lingual/palatal cortical bone thickness, and sinus morphology. Currently, the modalities used for this purpose include PA, panoramic radiography, and SV-CBCT. Our study showed that SV-CBCT performs better than PA and panoramic radiography in the preoperative evaluation of potential mini implant sites, with only 5% of sites

 Table 1.
 Average Total Root Perforation Comparison by Placement

 Method
 Placement

		No Root		Root
	No Root	Perforation,	Root	Perforation,
Method ^a	Perforation	%	Perforation	%
Blind	9.00	45	11	55
PA	8.00	40	12	60
Pan	10.00	50	10	50
SV-CBCT	19.00	95	1	5

^a PA indicates periapical radiograph; Pan, single panoramic radiograph; and SV-CBCT, small-volume cone-beam computed tomography.



Panoramic

Sites without

Root Perforation

50%

Sites with Root

Perforation

50%

/

SV-CBCT

Sites with Root Perforation

Sites without

Root Perforation 95%

showing root perforation, whereas it was 50% to 60% with other two-dimensional imaging techniques.

SV-CBCT provides the orthodontist with the most accurate interradicular distance as it offers multiplanar views such as axial, sagittal, and coronal of potential anchorage sites. Additionally, the axial view allows the dentist to measure the buccolingual thickness (B-L) of the bone. The B-L thickness is important in determining the length of the mini implant to be used at the potential placement site. The information obtained from the SV-CBCT allows the orthodontist to customize the mini implant placement, as interradicular distance and bone thickness may vary individually, thus resulting in the least amount of root perforations for the individual patient.

The most common diagnostic methods used for mini implant placement are PA and panoramic radiography. PA and panoramic radiographs are easy to acquire but are limited by their two dimensionality, single view, and geometrical and/or magnification distortion. Our findings suggest that blind placement, PA, and the use of panoramic radiographs are not reliable for evaluation of potential mini implant placement sites. Visual inspection of crown parallelism and root prominence of the buccal mucosa does not give us necessary information, and it needs to be supplemented by 3D imaging of the potential site. In this study, 55% of blind method sites showed root perforation.

Furthermore, our study showed that it was equally difficult to perform accurate measurements of the interradicular sites for mini implant placement and to transfer that information on to the skull with both PA and panoramic radiograph methods. This resulted in

Table 2. Chi-Square	Test for	Examiner	1 Results
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	Value	df	Asymp Sig (Two-Sided)
Pearson chi-square	13.364	3	.004
Likelihood ratio	14.553	3	.002
Linear-by-linear association No. of valid cases	6.376 84	1	.012

 Table 3.
 Chi-Square Test for Examiner 2 Results

	Value	df	Asymp Sig (Two-Sided)
Pearson chi-square	19.414	3	.000
Likelihood ratio	23.165	3	.000
Linear-by-linear association	9.724	1	.002
No. of valid cases	84		

60% of sites with root perforation for the PA method and 50% for the panoramic radiograph method. There was no significant difference (P < .05) between these two imaging techniques. Moreover, a panoramic radiograph or PA is not as accurate in preoperative treatment planning for mini implant placement because neither did any better than blind placement in terms of root perforation.

SV-CBCT can be utilized at a much lower radiation dose and with more reliable information for precise placement of mini implant.^{17,18} Moreover, a new dosimetry study has shown that the radiation exposure with SV-CBCT is equivalent in radiation dose to two bitewings radiographs.^{17,18} The above information allows us to conclude that SV-CBCT should be regularly used in the evaluation of the potential mini implant placement site.

The main limitation of our study was that we placed mini implants solely in the areas deemed by the literature to be "safe zones" for mini implant placement. For many of the skulls, after looking at a radiographic image, it was immediately clear that this would not have been the "safe zone" for this patient.¹⁹ Sometimes there was as little as 1 mm of interradicular space in these sites, further supporting the fact that blind placement of mini implants should be avoided. Literature suggests there should be at least 0.5 mm of space between mini implants and the adjacent root both mesially and distally.^{8,19} Sometimes it is difficult to place mini implants in "safe zones" due to limitation in mouth opening. In the current study, we strictly adhered to our protocol of placing the mini implants in the safe zones, but based on 3D imaging and evaluation of area of interest, the potential anchorage site can be changed or altered if the risk of root perforation is very high or questionable. The location of the mini implant can be changed to a site in the vicinity that will have adequate interradicular distance, thus

Agreement	Values
	Agreement

	Value	Asymp Std Error	Approx T	Approx Sig
Measure of agree- ment kappa No. of valid cases	.880 84	.052	8.069	.000

preventing root perforation and yet facilitating the desired anchorage consideration.

CONCLUSIONS

This study shows that:

- SV-CBCT is superior to other imaging techniques for the surgical placement of mini implants.
- SV-CBCT should be used in the preoperative evaluation of potential sites for mini implant placement and will result in less root perforations. With the radiation doses of SV-CBCT becoming very low, 3D evaluation of a potential mini implant site will be very valuable in the placement and success of mini implants.

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