Clinical Application of Micro-Implant Anchorage in Initial Orthodontic Retraction

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Micro-implant is a device that is temporarily fixed to bone for the purpose of enhancing orthodontic anchorage either by supporting the teeth of the reactive unit or by obviating the need for the reactive unit altogether, and which is subsequently removed after use. The purpose of this study was to evaluate the clinical efficiency of micro-implants in reinforcing anchorage during the initial retraction of anterior teeth, check the rate of initial retraction for 8 weeks, and assess the stability of micro-implants during this period. Eighteen micro-implants were placed (10 in the maxilla and 8 in the mandible) and immediately loaded with 200–250 g of force using 9-mm closed coil Nitinol springs. The amount of space closure was measured every 2 weeks until the eighth week. Cephalometric measurements were made at the end of the study to evaluate anchor loss, if any. Micro-implant stability was also assessed. The rate of initial retraction in the maxilla at the end of 8 weeks was 1.65 mm/quadrant and 1.51 mm/quadrant in the mandible. The amount of retraction on the left side of the arches was 1.66 mm/quadrant and 1.49 mm/quadrant on the right side. The average initial retraction for both arches per month was 0.78 mm. An anchor loss of 0.1 mm (0.06%) was observed in the maxilla while no mandibular anchor loss was recorded. The rate of initial retraction observed in the maxilla was more than that achieved in the mandible. Initial retraction was also more on the left side of the arches. There was no anchor loss in the mandible. The micro-implant-reinforced anchorage was helpful in minimizing anchor loss and accepted heavy traction forces but did not bring about a faster rate of retraction.

Key Words: anchorage; temporary anchorage devices; micro-implants; immediate loading; bimaxillary protrusion; initial retraction.

INTRODUCTION AND LITERATURE REVIEW

In the search for the ideal anchorage system, orthodontists turned to other solutions for reinforcing anchorage such as extra oral devices like the headgear, intraoral devices such as transpalatal, lingual arches, and the inclusion of second molars during treatment. Although extraoral appliances such as headgear provides stable anchorage, they depend largely on factors such as patient cooperation, age, and gender and have been reported to cause inadvertent injuries. Intraoral appliances, however, do not require extensive cooperation from the patient, but the anchorage derived is unstable, necessitating appliances that can be complicated, inefficient, and often require the extraction of dental units.

Therefore, the problems associated with anchorage were far from solved. The past 2 decades, however, has seen orthodontic therapy benefit greatly from recent advances in other areas of dentistry, and this is particularly true in the treatment of adult patients. One such advancement was the development of osseointegrated titanium endosseous implants, which are used in prosthetic rehabilitation.

It is interesting to note here that, even before Branemark, accidentally discovered the concept of osseointegration in 1960s and introduced the popular Branemark titanium implant system widely used today in prosthetic dentistry, two orthodontists—Gainsforth and Higley—reported in 1945 on the use of implant-supported anchorage with vitallium screws and stainless steel wires in dogs. However, the initiation of forces resulted in the loss of the screws in 16–31 days. Later in 1970, Linkow in his classic article described the use of endosseous blade implants, which were used as a replacement for a missing molar to which rubber bands were placed to retract maxillary anterior teeth, but this was only a case report and did not analyze the long-term stability of the implants. After Linkow, the use of implants for orthodontic anchorage was unheard of for some time until, in 1983, Creekmore and Eklund inserted a vitallium screw just below the anterior nasal spine of a 25-year-old female patient to intrude the anterior teeth with the help of light elastic thread tied from the head of the screw to the archwire.

In 1984, Roberts et al demonstrated the use of osseointegrated titanium implants in rabbit femurs. The results indicated that titanium implants provided firm osseous anchorage for not just orthodontics but also dentofacial orthopaedics as well. This was also proved by Smalley et al in 1988, who inserted Branemark titanium implants into the maxilla, zygoma, orbital, and occipital bones of monkeys and observed a 12-mm widening of the zygomaticomaxillary suture and 16-mm widening at zygomaticotemporal suture during skeletal protraction. They concluded that titanium implants placed in the facial bones provide stable anchorage for...
protraction of the maxillofacial complex without significant changes in the dentoalveolar complex.

Thus, a new class of specific fixtures or devices used as extradental intraoral anchorage systems—known as the skeletal anchorage system (SAS)—was developed. SAS has evolved from two lines: One category originated as traditional osseointegrated dental implants used as anchorage for orthodontic tooth movement and later serve as permanent abutments for tooth replacement. The other category consisted of surgical screws and the more recently developed onplants, mini-implants, miniplates, micro-implants and miniscrews that are referred to as temporary anchorage devices (TAD). These are devices temporarily fixed to bone for the purpose of enhancing orthodontic anchorage either by supporting the teeth of the reactive unit or by obviating the need for the reactive unit altogether, and which are subsequently removed after use. The term temporary anchorage device refers to all variations of implants, screws, pins, and onplants that are placed specifically for the purpose of providing orthodontic anchorage and are removed upon completion of biomechanical therapy. In 1997, Kanomi claimed that the mini-implant can also be used for horizontal traction, molar intrusion, and distraction osteogenesis.

Of the recently developed temporary anchorage devices, micro-implants and miniscrews have gained preference over the traditional standard implants. This is due to (1) the micro-implants and miniscrews being smaller in diameter (1.2 mm) and available in several lengths; (2) can be inserted in any desired location, including interradicular space; (3) can be loaded immediately; (4) can withstand typical orthodontic forces of 200–300 g for the entire length of treatment; (5) do not need osseointegration, unlike restorative implants; and (6) can be easily removed by orthodontists.

Although orthodontic literature is now replete with studies on TAD, the efficacy and anchorage have not been studied in detail. The present study is an attempt to evaluate the efficacy of TAD in providing absolute anchorage during the initial retraction of 6 anterior teeth.

**Materials and Methods**

Patients between the ages of 18–24 years requiring retraction of anterior teeth were selected for the study. Criteria for selection of patients included young patients with bimaxillary protrusion, satisfactory periodontal health, good bone support and adequate attached gingiva, and good oral hygiene.

Patients with severe crowding, systemic diseases, less than satisfactory periodontal health, improper bone support, inadequate width of attached gingiva, poor oral hygiene, and nonconsenting patients were excluded from the study.

After patient selection, routine records of all the patients such as a detailed case history, pretreatment study models, extraoral and intraoral photographs, lateral cephalograms, orthopantomograms, and intraoral periapical radiographs were acquired.

The armamentarium included MBT Versatile+ bracket prescription kits (3M Unitek, Monrovia, Calif), 9 mm closed coil Nitinol springs, AbsoAnchor micro-implants of CH 1312-08 in 1.3 mm diameter and 8 mm length (Densons Inc, Daegu, Korea) (Figure 1), a bone punch instrument, microscrew implant drivers, local anesthetic solution, sterile saline, dial gauge, and a Vernier caliper for measuring the amount of initial retraction.

All patients included in the study required first premolar extractions and were treated with the MBT technique (0.022” slot). Leveling and aligning was carried out with 0.016” heat activated nickel titanium (HANT) and 0.019” × 0.025” HANT arch wires. A study by Tidy showed that Nitinol and Ti wire produce more friction than stainless steel wires. Therefore, 0.019” × 0.025” rectangular stainless steel wires with soldered or crimpable hooks in a 0.022” slot were used for anterior retraction in this study as recommended by the MBT technique. It was decided to place the micro-implants just before retraction was initiated. Prior to surgical placement, records such as study models, lateral cephalograms, and intraoral photographs were made.

Intraoral periapical (IOPA) radiographs of the upper and lower second premolar and first molar regions of both right and left sides were taken to assess adequate availability of interradicular space, root anatomy, and the amount of bone present. The area mesial or distal to the first molar is the safest location for insertion. Miniscrews of less than approximately 1.5 mm in diameter and approximately 6–8 mm in length are considered to be of acceptable size.

IOPA radiographs were repeated immediately after micro-implant insertion to verify the intended position of surgical placement and to check for any root injuries.

A total of 18 micro-implants were placed under aseptic conditions, of which 10 micro-implants were placed in the maxilla and 8 micro-implants in the mandible. The upper and lower arches were evaluated as separate quadrants, that is, 5 upper-right quadrants, 5 upper-left quadrants, 4 lower-right quadrants and 4 lower-left quadrants.

At the end of 8 weeks, lateral cephalograms were taken to evaluate anchor loss and upper and lower anterior inclinations. IOPA radiographs were also taken at this time to evaluate the stability of the micro-implants (Figures 2 and 3) to verify the position of each micro-implant.

After the implant placement, the micro-implants were immediately loaded with 9 mm closed coil Nitinol springs (Figures 4 through 7). In an investigation by Samuels, Rudge, and Mair, it was found that 150-g closed coil nickel-titanium springs were found to be more effective than 100-g springs, but no more effective than 200-g springs. They also confirmed that nickel-titanium springs produce more consistent space closure than elastomeric modules. Therefore 9-mm closed coil Nitinol springs (200 g) were the preferred mode of force delivery system in our study. Each micro-implant was loaded with a force of 200–250 g, depending on the distance it was stretched, and this was checked with a dial gauge (Figure 8).

**Collection of Data**

**Measurement of extraction space**

Before space closure mechanics were initiated, the extraction space—that is, the distance between the contact point of the canine and the second premolar—was measured using a Vernier caliper (Figure 9). The same method was used to
measure the amount of retraction at 2-week intervals until the end of the eighth week.

Measurement of anchor loss

Lateral cephalograms were taken at the beginning of retraction, just before the placement of the micro-implants, and after 8 weeks of retraction to check for any anchor loss. The following parameters were used to measure anchor loss (Figure 10): (1) upper molar to the Pterygoid vertical (linear distance between A and B), and (2) lower molar to the most posterior point on the mandibular symphyseal outline vertical (linear distance between C and D).

Assessment of implant stability

Implant stability was checked clinically with the help of IOPA radiographs, taken immediately after placement of the micro-implants and at the end of 8 weeks of retraction to check for movement or tipping of the micro-implants under the orthodontic load.

RESULTS

In this study, the amount of initial retraction was measured at 2-week intervals until the eighth week. The amount of retraction and the closure of extraction space and the average retraction per quadrant for both maxillary and mandibular arches for each 2-week interval were measured and tabulated.

Evaluation of upper and lower anchor loss, amount of anterior retraction, and comparison between space closure and anchor loss were also evaluated.

Retraction for the first and second weeks

The retraction in the maxillary arch (both right and left sides) for the first 2 weeks was 0.80 mm that is, 0.40 mm per quadrant (Table 1), while the total initial retraction in the mandibular arch (both right and left sides) was 1.38 mm, that is, 0.69 mm per quadrant (Table 1). Therefore, the average initial retraction for the first and second weeks for both maxillary and mandibular arches was 0.54 mm per quadrant.
Retraction for the third and fourth weeks

The retraction in the maxillary arch (both right and left sides) for the third and fourth weeks was 0.70 mm or 0.35 mm per quadrant (Table 1), and the total initial retraction in the mandibular arch (both right and left sides) was 0.51 mm or 0.26 mm (Table 1). Therefore, the average initial retraction for the third and fourth weeks for both maxillary and mandibular arches was 0.30 mm per quadrant.

Retraction for the fifth and sixth weeks

The total initial retraction in the maxillary arch (both right and left sides) for the fifth and sixth weeks measured 0.50 mm or 0.25 mm per quadrant (Table 1). The total retraction in the mandibular arch (both right and left sides) was 0.38 mm or 0.19 mm per quadrant (Table 1). Therefore, the average initial retraction for the fifth and sixth weeks for both maxillary and mandibular arches was 0.22 mm per quadrant.

Retraction for the seventh and eighth weeks

The total initial retraction in the maxillary arch (both right and left sides) for the seventh and eighth weeks measured 1.30 mm or 0.65 mm per quadrant (Table 1), whereas the total retraction in the mandibular arch (both right and left sides) was 0.75 mm or 0.37 mm per quadrant (Table 1). Therefore, the average initial retraction for the final 2 weeks for both maxillary and mandibular arches was 0.51 mm per quadrant.

Retraction at the end of the eighth week

The total maxillary initial retraction at the end of the eighth week (Figures 11 through 14) was 1.60 mm on the right side and 1.70 mm on the left side for all patients, which measured to

<table>
<thead>
<tr>
<th>Week</th>
<th>Maxillary</th>
<th>Mandibular</th>
<th>Maxillary + Mandibular</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right (mm)</td>
<td>Left (mm)</td>
<td>Total (mm)</td>
</tr>
<tr>
<td>Second</td>
<td>0.30</td>
<td>0.50</td>
<td>0.80</td>
</tr>
<tr>
<td>Fourth</td>
<td>0.30</td>
<td>0.40</td>
<td>0.70</td>
</tr>
<tr>
<td>Sixth</td>
<td>0.30</td>
<td>0.20</td>
<td>0.50</td>
</tr>
<tr>
<td>Eighth</td>
<td>0.70</td>
<td>0.60</td>
<td>1.30</td>
</tr>
<tr>
<td>Total</td>
<td>1.60</td>
<td>1.70</td>
<td>3.30</td>
</tr>
</tbody>
</table>
Steel wire. Storey and Smith have shown that the optimal force range for moving the canines distally extends from 150–200 g. A force above this range will cause the molars to move mesially. However, in this study, since anchorage was derived from the molars, retraction was started using 9-mm closed coil Nitinol springs (200 g) attached from the micro-implant head to soldered or crimpable hooks on the 0.019” × 0.025” stainless steel wire. Storey and Smith have shown that the optimal force range for moving the canines distally extends from 150–200 g. A force above this range will cause the molars to move mesially. However, in this study, since anchorage was derived not from the molars but reinforced with the help of the micro-implants, it was expected that the molars would not move mesially. Therefore, slightly higher forces in the range of 200–250 g were used in the present investigation to achieve maximum initial retraction.

In a study done by Samuels, Rudge, and Mair, the rate of space closure of 6 anterior teeth with sliding mechanics was 0.76 mm, 1.04 mm, and 0.96 mm per month, respectively, using 3 force delivery systems: (1) elastic modules, (2) 150-g nickel-titanium closed coil springs, and (3) 200-g nickel-titanium closed coil springs. This amounts to 0.38 mm, 0.52 mm, and 0.48 mm per 2 weeks, respectively. The amount of initial retraction achieved in the first 2 weeks in our study (0.54 mm per quadrant) is comparable to the amount of retraction achieved per 2 weeks by the 150-g nickel-titanium closed coil spring (0.52 mm). Similarly, the amount of initial retraction achieved in the third and fourth weeks in our study (0.30 mm per quadrant) is closer to the retraction of 0.38 mm per 2 weeks achieved with elastic modules in the Samuels, Rudge, and Mair study. The initial retraction for the fifth and sixth weeks in our study is 0.22 mm per quadrant. This is less when compared to the amount of retraction achieved with any of the force delivery systems mentioned in the current study. The average initial retraction for the final 2 weeks—seventh and eighth—for both maxillary and mandibular arches in our study is 0.51 mm per quadrant, which is close to the 0.52 mm per 2 weeks of retraction achieved with the 150-g nickel-titanium closed coil spring in the Samuels, Rudge, and Mair study, whereas it is higher than the amount of retraction recorded with elastic module and 200-g nickel-titanium closed coil spring.

A study by Huffman and Way showed that the amount of retraction achieved while retracting maxillary and mandibular canines along 0.016” and 0.020” arches, when activated by a Pletcher spring to 200 g of force every 2 weeks, was 1.37 mm and 1.2 mm per month, respectively. When reduced to 2 weeks, this would equal to 0.68 mm and 0.60 mm, which is higher than the initial retraction achieved in any of the four 2-week intervals in our study (0.54 mm, 0.30 mm, 0.22 mm, and 0.51 mm, respectively). The reason for this could be that while the simultaneous retraction of 6 anterior teeth was being carried out in our study, only the canines were being retracted in the above-mentioned study. In addition, the dimension (round) and size of the wires (0.016” and 0.020”) used in the above-mentioned study may have reduced the friction during sliding and tipped the canines leading to a faster rate of retraction.

The amount of initial retraction achieved in all of the four 2-week intervals in our investigation was also less when compared to an investigation done by Ziegler and Ingervall.

### DISCUSSION

The retraction of anterior teeth following extraction of first premolars is a routine procedure followed in orthodontic treatment mechanics. However, the conservation of anchorage while retracting anterior teeth, especially in maximum anchorage cases, has always been a source of dilemma to orthodontists. Of late, small-sized titanium screws, called micro-implants or miniscrews, were introduced as temporary anchorage devices (TAD), and it is thought that these devices may provide solutions to many anchorage-related problems.

In the past, retraction of anterior teeth was achieved by separate retraction of canines followed by retraction of the four incisors. The MBT technique, however, recommends en masse retraction by using light continuous force.

In this study, initial retraction of anterior teeth with the MBT appliance system was carried out using micro-implant anchorage; 0.019” × 0.025” rectangular stainless steel working wires in a 0.022” slot were used in this study for retraction as recommended by the MBT technique.

Immediately after the placement of micro-implants in the interradicular space between second premolars and first molars, retraction was started using 9-mm closed coil Nitinol springs (200 g) attached from the micro-implant head to soldered or crimpable hooks on the 0.019” × 0.025” stainless steel wire. Storey and Smith have shown that the optimal force range for moving the canines distally extends from 150–200 g. A force above this range will cause the molars to move mesially. However, in this study, since anchorage was derived not from the molars but reinforced with the help of the micro-implants, it was expected that the molars would not move mesially. Therefore, slightly higher forces in the range of 200–250 g were used in the present investigation to achieve maximum initial retraction.

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The amount of initial retraction achieved in all of the four 2-week intervals in our investigation was also less when compared to an investigation done by Ziegler and Ingervall.

### TABLE 2

Total initial retraction (mm) at the end of 8 weeks – comparison between maxillary and mandibular right and left sides

<table>
<thead>
<tr>
<th>Arch</th>
<th>Right (mm)</th>
<th>Left (mm)</th>
<th>Total (mm)</th>
<th>Average/Quadrant (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maxillary</td>
<td>1.69</td>
<td>1.70</td>
<td>3.39</td>
<td>1.65</td>
</tr>
<tr>
<td>Mandibular</td>
<td>1.36</td>
<td>1.63</td>
<td>3.02</td>
<td>1.51</td>
</tr>
<tr>
<td>Total</td>
<td>2.99</td>
<td>3.33</td>
<td>6.32</td>
<td>3.16</td>
</tr>
<tr>
<td>Average (max + mand)</td>
<td>1.49</td>
<td>1.66</td>
<td>3.15</td>
<td>1.57</td>
</tr>
</tbody>
</table>

3.0 mm; that is, the average initial retraction per quadrant in the maxillary arch was 1.65 mm (Table 1). The total mandibular initial retraction at the end of 8 weeks was 1.39 mm on the right side and 1.63 mm on the left side, which measured to 3.02 mm; that is, the average initial retraction per quadrant in the mandibular arch was 1.51 mm per quadrant (Table 1). Therefore, the average total initial retraction at the end of 8 weeks for both maxillary and mandibular arches was 1.57 mm per quadrant, which averages to 0.78 mm per month.

The average initial retraction for both maxillary and mandibular arches on the right side was 1.49 mm; on the left side, it was 1.66 mm (Table 2).

An anchor loss of 0.1 mm was observed in the maxillary arch after 8 weeks of initial retraction. The percentage of anchor loss for a maxillary space closure of 1.65 mm was 6.06% or 0.06 mm of anchor loss per millimeter of retraction. No anchor loss was measured in the mandibular arch at the end of 8 weeks of initial retraction.
where the rate of canine movement with sliding mechanics using AlastiK chain was recorded to be 1.40 mm per month or 0.70 mm in 2 weeks. However, the source of force delivery used was different in these two studies: While the AlastiK chain in the above-mentioned study exerted a force of approximately 380 g at the time of insertion, the 9-mm closed coil Nitinol springs used in our study exerted less force, between 200–250 g. Moreover, 6 anterior teeth were retracted in comparison to separate canine retraction, possibly leading to lesser amount of retraction in our study.

All the previously mentioned studies neither specified nor checked the amount of retraction achieved at any particular 2-week intervals, as was done in our study. Therefore, the decreased velocity of retraction in the third to sixth week in the present study is not an accurate comparison with previous studies. It is possible that the rate of retraction in these studies also reduced to the same extent, as was observed in our study, by the end of 6 weeks of initial retraction. However, this is not certain.

**Comparison between retractions achieved at each 2-week interval**

Here, an initial retraction of 0.54 mm per quadrant in the first and second weeks was achieved. This was the highest amount of retraction recorded for any of the 2-week intervals in this study. The initial rate of retraction reduced to 0.30 mm per quadrant for the third and fourth weeks, which further dropped to 0.22 mm per quadrant in the fifth and sixth weeks. By the seventh and eighth weeks, the rate of retraction increased to 0.51 mm per quadrant, which was more than the rate of retraction observed during the third, fourth, fifth, and sixth weeks but slightly less than that recorded in the first and second weeks. According to a study by Iwasaki et al, when force magnitudes in excess of 100 g are used to retrac canine teeth, it results in a lag phase of approximately 21 days before tooth movement occurs. Therefore, the use of large forces of above 100 g in our investigation caused an initial mechanical compression of the periodontal ligament (resulting in a faster velocity of retraction during the first and second weeks), it may have been followed later by a lag phase that lasts approximately 21 days, which probably slowed down the rate of retraction during the third to sixth weeks. Thereafter, the increase in the rate of retraction in the seventh and eighth weeks may be due to cessation of the lag phase after the sixth week, thereby increasing the rate of tooth movement.

**Total initial retraction at the end of 8 weeks**

At the end of the eighth week of initial retraction, more retraction was seen in the maxillary arch (1.65 mm per quadrant) than in the mandibular arch (1.51 mm per quadrant). According to Roberts, the rate of tooth movement is inversely related to bone density. This means that more retraction was recorded in the maxillary arch due to the lesser density of bone in the maxilla.

The amount of total initial retraction on the right side was lesser when compared to the the left side (Table 2). The reason for increased retraction on the left side could be due to mastication or the left side of the patients’ arches being the functional occlusal side. In a study by Singh and Shetty, it was found that space closure was faster on the side where masticatory function is higher.

The average total initial retraction at the end of 8 weeks for both maxillary and mandibular arches was 1.57 mm per quadrant or 0.78 mm per quadrant per month. The retraction in our study averages to 0.78 mm per month. This is almost the same as the 0.76 mm per month of retraction achieved with the elastic module in the Samuels, Rudge, and Mair study, whereas it is less than the amount of retractions of 1.04 mm and 0.96 mm per month recorded with 150-and 200-g nickel-titanium closed coil springs, respectively.

When compared to the study by Huffman and Way, the amount of retraction achieved per month in this study (0.78 mm per quadrant) is less than the 1.37 mm and 1.2 mm per month achieved when retracting maxillary and mandibular canines along 0.016” and 0.020” arches, respectively.

The amount of initial retraction per month in this study was also less when compared to the Ziegler and Ingervall study, which measured 1.4 mm of canine retraction per month.

According to McLaughlin and Bennett, an elastic module stretched to twice its normal length will deliver 0.5 to 1.5 mm of space closure of month. The initial retraction per month achieved in this study (0.78 mm per quadrant) falls within this range. This implies that micro-implant anchorage did not produce a faster rate of retraction.

**Anchor loss**

The pre-retraction and post-retraction (at the end of 8 weeks) cephalograms for each patient were evaluated for anchor loss. In the maxillary arch, the molars moved anteriorly by 0.1 mm on average, for a retraction of 1.65 mm. The maxillary anchor loss was 0.06 mm per millimeter of retraction or 6.06% of anchor loss recorded, whereas no mesial mandibular molar movement was observed for a retraction of 1.51 mm, that is, there was no anchor loss in the mandibular arch during the entire period of our study.

In a study by Hart, Taft, and Greenberg, the mean anchor loss measured was 0.60 mm for a mean maxillary retraction of 5.35 mm, and 0.90 mm for a mean mandibular retraction of 3.05 mm. This amounts to an anchor loss of 0.11 mm per millimeter of maxillary retraction and 0.25 mm anchor loss per millimeter of mandibular retraction, which is more than the anchor loss of 0.06 mm per millimeter of maxillary retraction. Moreover, no anchor loss was recorded in the mandibular arch in our study.

In another study by Thiruvenkatachari et al anchor loss of maxillary and mandibular molars during canine retraction, with and without implant anchorage, was studied. Their results showed that no anchor loss occurred on the implant side in both maxillary and mandibular arches, whereas anchor loss of 1.60 mm and 1.70 mm was recorded on the nonimplant side in the maxillary and mandibular arches, respectively. In comparison, our present investigation recorded maxillary anchor loss of 0.1 mm, which is much less than the amount of mean anchor loss observed on the nonimplant side (1.60 mm) in the above-mentioned study. However, the mesial movement of the upper molars by 0.06 mm per mm of retraction in the maxillary arch observed in our study is negligible and may be due to the
normal physiologic migration during the period of retraction and not necessarily a result of loss of anchorage.

Assessment of micro-implant stability

The stability of all the 18 micro-implants was checked clinically and reasons for failure, if any, were assessed with the help of IOPA radiographs. Of the 18 micro-implants that were placed surgically, 4 micro-implants (3 micro-implants in the mandible and 1 micro-implant in the maxilla) either became loose or were completely extruded from its surgical site. Therefore, the success rate was 77.7%.

In a study conducted by Liou, Pai, and Lin\(^1\) to analyze whether miniscrews are absolutely stationary or move when force is applied, it was concluded that miniscrews are a source of stable anchorage but do not remain absolutely stationary throughout orthodontic loading. They recommended that to prevent miniscrews from injuring any vital organs because of displacement, it is advisable that they be placed in a non-tooth-bearing area that has no foramen, major nerves, or blood vessel pathways, or in a tooth-bearing area allowing 2 mm of safety clearance between the miniscrew and dental root. In the present study, on IOPA radiographic assessment, it was observed that 2 of the mandibular micro-implants were in close proximity to the roots even though there was a safety clearance of 2 mm between the micro-implant and the root.

Four micro-implants failed because of poor oral hygiene. A study by Deguchi et al\(^3\) quantitatively evaluated cortical bone thickness in various locations in the maxilla and the mandible using 3-dimensional computed tomographic images. Results showed that significantly more cortical bone was present in the mandibular molar region than in the maxillary molar region. However, miniscrews failed in both the mandibular and maxillary posterior regions. The reason for their failure remains unclear, but it might be associated with factors other than the amount of cortical bone surrounding the implant. Miniscrews are placed in the attached gingiva, which is a narrow site in the posterior region in the mandible, but poor oral hygiene might cause infection at these sites leading to failure. Another reason for increased failure of micro-implants placed in the posterior part of the mandible is that they can be easily irritated during mastication.\(^2\)

From these studies, it is clear that the success of the micro-implants depend mainly on proper maintenance of oral hygiene by the patient, which may otherwise impede a healthy bone-implant interface. A careful and precise technique for placement of the micro-implants is also essential in preventing failure.

Conclusion

The purpose of this present investigation was to assess the clinical efficiency of micro-implants in providing absolute anchorage during initial retraction of anterior teeth, to evaluate the rate of initial retraction at 2-week intervals for a period of 8 weeks, and to determine if there was any anchor loss during the period of the study. The results of this investigation led to the following conclusions:

- The rate of initial retraction was not any faster than that achieved in previous studies;
- The initial retraction during the first and second weeks and seventh and eighth weeks were faster than the third and fourth weeks and fifth and sixth weeks;
- More retraction was observed in the maxillary arch than the mandibular;
- Retraction was faster on the left side than the right side of the arches;
- The micro-implants were able to resist traction forces as high as 200–250 g;
- The micro-implants provided absolute anchorage during the period of the study but did not reduce the treatment time;
- Anchor loss was either definitely reduced or totally absent in comparison with other studies;
- Micro-implants failure during the study was 22.3%;
- Precise surgical technique, patient cooperation, and proper oral hygiene maintenance were important factors in determining micro-implant stability.

ABBREVIATIONS

IOPA: intraoral periapical
SAS: skeletal anchorage system
TAD: temporary anchorage devices

REFERENCES