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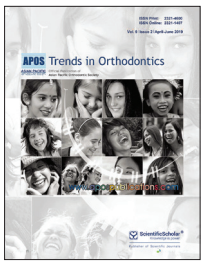

Original Article

Evaluation of root repair using an environmental scanning electron microscope after intentional contact with microscrew

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Received: 09 December 2022
Accepted: 09 January 2023
EPub Ahead of Print: 17 February 2023
Published: 14 April 2023

DOI
10.25259/APOS_223_2022

Quick Response Code:

ABSTRACT

Objective: The purpose of this study was to evaluate the amount of root repair that took place at varying intervals of 1 day, 2 weeks, 4 weeks and 8 weeks after intentional contact with microscrews. The results were evaluated by an environmental scanning electron microscope study (E-SEM).

Material and Methods: Ten orthodontic patients with 2 maxillary and 2 mandibular first premolars (40 premolars) to be extracted as part of the orthodontic treatment were included in this study (age 18–25 years). The position of the roots of the 4 premolars to be extracted was clinically determined and under local anesthesia, microscrew implants were placed in such a way that they directly hit the root from the buccal aspect. Implants were removed immediately after the above-mentioned procedure was performed. On the same day, premolar of the 1st quadrant (Group I) was extracted. Premolar of the 2nd quadrant (Group II) was extracted 2 weeks later. Premolar of the 3rd quadrant (Group III) was extracted 4 weeks later and premolar of the 4th quadrant (Group IV) was extracted 8 weeks later, from the day of intentional damage.

Results: Significant changes were observed in the deposition of cementum over 8 weeks which were analyzed using ESEM under magnifications of × 50, × 200, × 500, and × 5000.

Conclusion: The damaged root surfaces due to intentional contact with microscrews showed swift repair and healing within 8 weeks. In case, the root is damaged due to improper placement technique or wrong biomechanics which may result in the implant touching the root surface, a minimum healing period of 8–10 weeks is advocated before commencing further tooth movement.

Keywords: Microscrews, Absolute anchorage, E-SEM, Cemental repair, Root repair

INTRODUCTION

Anchorage is defined as resistance to unwanted tooth movement. It is a necessity for the orthodontic treatment of dental and skeletal malocclusions. Controlling anchorage helps to avoid undesirable tooth movements. However, even a slight reactive force might result in a loss of anchorage.

In clinical orthodontics, the use of screw-like titanium attachments, such as microscrews, micro-implants, mini-implants, and temporary anchorage devices, has shown to be advantageous when utilized as anchorage reinforcement or as the only source of anchorage in addition to fixed appliances.[1]

Microscrews should be placed into the alveolar bone without jeopardizing the adjacent roots.[2] It was suggested, that microscrews should be placed in the apical region as the available space increases in an apical direction, and the interradicular distances increase from the cementoenamel junction to the apical foramen.[3]

The problem with this, though, maybe that unattached gingiva might make it difficult to maintain good oral hygiene, which can result in periodontal and soft-tissue issues. Therefore, it is preferable to place the microscrew in the attached gingiva or at the junction where the attached and unattached gingiva intersect.[2,3]

Microscrews may not always remain perfectly stationary during orthodontic loading and can tip forward in some patients. In other cases, the space between roots for microscrew placement is constrained, forcing clinicians to place the screws near the roots.[4]

To avoid damaging dental roots, it was advocated to provide a 2-mm safety space between microscrews and tooth-bearing areas.[4]

In spite of all the precautions taken by the clinician, the clinician may end up with a wrong placement of the implant, which might brush against the root surface thus damaging it.

Numerous studies have demonstrated time-dependent cementum healing following deliberate root injury treated with temporary skeletal anchorage devices. In a prospective study done on 55 patients, Fabbroni *et al*.[5] found that 11.2% had significant contacts with neighboring teeth (i.e., more than 50% of the screw hole impinged on the root), and 15.9% had minor contacts (i.e., <50% of the screw hole impinged on the root). It is well documented that implant-tooth contact does happen with interradicular implants.

According to Alves *et al*.,[6] as long as root damage is contained to the cementum or the dentin, healing and nearly full restoration of the periodontal structure can take place under favorable circumstances (no inflammatory infiltrate or pulpal invasion).

Most of the studies on root repair were conducted using Scanning electron microscopy (SEM), Histomorphometery, Light microscopy, and Transmission electron microscopy (STEM). There are limited studies of root repair using ESEM. Biological specimens often require sufficient stabilization for ultrathin sectioning. They are often required to be chemically fixed, dried, and embedded in a polymer resin. The ESEM's ability to generate three-dimensional data from biological material surfaces in their "natural" condition (without the need to stain and fix) and to change environmental variables, has opened up new areas of use for material sciences with a focus on medicine.[7]

Thus, the purpose of this study was to evaluate the amount of root repair taking place at varying intervals of 1 day, 2 weeks, 4 weeks, and 8 weeks after damage due to contact with microscrews. The results were evaluated by an environmental scanning electron microscope study (E-SEM).

MATERIAL AND METHODS

Ten orthodontic patients were included in the study, from the Department of Orthodontics, Dr. D.Y. Patil Dental College and Hospital, Pimpri, Pune. The study design was approved by the Ethical committee at the University (Ref No.DYPDCH/2009/466).

Inclusion criteria

The following criteria were included in the study:

1. The need for fixed appliance therapy involving maxillary and mandibular 1st premolar extraction as part of their treatment
2. No medical history
3. Patients with permanent teeth erupted
4. Adult patients in the age range of 18–25 years with bimaxillary protrusion with minimal crowing.

Exclusion criteria

The following criteria were excluded from the study:

1. Patients having systemic diseases such as diabetes and bleeding disorders.
2. Periodontally compromised teeth
3. Medically compromised patient
4. Premolars with root canal therapy done
5. Patients with crowding in the premolar region might create difficulty while intentionally damaging the root.

Materials

1. Ten patients with 2 maxillary and 2 mandibular first premolars to be extracted as part of the orthodontic treatment from the Dept. of Orthodontics, Dr. D.Y. Patil Dental College and Hospital, Pimpri, Pune, were selected
2. Patients were prebonded with Preadjusted Edgewise Appliance systems
3. 40 Temporary anchorage device microscrew implants (Dental Instrument Co "DENTICON." Mumbai, Maharashtra) of dimensions 1.2 × 0.8 mm were used
4. Topical spray (Nummit Lidocaine Topical Aerosol USP, Mumbai, Maharashtra)
5. Local anesthetic infiltration (T. Walker's Lignocaine and adrenaline inj I.P., Pune, Maharashtra)
6. Implant driver

7. Periodontal Probe for standardization [Figure 1]
8. E-SEM (Environmental Scanning Electron Microscope study) - Icon Analytics Quanta 200.

Method

The patients were informed about the procedure prior, and their informed consent was taken. The patients were made to sit on a dental chair. All proper sterilization and disinfection protocol were followed. The position of the roots of the 4 premolars to be extracted was clinically determined for each of patient. The patients were then administered topical anesthetic spray before injection of the local anesthesia. Then local anesthesia (infiltration) was administered to the patients concerning all the premolars which were to be extracted.

Microscrew implants were placed in such a way that they were in direct contact with the buccal root surfaces of the first premolars (directly hit the root from the buccal aspect) of the maxillary and mandibular arches to be extracted for the orthodontic treatment purpose. To determine the position of placement of implants a periodontal probe was used and the same distance of that probe was maintained from the brackets for which the brackets were bonded on the premolars to be extracted, in each of the patients [Figure 2].

The initial leveling and alignment were done of the 0.012" archwire. The archwire was kept in a passive state for 8 weeks till the last premolar (Group IV) was extracted. No active retractive force was applied for 8 weeks.For determining whether the implants were in contact with the roots, resistance and tactile perception were the criteria [Figure 3]. After determining that the implant was in contact with the root surface, each implant was given 6 turns with approximately the same pressure for each patient. The implants were inserted by the same operator to avoid bias. This procedure was followed for each premolar of each patient. The implants were removed immediately after the above-mentioned procedure was performed. A descriptive analysis was done on the images obtained at different magnifications.The same day premolar of the 1st quadrant (upper right) was extracted. This was the baseline from where the repair of the root was evaluated. Premolar of the 2nd quadrant (upper left) was extracted 2 weeks later than the first one. Premolar of the 3rd quadrant (lower left) was extracted 4 weeks later than the first one and premolar of the 4th quadrant (lower right) was extracted 8 weeks later than the first one for each patient. Even though we are aware that the lower premolars would not show any difference in healing than the upper premolars, the lower premolars were used as to eliminate the healing bias of an individual. In addition, we used an ESEM image of a healthy extracted premolar from the archive to help us understand the amount of damage and repair.

Figure 1: Armamentarium used for the study.

Figure 2: Placement of the Probe.

Figure 3: Implant directly hitting the root surface.

All the patients were prescribed a course of a common analgesic for a duration of 3 days from the day of implant root damage. The samples were preserved in normal saline till the time they were carried to the center for environmental scanning electron microscope study. The root surfaces of all the premolars were studied under an environmental scanning electron microscope to determine the amount of repair

taking place in the damaged root surface area [Figure 4]. The evaluators performing ESEM analyses were blinded.

RESULTS

The following results were noted.

Group 1 (Same day of damage with implant)

The implant damage region was checked and at lower magnifications, it was found that the root damage had occurred in all the patients [Figure 5].

At higher magnifications, the central region of the damaged area did not show the presence of cementum on the surface. The surfaces in this region appeared smooth. The regions showed the appearance of threadmarks on the implants confirming that the root damage had occurred [Figure 6a].

Figure 4: Environmental Scanning Electron Microscope, Icon Analyticals Quanta 200.

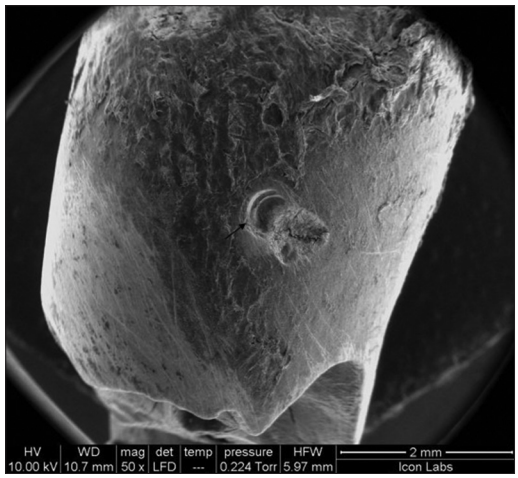

Figure 5: (×50) Showing damaged root surface with microscrew threadmarks.

At higher magnifications, the E-SEM image showed an absence of continuity of cementum in the damaged region. Some continuous strands were left which is seen as the elevated region in the image [Figure 6b]. The absence of cementoblasts was a concurrent finding throughout the Group I images [Figure 6b].

Group II (2 weeks after damage due to implant)

At lower magnifications, cementum formation was observed at the marginal regions of the damaged area. This observation was noted in all the Group II teeth [Figure 7a].

At higher magnifications of those particular marginal regions, we could see the appearance of minor amounts of cementum formation beginning. The number of cementoblasts which was observed was minimal [Figure 7b]. Some resorption lacunae were evident.

Group III (4 weeks after damage due to implant)

At lower magnifications, the damage was still visible but the amount of cementum deposition which started at the marginal regions of the damage had increased and nearly extended into the center of the damaged region [Figure 8a].

At higher magnifications, strands of new cementum which was laid down were seen. The number of cementoblasts that

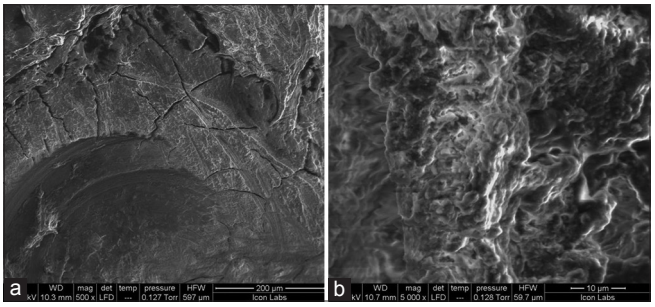

Figure 6: (a) (×500) Microscrew threadmarks at higher magnification. (b) (×5000) Continuous strands of cementum seen as elevated region.

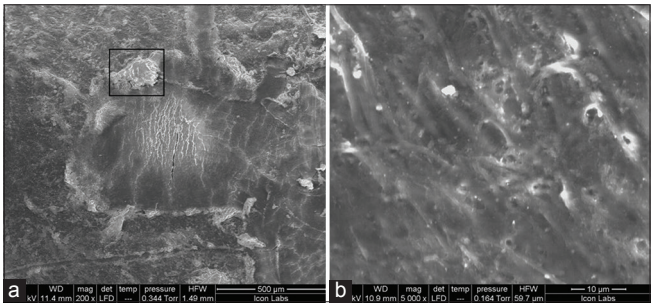

Figure 7: (a) (×200) At the lower magnification, cementum formation seen at margins of the defect (box). (b) (×5000) Few cementoblast at the margin of the defect.

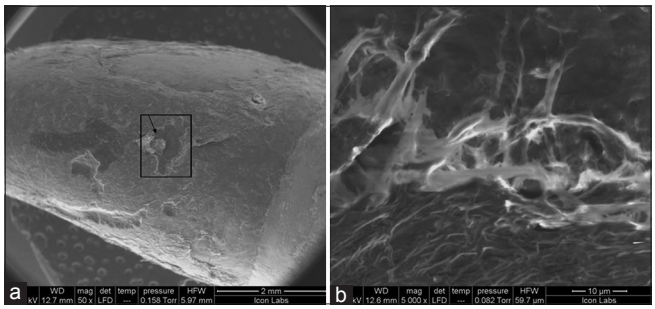

Figure 8: (a) (×50) Damaged area (box) and cementum extending to the center of the damaged region (arrow). (b) (×5000) At higher magnification, strands of new cementum are seen with increasing number of cementoblast.

were seen was more as compared to the previous group. The resorption lacunae had reduced in number [Figure 8b].

Group IV (8 weeks after damage due to implant)

At lower magnifications, the damaged region could not be differentiated properly.

At higher magnifications near about complete cementum deposition was seen. The cementoblasts were vastly more in number than the previous three groups. Resorption lacunae were not observed [Figure 9a]. Although there were some regions where cementum deposition had still not taken in this group, as compared to the amount of magnification into consideration, those areas were minuscule [Figure 9b].

Toward the end of 8 weeks, some amount of collagen fiber reorganization took place which were immature and were observed at the bottom of the resorption crater at higher magnifications [Figure 9c]. The findings are similar to the observations made by Kadioglu *et al.*[16] in their SEM study.

DISCUSSION

In day-to-day orthodontics, anchorage is one of the most important considerations, for which implant as anchorage is used in varied clinical situations. During the use of microscrew implants, the most sought-after area is the interradicular area which at times could be a challenge, because of space constrain, there is a chance that the root may be damaged accidentally while placing the microscrew implant or the implant might touch the root during tooth movement. Thus, it was necessary to determine whether the damaged root heals and if it heals how long does the healing process take.

The reason for conducting this study was to check the duration taken for the root repair to occur in cases in which the root may be accidentally damaged while the placement of the microscrews. The placement of microscrew implants carries many dangers, and the proximity of the microscrew

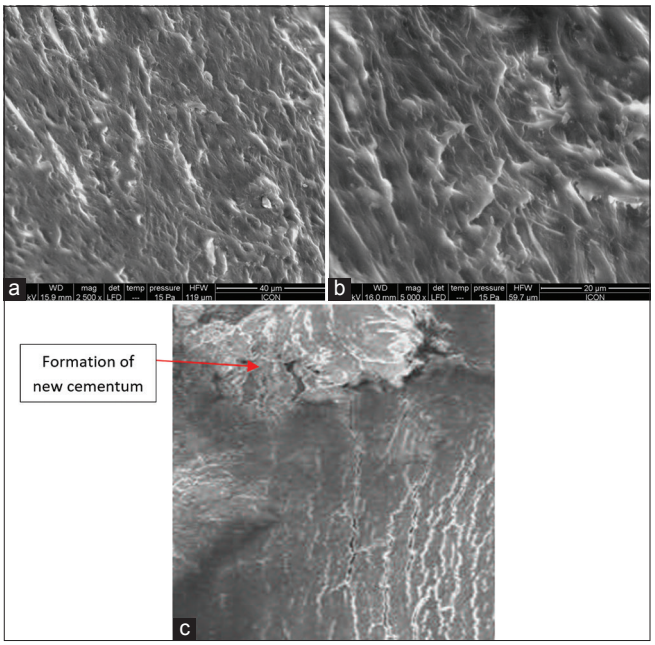

Figure 9: (a) (×2500) More complete cementum deposition (80%) seen with more number of cementoblast. (b) (×5000) At higher magnification, cementum is comparable with normal cementum but with less organization of laid down cementum. (c) (×5000) Appearance of new and immature collagen fibers.

to the root is a significant risk factor for screw anchorage failure.[8] Furthermore, the stability of the microscrew implants under orthodontic forces is questionable,[9] and being placed in the interradicular region they may end up damaging the root surface if they are unstable.

Brudvik and Rygh used light microscopy and transmission electron microscopy to research the repair of orthodontically caused inflammatory root resorption after applying 50 g of force for 21 days. In the periphery of the resorption lacunae, new tooth-supporting structures were shown to emerge, but the center regions of the lacunae experienced active resorption by multinucleated odontoclast-like cells. The reparative process after the removal of orthodontic force resembled the early stages of cementogenesis during tooth growth.[10,11]

Cementum plays a significant role in the development and regeneration of periodontal tissues. Cementoblasts are necessary for cementum regeneration. It is unclear where cementoblasts come from or what molecular mechanisms control how they are recruited and differentiated. However, it has been hypothesized that cells from an existing layer of cementum or periodontal ligament migrate to generate new cementum, and this is thought to produce dimensional changes in the apico-coronal direction.[12] Cheng *et al.* compared new cementum taking place after heavy orthodontic force application given for 4 weeks and light orthodontic force for the same period; the reparative

processes seem to depend on time, with a longer retention time yielding the most amount of repair.[13]

Thus, this study may clarify the number of weeks it takes for the injured cementum to repair and the number of weeks for which the tooth should not be subjected to any pressure or movement so that the cemental repair is complete. For better understanding, we have used Environmental Scanning Electronic Microscope (ESEM) in this study to obtain high-resolution surface images of the specimen. Its higher resolution compared to light microscopy and wide field of view makes it ideal for studying many sample types. The ESEM technology does not require high vacuum conditions or time-consuming preparation steps such as chemical fixation, drying with organic solvents, or critical point drying with CO_2. When surrounded by a 100% vapor atmosphere, biological structures can bind and sustain structural links or associated water at their surfaces even at low working pressures in the specimen room.[7]

The results of the Ist group (tooth extracted same day of damage) signify that the root surfaces at the lower magnifications show the damaged root surface. At higher magnifications the cemental structure in Group I was compared to the SEM evaluation of normal cementum in a study done by Bilgin *et al*.[14] Also for comparison purposes, this study had taken the E-SEM image of the cementum in the undamaged region of the root so that the study may compare the images in all the groups with these images of normal cementum to evaluate them [Figure 10]. Comparing the images in Group I with those of normal cementum we can see a break in the continuity of the cemental layer [Figure 6b] occurred due to the damage by the microscrew. E-SEM images showed some continuous strands of cementum left, which were seen as elevated regions in the images, and the damaged cementum was seen in the background [Figure 6b]. These images were taken from the peripheral area of the damaged region, so the image is bound to show some normal cemental structure left as well as the damaged cementum. The images of the Ist group did not show any presence of resorption lacunae nor did they show any evidence of cementoblasts.At lower magnifications, the damaged regions showed the beginning of cementum formation at the marginal regions of the area [Figure 7a]. Based on the histological study carried out by Maino *et al*.[15] to determine the type of cementum which gets deposited after a microscrew or a drill injury to the root it was concluded that cellular cementum gets deposited in these regions. Furthermore, if there is any injury to the root structures, there is an appearance of resorption lacunae in the damaged region before the beginning of the laying down of the reparative cementum takes place. The E-SEM results of this study could be correlated to the histological findings of the study by Maino *et al*.[15] wherein the appearance of resorption lacunae in the cemental region was confirmed in the E-SEM images in this study [Figure 11].

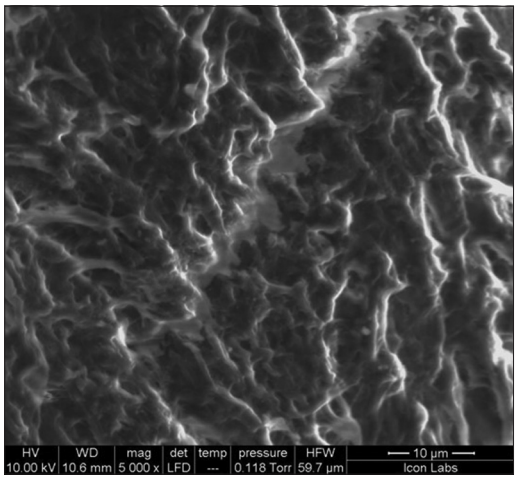

Figure 10: (×5000) Normal cementum.

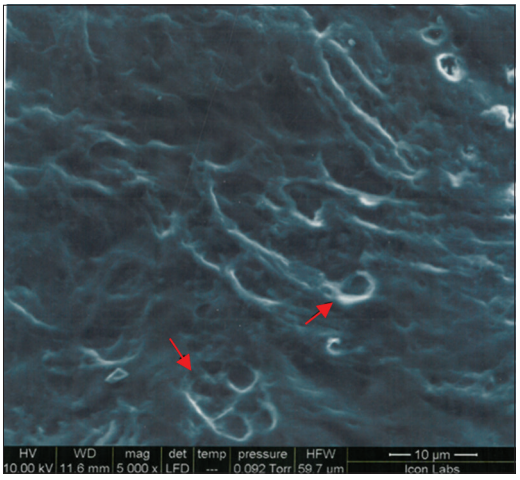

Figure 11: (×5000) Resorption lacunae seen (arrows).

Furthermore, the appearance of the cementoblasts[16] was evident, but the number of cementoblast seen were far lesser than the ones observed in the 4 weeks and 8 weeks images. This may be due to earlier extraction of the teeth studied in this group. It signifies that the number of cementoblast goes on increasing as the damaged root is kept for a longer duration in the oral cavity without orthodontic force thus giving it more time to heal. The beginning of the laying down of strands of immature cementum could be observed.[17]

At lower magnifications (× 50) the amount of cementum deposition from the marginal regions was found to proceed toward the center of the damaged structure. Hence, it can be safely stated based on the results of this study that the repair process of the cementum begins at the peripheral regions of the damaged area and proceed toward the center to fill the defect [Figure 8a].

At higher magnifications (× 5000) the areas of cemental repair showed a decrease in the amount of resorption

lacunae that were present in the previous group and also showed a greater number of cementoblasts. Although the amount of cementum that was deposited had increased,[16] the organization of this cementum when compared with the images of normal cementum showed that the cementum which was laid down was not well organized. This may lead us to state that around 4 weeks of healing the reparative cementum which is being laid down has still to undergo structural organization. The cementum which was being laid down in this group thus seemed immature [Figure 8b].

In the IVth group, the teeth were extracted 8 weeks after they were injured due to the microscrew. The images at lower magnifications [Figure 9a] showed a better organization of the cementum than the previous group and it was comparable to that of the normal cementum. The defect could not be made out at lesser magnifications. The amount of cementoblasts that were present in these images was significantly greater than in the previous group. Furthermore, the absence of resorption lacunae was a fact to be noted. This signified that the deposition of cementum was near its completion in the defect area.

At higher magnification [Figure 9b] the cementum deposition, which was seen, was similar to the one observed in a study done by Kadioglu *et al*.,[16] although some regions in the images showed that the deposition of cementum had not taken place in some areas. This may be due to the duration the tooth was allowed to heal. If the teeth were not extracted for some more weeks then maybe we could have observed a uniform cementum deposition throughout the images. But considering the fact that the magnification under which the regions were observed was much higher, the regions where the cementum was not yet seen to be deposited were very miniscule. ([In Figure 9b] cementum deposition is yet to take place in the lower right hand corner of the image.) Thus results of this E-SEM study stating that the root repair occurs at around 8 weeks are comparable with the study done by P Owman-Moll *et al*.,[18] Langford and Sims[19] and Ghanbarzadeh *et al*.[20] which stated that the repair process of cementum started as early as 7–10 days and 75% of the repair might be completed within 8 weeks. Furthermore, the study was done by Kadioglu *et al*.[16] shows similar results as this study. However, in the study done on a small sample by Cornelis *et al*.[21] states that 7 weeks are too short for cementum healing to take place and a limited amount of healing takes about 29 weeks provided the microscrews are not loaded after the intentional damage. In another study, Guler *et al*.[22] concluded that force loading from springs on injured roots produced by TAD contact during orthodontic treatment may worsen damage and decrease healing. Our study corroborates with the findings of the study done by Yerawadekar *et al*.[23] which states thats significant root repair is seen between 3 weeks and 12 weeks after intentional damage.

We would like to point out a few limitations of the study. First, a torque measuring device would have been more appropriate to ascertain the equal amount of torque and pressure application to all the inserted microscrews. Second, the effect of intentional root damage should have been evaluated on the pulp tissue as well. Hence, pulp testing should also be performed in such cases.

CONCLUSION

The damaged root surfaces due to intentional contact with microscrews showed swift repair and healing within 8 weeks. Although the root repair was not 100% complete at the end of 8 weeks (Group IV), it can be said that complete healing will occur over 12 weeks without subjecting the damaged tooth to orthodontic forces.

1. The repair process was noted to start from the marginal region of the damaged regions (Group II) and proceeded to the central area of the damage (Group III)
2. The number of cementoblasts went on increasing and the number of resorption lacunae went on decreasing as the healing progressed. (Changes evident from Group II to group IV)
3. In case the root is damaged due to improper placement technique or wrong biomechanics which may result in the implant touching the root surface, a minimum healing period of 8–12 weeks is advocated before applying retractive force.

Declaration of patient consent

The authors certify that they have obtained all appropriate patient consent.

Financial support and sponsorship

Nil.

Conflicts of interest

There are no conflicts of interest.

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How to cite this article: Patil GS, Deshmukh SV, Das A. Evaluation of root repair using an environmental scanning electron microscope after intentional contact with microscrew. APOS Trends Orthod 2023;13:74-81.