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CLINICAL RESEARCH:

Radiolucent Lesions Associated with Stainless Steel Mini-Implants During Routine Examination with Cone Beam Computed Tomography-An Observational Study

Lesiones radiolúcidas asociadas a mini-implantes de acero inoxidable durante el examen de rutina con tomografía computarizada de haz cónico: un estudio observacional

A. Sumathi Felicita MDS, M(Orth) RCPS(Glasg), MOrth RCSEd, MDFTEd, FDSRCSEd, DIBO[1] https://orcid.org/0000-0003-2002-0140
T.N. Uma Maheswari MDS, PhD[2] https://orcid.org/0000-0002-2366-2336

[1]Professor, Department of Orthodontics, Saveetha Dental College & Hospital, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India.
[2]Professor, Department of Oral Medicine, Saveetha Dental College & Hospitals, Saveetha Institute of Medical and Technical Sciences, Saveetha University, Chennai, Tamil Nadu, India.

Correspondence to: A. Sumathi Felicita - sumifeli@hotmail.com

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ABSTRACT: The aim of this study was to determine the prevalence of radiolucent lesions around mini-implants used for orthodontic anchorage due routine evaluation with cone beam computed tomography. Twenty two mini-implants were examined prior to and after orthodontic treatment in young adults requiring absolute anchorage. All mini-implants were placed in the maxillary arch between the second premolar and first permanent molar. CBCT taken immediately after mini-implant placement (T1) and towards the end of treatment (T2) were checked for the presence of radiolucency around the mini-implants. A radiolucent lesion was recorded when it was present in any one of the planes, either the tangential or cross-sectional view of the panoramic window or the coronal or sagittal view of the multiplanar window. The presence/absence of radiolucency was checked individually at T1 and T2 and also compared between T1 and T2. Descriptive statistics with frequency distribution and percentage was done. 31.82% of mini-implants showed a small radiolucency at its tip at T1 and T2. 13.64% of mini-implants showed a linear radiolucency along the length of the mini-implant at T1 and T2. Two mini-implants had periapical lesion at the time of mini-implant at T1 which exaggerated and increased in size at T2 while two mini-implants had a tiny periapical lesion at T1 which resolved at T2. Three mini-implants had radiolucent lesions around the tip of the mini-implant at T1 which changed to a linear radiolucency along the length of the mini-implant at T2 and vice versa. 45.45% of all the mini-implants evaluated showed the presence of radiolucency around it at T1 and 50% of all the mini-implants evaluated showed radiolucency at T2.

KEYWORDS: Mini-implant; Radiolucent lesion; CBCT.

RESUMEN: El objetivo de este estudio fue determinar la prevalencia de lesiones radiolúcidas alrededor de mini-implantes utilizados para anclaje ortodóntico, durante la evaluación de rutina mediante tomografía computarizada de haz cónico (CBCT). Se evaluaron veintidos mini-implantes antes y después del tratamiento ortodóntico en adultos jóvenes que requerían anclaje absoluto. Todos los mini-implantes se colocaron en el arco maxilar, entre el segundo premolar y el primer molar permanente. Las CBCT tomadas inmediatamente después de la colocación de los mini-implantes (T1) y hacia el final del tratamiento (T2) se analizaron para determinar la presencia de radiolucidez alrededor de los mismos. Se registró una lesión radiolúcida cuando estaba presente en cualquiera de los planos: vista tangencial o corte transversal de la ventana panorámica, o en la vista coronal o sagital de la ventana multiplanar. La presencia/ausencia de radiolucidez se verificó individualmente en T1 y T2 y también se comparó entre T1 y T2. Se realizaron estadísticas descriptivas con distribución de frecuencias y porcentajes. El 31,82% de los mini-implantes mostró una pequeña radiolucidez en su punta en T1 y T2. El 13,64% de los mini-implantes presentó una radiolucidez lineal a lo largo de la longitud del mini-implante en T1 y T2. Dos de ellos mostraron una lesión periapical en el momento de la colocación del mini-implante (T1), la cual se acentuó y aumentó de tamaño en T2, mientras que dos presentaron una pequeña lesión periapical en T1 que se resolvió en T2. Tres presentaron lesiones radiolúcidas alrededor de la punta del mini-implante en T1, que cambiaron a una radiolucidez lineal a lo largo de la longitud del mini-implante en T2 y viceversa. El 45,45% de todos los mini-implantes evaluados mostró presencia de radiolucidez a su alrededor en T1 y el 50% presentó radiolucidez en T2.

PALABRAS CLAVE: Mini-implante; Lesión radiolúcida; CBCT.

INTRODUCTION

Cone beam computed tomography (CBCT) is being used more routinely in orthodontics for diagnosis and treatment planning, risk assessment, localization of impacted teeth and identifying pathologies. With the advent of cone beam computed tomography, it is possible to visualize the cranial structures in all three dimensions (1-3). Measurements made on cone beam computed tomography are reliable and can used for assessment of various structures of the skull. The radiation exposure associated with cone beam computed radiography is considerably reduced in recent years (4,5). Hence cone beam computed tomography may be used for evaluation of the teeth and its associated structures.

Mini-implants have become an integral part of orthodontic treatment mechanics (6-9). They are placed at various sites in the maxilla and mandible depending on the proposed treatment plan for a particular malocclusion (10). The stability of the mini-implant and the successful outcome depends on several factors (11,12). Inadequate stability or failure of the mini-implant may result in increased treatment time, unwanted tooth movement, repeated procedures with undue discomfort to the patient and in certain situations, a need to identify an alternate site requiring a change in biomechanics. Failure of the mini-implant may be associated with radiolucency around it.

Interpretation of radiolucent lesions on a cone beam computed tomography should be done to differentiate between the presence of artifacts (13,14,15) and true pathology such as periapical lesions that may occur around the mini-implant (13,14,15). Presence of radiolucent lesions around the mini-implant is a sign of peri-implantitis and adequate measures should be taken to identify and treat these lesions.

Periapical lesions associated with dental implants have been reported in literature and several factors have been attributed to its etiology. However, the presence of these lesions with the use of mini-implants has not been evaluated.

Hence the present study was conducted to identify the incidence of these lesions with the use mini-implant for absolute anchorage. The aim of this study was to determine the prevalence of radiolucent lesions associated with mini-implants immediately after placement and towards the end of treatment using CBCT.

MATERIALS AND METHODS

This observational study was conducted in the department of orthodontics of our university. The study was approved by the scientific review board of our university under the reference number SRB/SDC/FACULTY/20/ORTHO/10. It was further reviewed and approved by the ethical committee under the reference number IHEC/SDC/FACULTY/20/ORTHO/10. Patients who had undergone orthodontic treatment with mini-implants as anchorage were selected. All patients who had cone beam computed tomography taken immediately after mini-implant placement and towards the end of treatment were included in the study. All patients included in the study had a healthy periodontium, without systemic diseases or previous history of orthodontic treatment. The patients included in the study had a mean age of 21.80±3.05 years. All the mini-implants were placed in the maxillary arch between the second premolar and first permanent molar. Patients with insufficient records, periodontally compromised patients with bone loss and history of mini-implant failure during treatment were excluded from the study.

After a detailed explanation of the procedure, written informed consent was obtained from all patients who matched the inclusion criteria and agreed to the use of their CBCT in the study. The CBCT scans of the thirty four patients were screened. Eleven patients were selected for the study according to the inclusion and exclusion criteria and twenty two mini-implants were evaluated. The demographic data of the patients included in the study are given in Table 1.

Table 1. Showing the baseline data and demographics of the patients included in the study.

Number of patients	Number of mini-implants	Age (years) Mean±SD	Duration of loading (months) Mean±SD	Site of mini-implant placement
11	22	21.80(3.05)	7.60(1.65)	Maxillary second premolar and first permanent molar

All patients were bonded with 0.022” MBT bracket prescription. Mini-implants were placed in all patients at the end of leveling and aligning between the maxillary second premolar and first permanent molar with a stent (16). 1.2mm X 8mm stainless steel mini-implants were placed in all patients. All mini-implants were placed at an angulation of 10º to 20º to the occlusal plane. The mini-implants were autoclaved in sealed pouches prior to placement and care was taken to avoid contamination during insertion. All patients were asked to rinse the mouth with chlorhexidine mouthwash prior to mini-implant placement. The mini-implants were unpacked with proper adherence to aseptic procedure. Topical anesthetic was applied adjacent to the site of mini-implant placement. 1 ml of 2% lignocaine with 1:2,00,000 adrenaline was injected and adequate anesthesia was achieved (17). Mini-implants were placed in the attached gingiva at the muco-gingival junction. The mini-implants were placed manually with a hand held driver with gradual drilling into the bone. Primary stability was achieved. The mini-implant was checked clinically for the presence of mobility. All the mini-implants were firmly adherent to the bone. The mini-implants were loaded immediately after placement with approximately 200 grams of force. Treatment was carried out with periodic review every month until the desired treatment was achieved.

The mini-implant and the surrounding bone were examined with CBCT taken with Sidexis XG 2.63 machine (Sirona Dental Systems, GmbH). The specifications of the CBCT machine were 90 kV, 9-12 mA, 8-14-second exposure time, 200 microns voxel resolution, and 80X80 mm field of view. The image was viewed with a Galileos viewer 1.9 (Sirona Dental Systems, GmbH). The bone density around the mini-implants was evaluated in all the three views in both the panoramic and multiplanar window. A decrease in bone density or loss of integrity of the bone surrounding the mini-implant appearing as a darker area compared to the surrounding region was considered as radiolucency. Presence of radiolucency was confirmed if it was present in any one of the planes, either the tangential or cross-sectional view of the panoramic view or the coronal or sagittal view of the multiplanar view of the CBCT. Since the mini-implant was present between the second premolar and first permanent molar in all the patients, all the slices in this region were sequentially examined to identify any abnormalities in the bone surrounding the mini-implant. Presence of radiolucent lesions or good bony architecture around the mini-implant was recorded. Sometimes bone traberculae may appear as accentuated radiolucent lesions around the tip of the mini-implant, careful examination is required to identify and delineate these structures. The CBCT images were examined by a single examiner with more than 15 years of clinical and academic experience. The presence or absence of these radiolucent lesions in each patient was evaluated and the data was tabulated and subjected to statistical evaluation. Ten CBCT images were reassessed to check for intra-operator error.

STATISTICAL ANALYSIS

Descriptive statistics with frequency distribution and percentage was performed with SPSS software version 22 to determine the presence of radiolucent lesions, the mean age of the patients and the mean duration of treatment. Intra-operator error was determined with intraclass correlation co-efficient.

RESULTS

Fifty patients with mini-implants were selected. Of these only eleven patients had cone beam computed tomography taken at the time of mini-implant placement and towards the end of treatment.

The mean age of the patients was 21.80±3.05 years. The mean duration of treatment was 7.60±1.65 months. Twenty two mini-implants were evaluated. All mini-implants were present between the second premolar and first permanent molar of the maxillary arch (Table 1). The intraclass correlation coefficient was 0.89, indicating good intra-operator reliability.

CBCT taken at T1 showed a small radiolucency at the tip of 7 mini-implants (31.82%) (Figure 1). Similarly, 7 mini-implants (31.82%) showed a small radiolucency at T2. At T1 three mini-implants (13.64%) showed a linear radiolucency along the length of the mini-implant and three mini-implants (13.64%) had a linear radiolucency along the length if the mini-implant in T2 (Figure 2). One mini-implant (4.55%) showed sinus invasion which appeared as a radiolucent lesion at the tip of the mini-implant at T2. Although the percentage of distribution was similar at T1 and T2, the radiolucent lesion was present in the same individual when compared between T1 and T2. Overall, 10 mini-implants (45.45%) showed radiolucency at T1 and 11 mini-implants (50%) showed radiolucency at T2. At T1, 12 mini-implants (54.55%) showed normal bony trabeculae and at T2, 11 mini-implants (50%) had normal bone architecture (Table 2).

Figure 1. Shows a periapical radiolucency at the tip of the mini-implant.

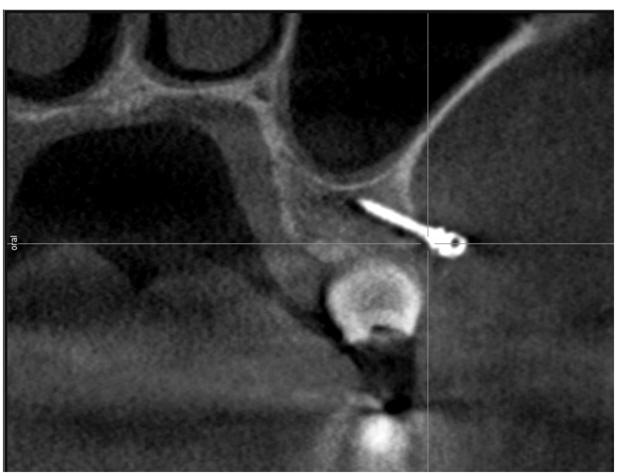

Figure 2. Shows a linear radiolucency extending from the tip to the head of the mini-implant.

Table 2. Showing the frequency and percentage of radiolucent lesions around mini-implants placed between the maxillary second premolar and first permanent molar examined using CBCT immediately after placement (T1) and towards the end of treatment (T2).

	T1		T2	
	Frequency n=22	Percentage	Frequency n=22	Percentage
Small radiolucency	7	31.82%	7	31.82%
Sinus invasion	0	0	1	4.55%
Linear radiolucency extending along the entire length of the mini-implant	3	13.64%	3	13.64%
Normal trabecular pattern	12	54.55%	11	50%

Of the twenty two mini-implants that were examined two mini-implant had periapical lesion immediately after mini-implant placement (T1) which exaggerated and increased in size with treatment (T2). However, failure of the mini-implant was not encountered. Two mini-implants had a tiny periapical lesion immediately after insertion of the mini-implant (T1) which was not present at the end of treatment (T2). Three mini-implants had radiolucent lesions around the tip of the mini-implant at T1 but showed a linear radiolucency along the length of the mini-implant at T2. Linear radiolucency along the entire length of the mini-implant was noted in three mini-implants at T1 but changed to a small radiolucency at the tip of the mini-implant at T2. Two mini-implants did not have radiolucency at T1 but had a small radiolucency at the tip of the mini-implant at T2 (Table 3).

Table 3. Showing comparison of radiolucent lesions present in relation to each mini-implant at T1 and T2.

	Frequency	Percentage
Small radiolucency at the tip of the mini-implant at T1 and T2	2/22	9.09%
Small radiolucency at the tip of the mini-implant at T1 and absent T2	2/22	9.09%
Small radiolucency at the tip of the mini-implant at T1 and linear radiolu-cency along the length of the mini-implant at T2	3/22	13.64%
Linear radiolucency along the length of the mini-implant at T1 and small Radiolucency at the tip of the mini-implant at T2	3/22	13.64%
No radiolucency at the tip of mini-implant at T1 and small radiolucency at T2	2/22	9.09%

No harm was encountered during the conduct of the study as it involved retrospective evaluation of cone beam computed tomography of the treated patients.

DISCUSSION

The current study was conducted to determine the presence of radiolucent lesions associated with mini-implants during routine examination of cone beam computed tomography at the end of orthodontic treatment. Not all radiolucent lesions are pathological and careful diagnosis is required to confirm the presence of these lesions. In the current study although 10 samples at T1 and 11 samples at T2 had some form of radiolucency associated with the mini-implants not all of them could be considered to be due to dis-integration of the alveolar bone around the mini-implant. The linear radiolucency associated with the mini-implant which accounted for 13.64% may be abeam hardening artifacts associated with CBCT imaging process or peri-implantitis due to inflammation around the mini-implant. However, such linear radiolucency must be correlated clinically to check for mobility of the mini-implant due to peri-implantitis. Sometimes invasion of the maxillary sinus in between the roots of teeth appear as a well-defined radiolucency that may be mistaken for a periapical lesion which accounted for 4.55% of the current sample. Normal trabecular bone around the tip of the mini-implant may be well circumscribed and may be mistaken for periapical radiolucency. Periapical lesions per se did occur in 31.81% of the samples and the causes of these have been discussed.

Periapical lesion associated with mini-implants is not reported in literature. Lesions associated with dental implants have been reported and are caused due to various factors such as endodontic pathology of the tooth adjacent to the implant (18-20). Periapical lesions may also occur due to contamination of the implant surface (19,21,22) or overheating of the bone during the placement procedure or predrilling with a diameter greater that necessary for the dental implant (21,23). Peripical lesions can also occur due to the presence of pre-existing bone disease or presence of root fragments or foreign bodies (18,23).

The periapical radiolucency around the tip of the mini-implant can be provisionally diagnosed as apical implantitis around the tip of the mini-implant. The radiolucency should be evaluated through multiple slices to check if the tip of the mini-implant was extending into maxillary sinus which occurred in one patient. A thin linear radiolucent line extending along the length of the mini-implant in the coronal section or axial section may be a beam hardening artifact due to the metallic nature of the mini-implants and associated with the process of taking the CBCT scan or may be due to peri-implantitis around the mini-implant.

In the current study, all the mini-implants were firmly adhered to the bone. Hence, the linear radiolucency that was observed in the present study was probably a beam hardening artifact.

Since stainless steel mini-implants were used osteo-integration of the mini-implants cannot to be expected as would occur with titanium mini-implants (24).

Comparison of the bony architecture around the mini-implant between T1 and T2, showed periapical lesion in two mini-implanta immediately after placement (T1) which exaggerated and increased in size with treatment (T2). This was probably due to the soft tissue debris that was accumulated during manual insertion of the mini-implant which failed to resolve during the course of treatment. However, failure of the mini-implant was not encountered. Two mini-implants had a tiny periapical lesion immediately after insertion of the mini-implant (T1) which resolved at the end of treatment (T2) possibly due to bone matrix formation during the course of treatment. Three mini-implants had radiolucent lesions around the tip of the mini-implant at T1 but a linear radiolucency along the length of the mini-implant. This could either be artifacts due to metallic nature of the mini-implant or could be peri-implantitis due to progressive periodontal breakdown. Clinical correlation such as erythema around the mini-implant, mobility of the mini-implant and pain may be associated with periodontal breakdown although significant mobility resulting in failure of the mini-implant was not encountered. Linear radiolucency along the entire length of the mini-implant was noted in three mini-implants at T1 but reduced to a small radiolucency at the tip of the mini-implant at T2 and was probably an artifact due to the stainless steel mini-implant noted at T1 with the small radiolucency present at the end of treatment probably being an artifact or lytic change at the tip of the mini-implant. Two mini-implants did not have radiolucency at T1 but had a small radiolucency at T2. This was probably due to lytic change at the tip of the mini-implant. Further, histopathologic studies may be considered for evaluation of these lesions. The progressive change in the radiolucency from T1 to T2 can alco be evaluated with the use of 3D (25) superimposition software. But such software are expensive and was not used in the present study.

With mini-implant placement especially in a young healthy individual with a full complement of teeth peri-implantitis due to pre-existing infections of bone or presence of root remnants is very unlikely. Apical implantitis at the tip of the mini-implant is more likely to occur due to trauma to the bone during the insertion procedure. Sometimes, bone in the inter-radicular region of the mini-implant is very dense and placement of the mini-implant may be associated with undue forces during placement, resulting in a traumatic procedure with damage to the surrounding bone. Also, there is a possibility of gingival tissue and bone debris being put forward ahead of the tip of the mini-implant resulting in peri-implantitis or apical implantitis. Bleeding of the gingival tissue during mini-implant placement can cause contamination of the mini-implant with blood breakdown products or saliva which can also contribute to peri-implantitis. Histological examination of the soft tissue and cells attached to the mini-implant upon removal may throw light on the type of reparative tissue at the tip of the mini-implant being inflammatory or non-inflammatory and contribute to these periapical lesions. Lesions such as those reported in the current study are asymptomatic and intervention is less likely with periodic observation to check for increase in size or development of symptoms. When the bone-implant interface appears to be compromised radiographically but not clinically, such implants may have a favorable prognosis through a currently unknown biologic host response (26).

Beam hardening artifacts reported in the current study are usually dark bands caused due to attenuation or removal of x ray beam due to interaction with metal objects resulting in a disturbance in the reconstruction process. These artifacts may project over and mask underlying structures, or they may provide false information regarding the density and morphology of those areas within the subject (14).

They are two types of beam hardening artifacts namely cupping and streaks. Cupping occur due to distortions around metallic structures as a result of differential absorption when x-rays passing through the center of a large object have to penetrate a greater amount of material compared to the edge of the object Streaks and dark bands are seen between two dense objects. They are seen more prominently seen in the axial planes and 3D reconstruction images (13).

Presence of metal components such as mini-implants may highly influence image quality (27). The anatomical location of the mini-implant may influence the prevalence of artifacts (28).

These artifacts can be minimized with proper protocol selection (29). Metal artifacts in CBCT can be reduced with correction methods such as the projection images interpolation correction method, prior image correction method, iterative reconstruction method, dual-energy/energy spectrum computed tomography correction method and correction method based on deep learning (30).

Although there are several studies evaluating the abnormalities of the maxillary sinus, (31,32) mis-interpretation of maxillary sinus invasion around the tip of the mini-implant as a periapical lesion have not be described. Infrazygomatic mini-implants have a high tendency to penetrate the maxillary sinus (33).

There are several precautions to be taken during placement of mini-implant to prevent the development of periapical lesions. Contributing factors to the development of periapical lesion may occur due to contamination with saliva, epithelial cells or lubricant oil from the rotary material. It can also occur due to overheating of the bone, inadequate irrigation or an undue time taken to place the mini-implant when predrilling is involved. Use of motor driven mini-implants may be better than manual placement (34).

Antibiotics can be used to resolve periapical lesions when symtomatic. Amoxicillin, amoxicillin/clavulanate, metronidazole and clindamycin have been suggested for dental implants (35,36). These drugs are to be used for at least one week. Amoxycillin may be combined with metronidazole may be effective against anaerobic infection. Care should be taken during the placement of mini-implants in patients with systemic diseases (37).

In dental implants periapical lesions are identified during radiologic examination between 7 and 16 days after surgery but may develop 3 months after implant placement (38).

It is difficult to detect a radiolucent area on a periapical x-ray or panoramic radiograph when the osseous cortical plate is intact. CBCT is more appropriate in these situations (38). Periapical lesions around mini-implants may not be visible on routine radiographic examination especially when they are very small and therefore there incidence is more when examined with cone beam computed tomography. Bone density to ascertain the presence of periapical lesions between pretreatment and post-treatment can be also be evaluated using Hounsfield units (39) or 3D CBCT (40).

Although there are several procedures that are suggested for the treatment of periapical lesion to avoid failure of the dental implants placed for replacement of missing teeth, these may not be required for mini-implants as the applied forces on the mini-implant are unidirectional and not multidirectional as with prosthetic implants under masticatory load. Hence, the mini-implants may not fail or failure of the mini-implant may be delayed. Since the mini-implants are temporary anchorage devices and are present in the oral cavity for only a short period of time, periodic observation of these lesions is sufficient when they are asymptomatic.

Periapical lesions associated with dental implants may be divided into inactive when not infected and active when infected. The inactive form is asymptomatic and it is diagnosed because of the presence of radiolucency around the apex of the implant and may be an apical scar caused by vertical over-preparation of the implant bed or bone necrosis due to overheating during implant insertion. Inactive lesions do not require treatment unless the radiolucency grows in size (41). The same may be considered for mini-implants.

Radiation exposure associated with CBCT can be minimized by reducing the field of view. A small field of view improves image resolution (42) and reduces scatter and has performance similar to a CBCT scan with a large FOV (42). The he use of shielding devices such as thyroid collar and eyeglasses reduce radiation exposure (43,44).

CONCLUSION

Asymtomatic periapical lesions may be frequently noticed around the tip of the stainless steel mini-implants and may be a common occurrence. 54.55% and 50% of all the mini-implants evaluated showed radiolucent lesions around it at T1 and T2, respectively.

LIMITATIONS: The sample size is small and hence further studies with a greater sample size may be required.

GENERALIZABILITY: These studies were conducted in a single centre in a small group of patients. A detailed investigation may produce more conclusive results.

AUTHOR CONTRIBUTION STATEMENT: Conceptualization and design: A.S.F.; Literature review A.S.F.; Methodology and validation: A.S.F.; Formal analysis: A.S.F.; Investigation and data collection: A.S.F.; Resources: A.S.F.; Data analysis and interpretation: A.S.F.; Writing-original draft preparation: A.S.F.; Review & editing: A.S.F. and T.N.U.M.

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