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Clinical Effectiveness of a Subperiosteal Anchorage Device

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Clinical Effectiveness of a Subperiosteal Anchorage Device

by

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A Thesis submitted in partial satisfaction of
the requirements for the degree of
Master of Science in Orthodontics and Dentofacial Orthopedics

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Each person whose signature appears below certifies that this thesis in his opinion is adequate, in scope and quality, as a thesis for the degree Masters of Science.

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DEDICATION

Dedicated to my loving parents who taught me to believe in myself, to reach for my goals, and to enjoy the journey.

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ABSTRACT

Clinical Effectiveness of a Subperiosteal Anchorage Device

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Master of Science, Graduate Program in Orthodontics and Dentofacial Orthopedics
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Dr. Joseph Caruso, Chairperson

The purpose of this pilot study was to evaluate the clinical efficacy of a subperiosteal anchorage device, the palatal OnPlant™, during orthodontic retraction of protruding anterior teeth in cases requiring maxillary premolar extraction. Seven subjects (5 female, 2 male), ages 13 to 55, were selected for the study. The OnPlant was surgically placed in the mid-palatal region through a well-defined subperiosteal tunnel. Following the manufacturer recommended osseointegration period of four months, the OnPlant was uncovered and attached to the first molars by means of a transpalatal bar. Standard orthodontic treatment then commenced to retract the anterior teeth after the first premolars were extracted.

A new volumetric tomography scanner, the NewTom 9000, was used to evaluate the clinical efficacy of the OnPlant. The study design called for records to be taken at two intervals: 1) Following placement of the OnPlant-transpalatal bar, immediately prior to retraction of the anterior dentition and 2) Following completion of retraction as well as any necessary torquing of the maxillary incisors. Limited time allowed only partial treatment for three of the subjects, whose final NewTom records were taken within the retraction phase of treatment.

Six of the OnPlants performed without failure, providing absolute anchorage of the molars during treatment. One OnPlant failed near the end of incisor retraction.

The NewTom proved to be a consistent and reliable tool for evaluating the OnPlant's clinical performance. Future research into the OnPlant and other such skeletal anchorage devices may continue to expose the orthodontic community to the benefits of such devices in cases requiring maximum anchorage.

INTRODUCTION

The basic foundation of a well-treated orthodontic extraction case is adequate stability of those dental segments that are not to change position during treatment. Achieving this stability, or anchorage, is one of the greatest challenges in the practice of Orthodontics and Dentofacial Orthopedics.[25] This research addresses this age-old problem in orthodontics through the use of new, advanced technology – both in the anchorage device itself, the palatal OnPlant, and in the digital imaging method used to evaluate its performance.

The traditional toothborne methods of obtaining anchorage are severely limited because teeth move in response to force.[9] Disadvantages of toothborne anchorage become readily apparent in patients of compromised periodontal status. Extraoral anchorage can be used to supplement toothborne anchorage, directionally delivering forces in a manner not possible with intraoral forces alone; however, this method is dependent upon patient compliance.[10] Dental implants, planned for later restoration, can be utilized to provide support against unwanted tooth movement. In addition, temporary implants can be used as anchorage devices, with the plan to remove them following their use.[29]

Recently, Block and Hoffman introduced a flat subperiosteal disk, the palatal "OnPlant", as an alternative to traditional implants in obtaining orthodontic anchorage.[4] This stabilization device, measuring 8 millimeters in diameter and less than 3 millimeters in height, has been demonstrated to provide absolute anchorage when retracting the anterior teeth in monkeys.[4] In addition, it has been shown to allow for unilateral tooth movement in dogs.[4] Both studies demonstrated osseointegration of the OnPlant. The textured, hydroxyapatite-coated surface of the OnPlant is placed in direct contact with palatal bone. The opposite surface of the OnPlant, a smooth, titanium material that is covered by the periosteum, has an internally threaded hole with an external hex to accept a variety of attachments depending on the needs of the clinician. Following an osseointegration period of four months, the OnPlant is surgically exposed and an orthodontic transpalatal abutment is connected from the OnPlant to the maxillary molars to provide the necessary anchorage of the posterior dental segments.

A new, volumetric tomography scanner, the NewTom 9000 has been developed. Using cone beam technology, three-dimensional digital images are produced that can be reconstructed and viewed in any spatial orientation. A recent study has revealed the accuracy of using the records obtained from the NewTom over conventional radiographic methods and study models to evaluate the treatment outcomes when using the palatal OnPlant.[13]

Purpose of Study

The purpose of this pilot study was to evaluate the clinical efficacy of a subperiosteal anchorage device during orthodontic retraction of cuspids and protruding anterior teeth in cases requiring maxillary premolar extraction. The NewTom 9000, a volumetric tomography scanner, was used for the evaluation.

REVIEW OF LITERATURE

Obtaining adequate stability, or anchorage, of those dental segments that are not to change position during orthodontic treatment is one of the most difficult tasks in the practice of Orthodontics and Dentofacial Orthopedics.[21] When a treatment plan includes extractions, the orthodontist must decide if the extraction space will be closed by moving anterior teeth only (maximum anchorage), posterior teeth only (minimum anchorage) or a combination of anterior and posterior teeth (moderate anchorage). Maximum anchorage, or no movement of the posterior dental segments, is often the goal in cases consisting of a protrusive maxillary dentition and a strained or full soft tissue profile. Maximum anchorage is also necessary in cases requiring distalization of the maxillary molars.

Headgear and Class II elastics are methods commonly employed for obtaining maximum anchorage in extraction cases.[20] Headgear can be used to apply an extraoral distally driven force to the posterior segment to prevent these teeth from moving mesially during treatment. Class II elastics are typically worn from the mandibular first molars to the maxillary canines, thereby creating a force to assist with retraction of the maxillary anterior segment while holding the posterior segment in place. Long-term use of Class II elastics can cause excessive flaring of the mandibular incisors however, and should be avoided in cases where this flaring is not desirable. Both headgear and Class II elastics can be an effective means of obtaining maximum anchorage, however they are dependent on patient compliance.[10, 20] Giving the responsibility of maintaining adequate anchorage to a potentially noncompliant patient risks a negative treatment outcome.[10]

The Nance appliance is a method of obtaining maximum anchorage without the need for patient compliance.[5] This appliance consists of an acrylic palatal button positioned in the anterior palatal vault, attached to the posterior teeth through wires soldered to the maxillary molar bands. Unfortunately, the acrylic button must be removed prior to incisor retraction, thereby eliminating any anchorage provided during this important stage of treatment. In addition, tongue pressure on the acrylic button portion of the appliance may produce the opposite effect on anchorage, a mesial molar movement.

It is also difficult to obtain the anchorage necessary to prevent mesial movement of the maxillary dentition during maxillary molar distalization. Molar distalization can be achieved many different ways. Examples include headgear, as well as various intraoral, toothborne appliances eliminating the need for patient compliance such as the Pendulum, Jones-jig, Wilson, Distal Jet, and repelling magnets.

In 1978, Wilson introduced the concept of "modular orthodontics".[27] One aspect of this treatment modality consists of rapid maxillary molar distalization. Class II elastics are used in conjunction with a distalizing maxillary archwire. Although the Wilson appliance is effective at molar distalization, the maxillary incisors show significant proclination and protrusion. The incisors must then be returned to their original position; an act that prolongs treatment and can result in root shortening.[18] In addition, this method of distalization is also dependent upon patient compliance in wearing the Class II elastics.

The Pendulum appliance, first described by Hilgers in 1992, consists of an anterior acrylic Nance with an expansion screw and posteriorly extending springs which fit into lingual sheaths on the molar tubes.[4] This appliance has been found to effectively distalize molars, but not without a significant loss of anchorage.[4, 8] Byloff and Darendeliler reported that only seventy-one percent of the space created mesial to the molars during treatment with the Pendulum appliance was due to distal molar movement.[4] A significant amount of mesial tipping of the second premolars and anterior movement of the incisors was noted. Another problem associated with the Pendulum appliance is the high relapse tendency of the molars, rendering the anchorage available for incisor retraction minimal.[4, 3]

Repelling magnets can provide enough force to distalize molars.[9, 12,19] To achieve molar distalization, sectional wires containing two opposing magnets are inserted into the headgear tubes of the first molars. These magnets are reactivated every two to three weeks. A Nance appliance provides anchorage against the reactive force of the magnets. Itoh *et al* reported that despite the use of the Nance holding arch, labial movement of the anterior teeth did occur, usually 30 to 50 percent of the distal movement of the molars.[12] It is suspected that magnetic fields may have an indirect effect on cellular activity which could be helpful or harmful.[19] For instance, static as well as pulsed magnetic fields can possibly increase the rate of bone formation and accelerate the rate of tooth movement.[19] On the other hand, there is evidence that magnets in close contact with skin and bone can result in a reduction of the number of epithelial cells as well as cause resorption of the cortical bone surface.[19]

The Jones Jig contains a nitinol open coil spring that exerts 70 to 75 grams of force over a compression range of 1 to 5 millimeters to the maxillary molars.[11] Haydar and Uner reported that although the Jones Jig distalized molars faster than headgear, anchorage loss was a significant problem.[11] Runge *et al* stated that anchorage loss, flared maxillary incisors, and increased facial height are negative treatment effects that should be expected when using this appliance.[22] For every 2.5 millimeters of distal movement of the molars, there is a resulting 2 millimeter mesial movement of the premolars and incisors.[11, 22] The premolars experience mesial tipping of about 5 degrees.[3]

Much literature during the late 1970's and 1980's is devoted to the use of osseointegrated implants in orthodontics. In 1983, Creekmore and Eklund published a case report of a twenty-five year old female with a Class I molar relationship and a deep overbite.[7] A surgical vitallium bone screw was inserted just below the anterior nasal spine and loaded ten days later with a light elastic thread, producing an intrusive force on the anterior segment. The maxillary centrals were elevated 6 millimeters and torqued 25 degrees. The authors stated that their presentation of the case report was meant to stimulate an in-depth investigation of the possibility of applying skeletal anchorage to orthodontic tooth movement and orthopedic jaw movement.

Research has shown that osseointegrated implants display absolute resistance to movement against an orthodontic load.[6] In fact, continuously applied levels of stress, within the range that can be applied by orthodontic biomechanics, actually appear to maintain or support the osseointegration of an implant.[6] The density of bone adjacent to the loaded implant actually increases against continuous horizontal loading.[1] Histologic studies have shown that implants remain osseointegrated against continuous oblique forces of 2 to 6 Newtons, forces much greater than that required for normal biologic orthodontic tooth movement.

Studies have shown that palatal implants provide absolute anchorage. Wehrbein reported absolute stability of the palatal implant during anterior retraction.[23] This early study by Wehrbein did reveal a slight loss of dental anchorage that was attributed to deformation of the long arms of the transpalatal arch rather than movement of the implant itself. When coupled with a more rigid transpalatal bar, the implants do provide absolute anchorage. This has been supported by several studies.[23, 25, 26]

Some problems do exist with the palatal implant, however. Considering the anatomy of the palate, the length of the implant must be short to prevent perforation of the nasal cavity and possible sinus tract formation. It has been suggested that 4.5 to 6 millimeter implants be used to minimize these potential complications.[17, 18] Bernhart, recognizing the variation in volume of individual palates, has recommended that a preoperative diagnostic evaluation be performed on each patient prior to implant placement. This evaluation would determine the safest location for the implant based upon the exact position of the incisor apices and the thickness of palatal bone, taking into account that palatal bone thins as one moves posteriorly.

Wehrbein has advocated the use of 4.5 to 6 millimeter implants (Orthosystem, Institut Straumann, Waldenburg, Switzerland).[23, 24] A mucosal punch corresponding to the diameter of the transmucosal neck section of the implant is used during the one-stage placement surgery. This eliminates the need for sutures and simplifies the management of the palatal mucosa.[24] Although the length of the implant is relatively short, there is a risk of nasal cavity perforation which can result in sinus tract formation. Lateral cephalograms are an aid in finding the actual available space for a palatal implant. The thickness of the palatal bone immediately lateral to the midline suture is significantly thinner than the bone of the palatal midline.[24] Cephalometric measurements of actual skulls, when compared to the physical measurement of the same skulls, showed that in some cases the bone was up to 2 millimeters thicker in the physical measurement than was measured on the lateral cephalogram.[24] Although this information may help in evaluating the adequacy of palatal bone for an implant, the variability of radiographic measurements and the potential adverse effects of incorrectly assessing the palatal bone thickness may outweigh the advantages of this particular palatal implant system.

Recently, Park has researched and advocated the use of a different implant system, MIA or "micro-implant anchorage" (Absoanchor, Dentos Co.).[15] This implant has a width of 1.2 millimeters and comes in a variety of lengths. The microimplant's main advantage is its ability to withstand force immediately following placement. Removal can be performed without any local anesthesia. Although there is a risk of penetrating the root of a tooth near the placement site, it has not been reported.

In 1995, Block and Hoffman introduced the palatal OnPlant (Nobel Biocare, Yorba Linda, CA), a subperiosteal disk measuring 8 millimeters in diameter and less than 3 millimeters in height.[2] The textured surface of the OnPlant that lies against the bone is coated with a thin later of hydroxyapatite whereas the superficial surface that contacts the periosteum is a smooth-surfaced titanium. Block and Hoffman demonstrated absolute anchorage when using the palatal OnPlant while retracting the anterior teeth of monkeys.[2] They also showed the ability to use the OnPlant for unilateral tooth movement in dogs.[2] Osseointegration of the OnPlant was demonstrated in both studies.

In summary, adequate anchorage control is vitally important in the practice of Orthodontics and Dentofacial Orthopedics. Traditional means of obtaining maximum anchorage have proven to be problematic in terms of patient compliance and appliance design shortcomings. For this reason, there has been a recent shift in Orthodontics to explore skeletal anchorage as a means of obtaining the anchorage necessary during treatment. The palatal OnPlant has been shown to provide absolute anchorage in animal studies and its flat design eliminates the risk of nasal cavity perforation associated with implants.[2] Further research into the clinical effectiveness of the OnPlant may broaden the use of this anchorage device in orthodontic cases.

MATERIALS AND METHODS

Subject Selection

Patients were screened in the Graduate Orthodontics Clinic of Loma Linda University. Standard diagnostic records (panoramic radiograph, lateral cephalogram, frontal cephalogram, modified full mouth periapical radiographs, occlusal films, and tomograms) were used to evaluate and fabricate appropriate treatment recommendations for each patient. A thorough medical history was also reviewed on each potential subject. All subjects selected for this pilot study were systemically healthy, non-pregnant patients requiring upper premolar extractions due to protrusion of maxillary dentition measuring ≥ 4 millimeters beyond the lower incisor position or maxillary crowding of ≥ 4 millimeters. Each subject denied the option of extraoral anchorage and refused the option of orthognathic surgery. All patients were free from destructive periodontal disease and demonstrated good oral hygiene. Finally, the completion of growth was confirmed in all patients under eighteen years of age by a hand-wrist radiograph revealing closure of the metacarpal epiphyseal growth plate.

Treatment

Patients selected for this study underwent pre-surgical preparation in the orthodontic clinic. Two alginate impressions were taken of the maxillary dentition and palate and poured immediately with plaster to fabricate two orthodontic models. The first model was necessary to fabricate a vacuum-formed, pre-surgical stent to aid in the exact placement of the OnPlant in the midpalatal region. The desired location of the OnPlant was carefully marked on the stent, and a perforation was made in this area using an acrylic bur to enable the surgeon to mark the palatal tissue with the stent in place (Figure 1c). In this manner, the OnPlant was surgically positioned in the location prescribed by the orthodontist. The second model was used to fabricate a vacuum-formed, post-surgical stent (Figure 1a). Prior to vacuum formation, impression putty was placed on the model in the future site of the OnPlant, creating a recess for the OnPlant body (Figure 1b). The stent was to be relined in the recess area prior to placement in the patient's mouth post-surgically. Ball clasps were fitted between the second premolars and first molars. The palatal extensions of these clasps were embedded in acrylic immediately prior to vacuum formation, thereby allowing the wet acrylic to bond to the plastic stent material. The post-surgical stent was then trimmed and polished.

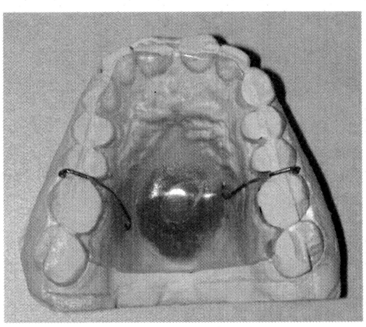


Figure 1a. Post-surgical stent

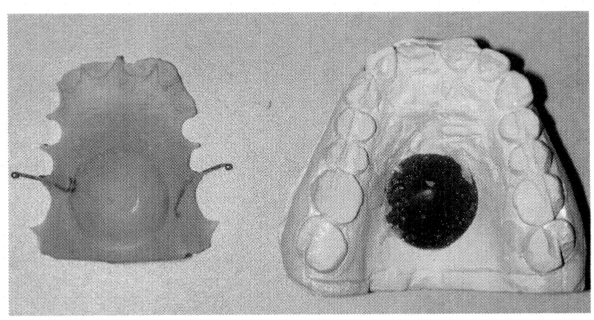


Figure 1b. Recess created in post-surgical stent. Impression putty placed in future OnPlant site.

The surgical procedure to place the OnPlant was carried out in the Loma Linda University Periodontics Department. Local anesthetic (2% xylocaine with 1:100,000 epinephrine) was delivered to the mid-palatal region. After adequate anesthesia was obtained, the pre-surgical stent was placed in the patient's mouth. The prescribed OnPlant site, evident through the midpalatal perforation of the stent, was marked on the tissue using a tissue marker (Figure 1c). A semilunar incision was then made accessing the mid-palatal bony suture just anterior to the future OnPlant site. A periosteal elevator was used to reflect the periosteum from the underlying bone and a tunnel was created through blunt dissection along the mid-palatal ridge, extending one centimeter posterior to the incision access point to reach the OnPlant recipient site. Hand and rotary instruments were used to assure a flat osseous bed to allow a close adaptation of the eight-millimeter diameter OnPlant device.

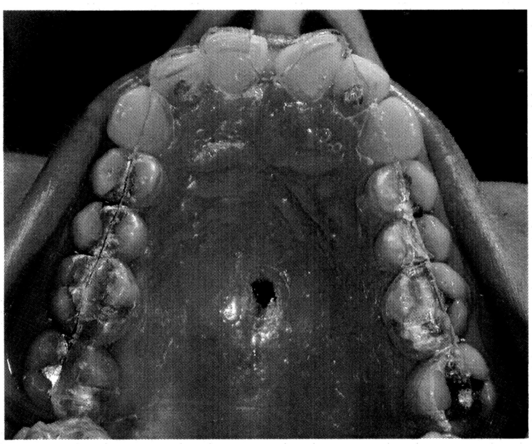


Figure 1c. Pre-surgical stent in place.
A tissue marker is used to mark the prescribed OnPlant location through the perforation in pre-surgical vacuum-formed stent

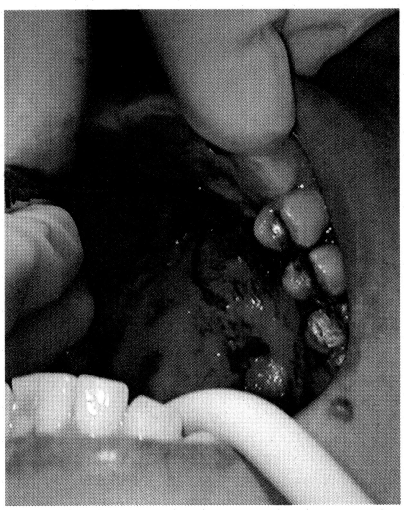


Figure 1d. Instrument used to create a flat osseous bed for OnPlant body.

The OnPlant was then placed beneath the periosteum, its hydroxyapatite-coated base surface directly against the bone (Figures 1e, 1f). Following placement of the OnPlant, the incision was closed with chromic sutures (Figure 1g).

Figure 1e: OnPlant removed from sterile container.

Figure 1f. OnPlant's hydroxyapatite surface will be placed directly against the bone.

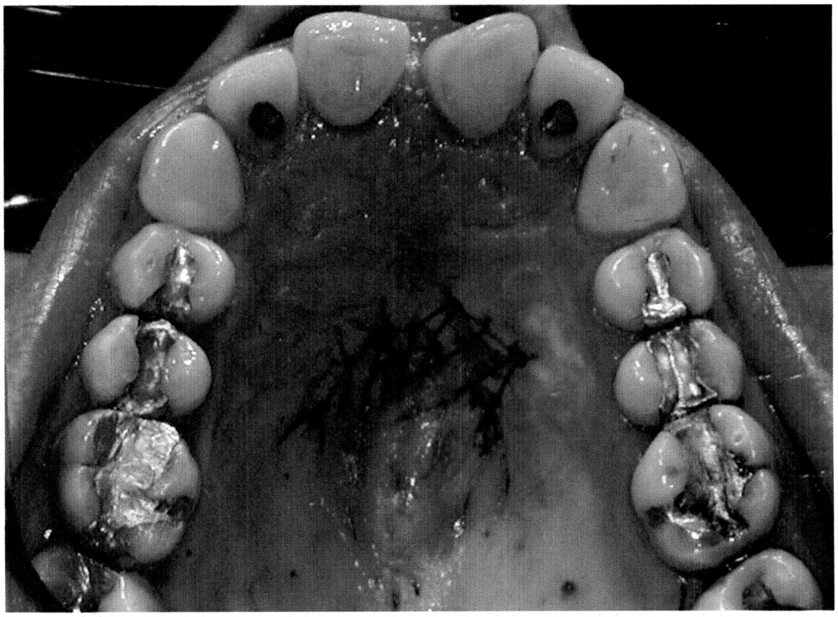


Figure 1g: OnPlant is placed and incision is closed with chromic sutures.

A soft denture reline material was then used to fill the previously prepared recess in the post-surgical stent creating support to hold the OnPlant against the bone (Figures 1h, 1i, 1j). Patients were advised to wear the post-surgical stent during the first two weeks of healing and were prescribed systemic antibiotics (amoxicillin: five hundred milligrams taken immediately and two hundred and fifty milligrams taken four times a day for ten days) and oral rinses (Peridex: one ounce taken twice a day for two weeks). Postoperative checks were made at two weeks and at two and four months. Following the four-month osseointegration period, the cover screw of the OnPlant was exposed with a soft tissue punch and an attachment, the healing cap, was placed to assure proper healing of the peri-Onplant tissues. At this time, patients were referred for maxillary first premolar extractions.

Figure 1h. Tissue conditioner used to reline post-surgical stent.

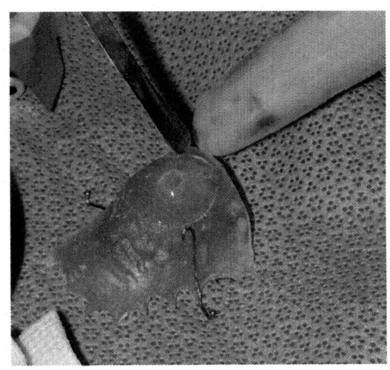


Figure 1i. Tissue conditioner used to fill previously created recess in post-surgical stent.

Figure 1j. Relined post-surgical stent in place.

One week after exposure of the OnPlant, the patient returned to the Orthodontic Department. The healing cap was removed from the OnPlant and a three-dimensional abutment was placed, using a hex screwdriver, to resist any unwanted rotational movement of the anchor teeth around the OnPlant (Figures 1k, 1l, 1m).

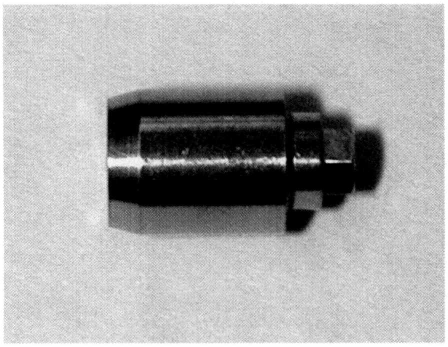


Figure 1k. Three-dimensional abutment.

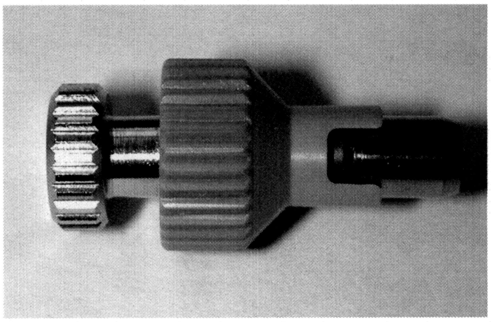


Figure 1l. Hex screwdriver used to attach three-dimensional abutment to Onplant.

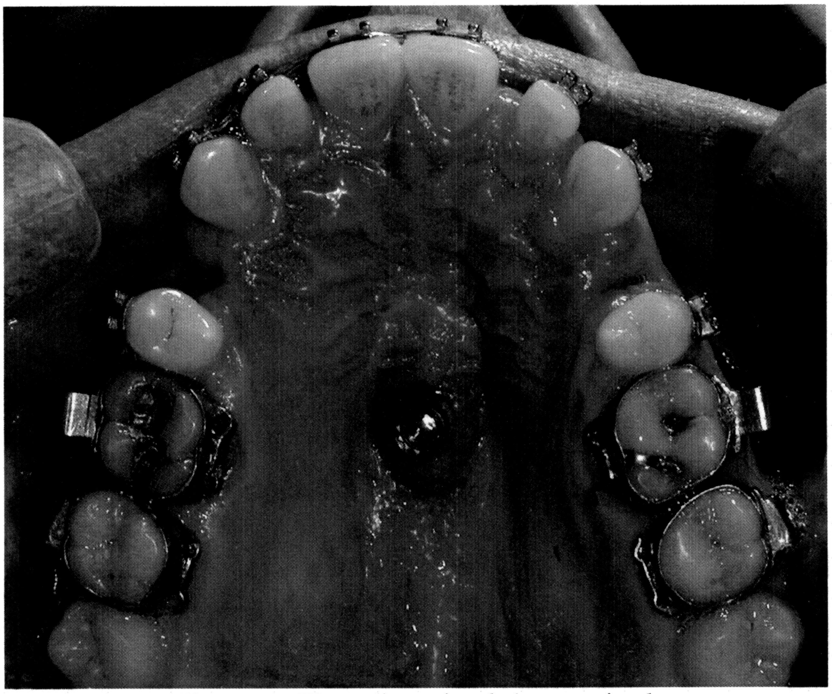


Figure 1m. Three-dimensional abutment in place.

Bands were fitted on the maxillary first molars. An impression coping was attached to the OnPlant, and an alginate impression was made (Figures 1n, 1o). The impression coping was then removed from the patient's mouth, and attached to an abutment replica (Figure 1p). The combined impression coping and abutment replica unit was then inserted, along with the maxillary bands, into the alginate impression (Figure 1q).

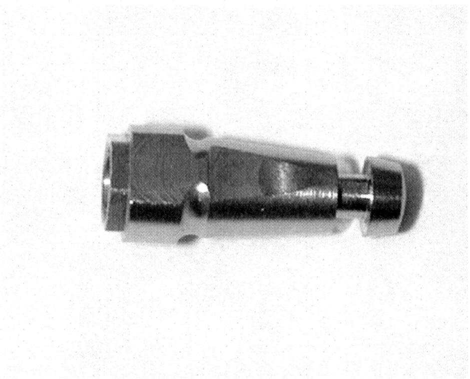


Figure 1n. Impression coping.

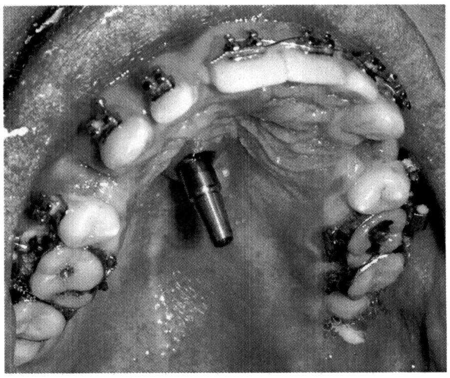


Figure 1o. Impression coping attached to three-dimensional abutment.

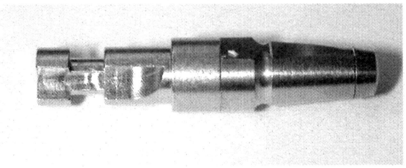


Figure 1p. Impression coping removed from patient's mouth following alginate impression and attached to the abutment replica.

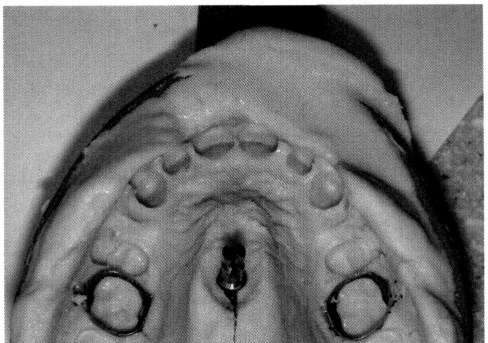


Figure 1q. Combined impression coping and abutment replica unit placed in alginate impression along with maxillary bands.

The impression was immediately poured in orthodontic laboratory stone to create a working model (Figure 1r). After the model was removed from the alginate impression, the impression coping was removed, revealing the stone-embedded abutment replica – a duplicate of the OnPlant's location in the mouth (Figures 1s, 1t).

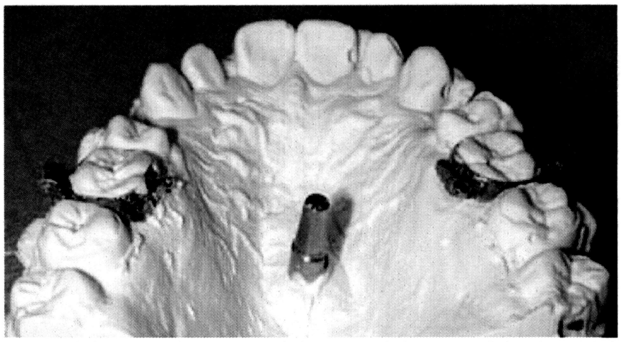


Figure 1r. Alginate impression poured with orthodontic plaster to create a working model.

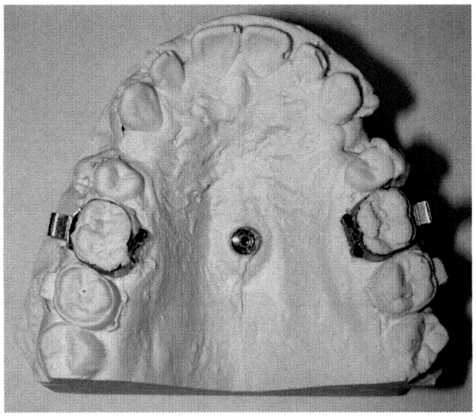


Figure 1s. Working model. Impression coping is removed to reveal the stone-embedded abutment replica

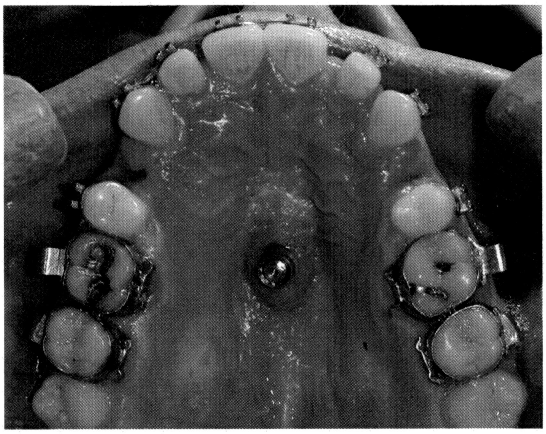


Figure 1t: The working model (Figure 1s) is a duplicate of the OnPlant's location clinically.

From this working model, a pre-formed transpalatal bar was shaped to contact the molar bands while attached to the hexagonal attachment interface of the abutment replica (Figure 1u). The wires were then soldered to the molars and the OnPlant-transpalatal bar appliance was removed from the model for polishing and disinfecting (Figure 1v). The OnPlant-transpalatal bar appliance was transferred to the patient's mouth, secured to the three dimensional abutment and cemented to the molars (Figure 1w).

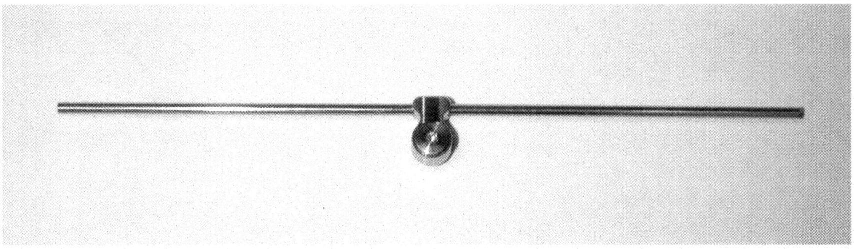


Figure 1u. Pre-formed transpalatal bar.

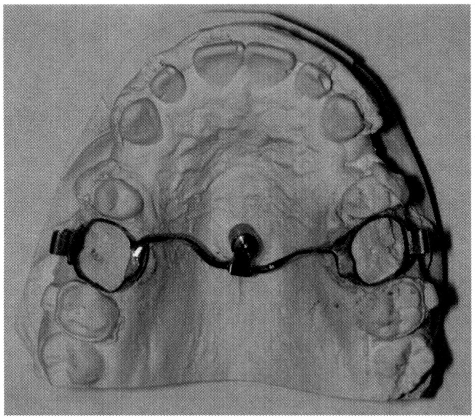


Figure 1v: Transpalatal bar shaped to fit molar bands and fit securely in hexagonal OnPlant attachment interface.

Figure 1w: Transpalatal bar transferred to patient's mouth.

The initial record was taken on the NewTom following the OnPlant-transpalatal bar cementation (Figure 1x). The final record was taken on the NewTom following retraction of the anterior dentition to close the extraction spaces as well as the completion of any necessary torquing of the incisors.

With the anchorage provided by the OnPlant no longer required, a similar anesthetic and surgical procedure were employed for its removal. Following surgical exposure of the anchorage device, a blunted chisel placed at the OnPlant-bone interface was gently tapped with a hand-held mallet and then twisted to test the residual attachment. Alternating tapping and twisting continued until the OnPlant device separated from the bone surface and was removed.

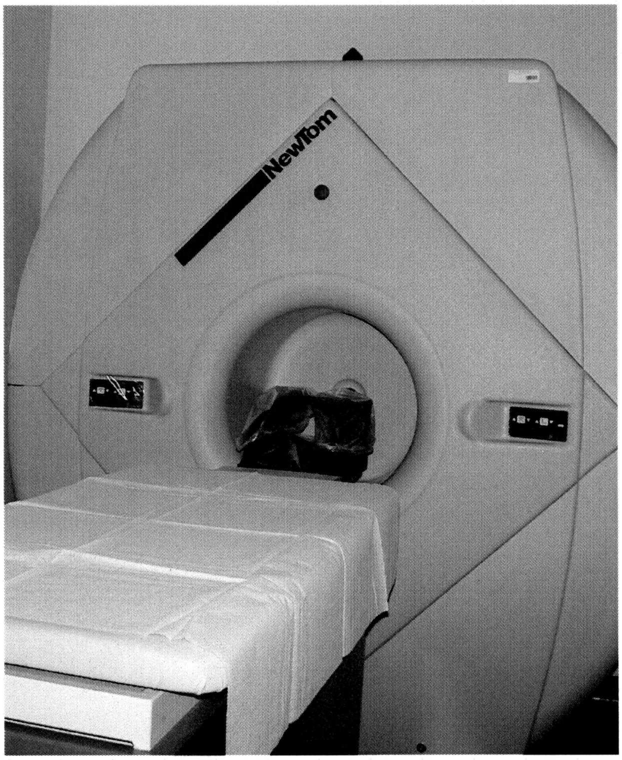


Figure 1x: The NewTom 9000

Measurements

The following outline lists the landmarks used and measurements taken for the study:

I. Landmarks
   A. Anatomic Landmarks
      1. Center of Incisive canal (CIC)
      2. Depth of pterygoid plates (PD) – R & L
      3. Midpoint of R & L pterygoid plates (MPD)
      4. Apical tip (AT) of 1st molar palatal root, central incisor, lateral incisor, and canine – R & L
      5. Incisal tip (IT) of central incisor, lateral incisor and canine – R & L
      6. Palatal vault crest (PVC)

   B. Artificial Landmarks
      1. Superior center of Onplant Body (SCO)
      2. Anterior portion of 1st molar tubes (AMT) – R & L

II. Measurements
   A. Stability of Onplant position - Figure 2c
      1. SCO to PD-R
      2. SCO to PD-L
      3. SCO to CIC

   B. Loss of Anchorage:
      1. Molar tooth crown movement - Figures 2d, 2e
         a. AMT-R to PD-R
         b. AMT-L to PD-L
      2. Molar root movement (palatal root of 1st molars) – Figures 2f, 2g
         a. AT-R to PD-R
         b. AT-L to PD-L
      3. Transverse molar movement – Figure 2h
         a. AMT-R to AMT-L

   C. Amount of anterior retraction, crown movement – Figures 2i, 2j
      1. IT-R to MPD (right central incisor, right canine)
      2. IT-L to MPD (left central incisor, left canine)

   D. Amount of anterior retraction, root movement – Figures 2i, 2j
      1. AT-R to MPD (right central incisor, right canine)
      2. AT-L to MPD (left central incisor, left canine)

   E. Palatal Dimensions:
      1. Surgical interpalatal width – Figures 2k, 2l
      2. Palatal Depth – Figure 2m

Preparation for Measurements:

The three-dimensional raw data for each subject taken by the NewTom was reconstructed parallel to the OnPlant body (Figure 2a). In this way, cross-sectional images, 0.3 millimeter slices, were created, each slice made in a parallel plane to the OnPlant itself. Measurements were then taken from various slices of the three-dimensional image. Figure 2b can be used as a guide to help the reader visualize the particular slice, or level, at which the various measurements were made.

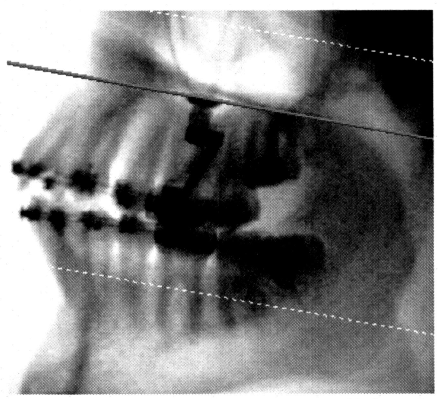


Figure 2a. NewTom data reconstructed parallel to OnPlant body.

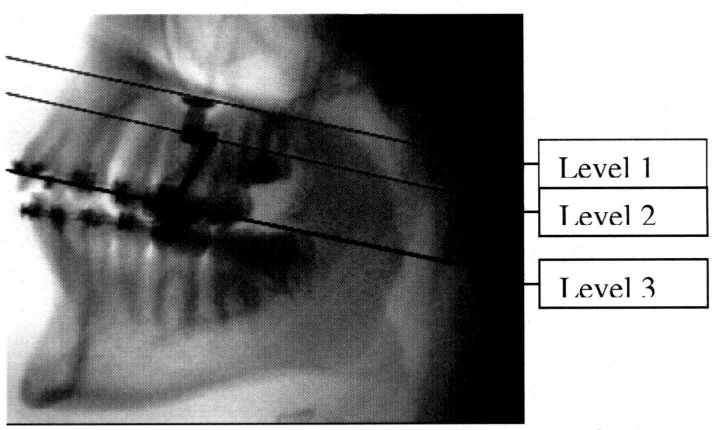


Figure 2b. Image representing the three main slices, or levels, used for the measurements.

Stability of OnPlant Position:

The center of the incisive canal (CIC) and the depth of the right and left pterygoid plates (PD – R & L), were selected as stable skeletal landmarks. Measurements were made from the superior center of the OnPlant body (SCO) to each of these three skeletal reference points. These measurements established the horizontal position of the OnPlant during treatment (Figure 2c).

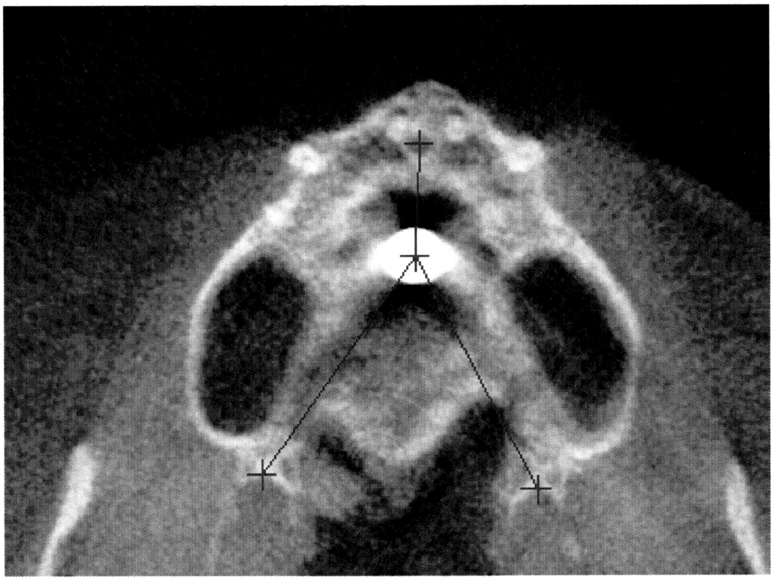


Figure 2c. (Level 1, Figure 2b)
Stability of OnPlant position.
Stable skeletal landmarks (center of incisive canal and right and left pterygoid depths) measured to the superior center of OnPlant body.

Loss of Anchorage

A. Molar Tooth Crown Movement:

Molar crown movement was also recorded in order to determine if a loss of anchorage occurred. Markers were placed at the most anterior portion of the right and left first molar tubes at the cross-sectional level of the wire slot. Measurements were then made first from the anterior portion of the right molar tube (AMT – R) to the right pterygoid depth (PD – R) and next from the anterior portion of the left molar tube (AMT - L) to the left pterygoid depth (PD - L) to determine if molar crown movement occurred in an anterior-posterior direction (Figures 2d, 2e).

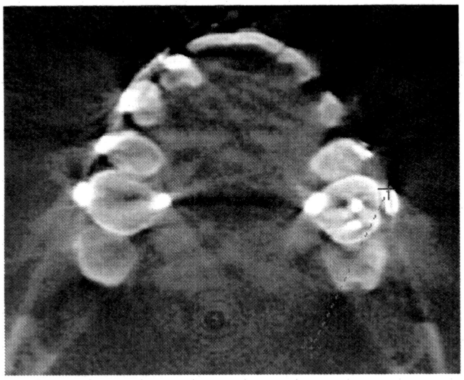


Figure 2d. (Level 3, Figure 2b)

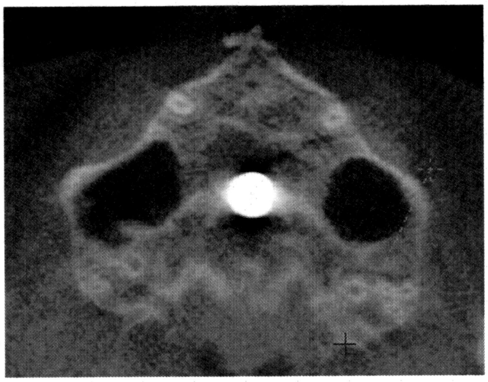


Figure 2e. (Level 1, Figure 2b)

Molar crown movement. Recorded from the most anterior point of right/left molar tube at center of wire slot (Figure 2d) to right/left pterygoid depth (Figure 2e).

The left side measurement is shown here.

B. Molar Root Movement:

Molar root movement was recorded in a similar manner, measuring from the apical tip of the right molar palatal root (AT – R) to the right pterygoid depth and from the apical tip of the left molar palatal root (AT – L) to the left pterygoid depth (Figures 2f, 2g).

C. Transverse Molar Movement:

Intermolar width was also measured from the anterior portion of the right molar tube (AMT-R) to the anterior portion of the left molar tube (AMT-L) to determine if any transverse movement of molars occurred during treatment (Figure 2h).

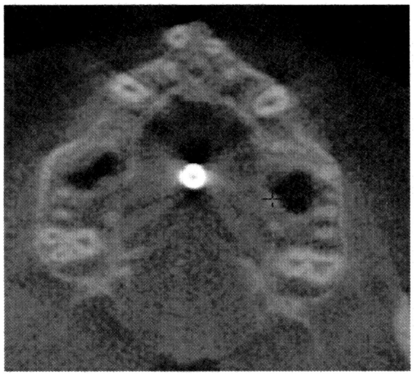


Figure 2f. (Level 2, Figure 2b)

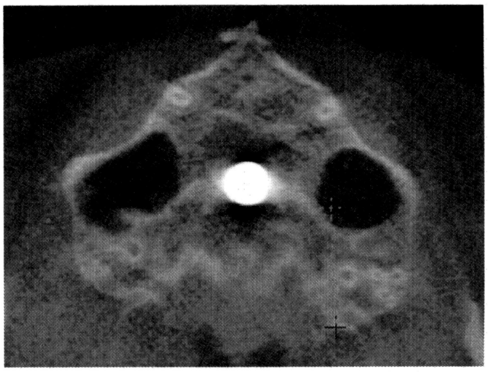


Figure 2g. (Level 1, Figure 2b)

Molar root movement. Measured from tip of right/left palatal root (figure 2f) to right/left pterygoid depth (figure 2g). The left side measurement is shown here.

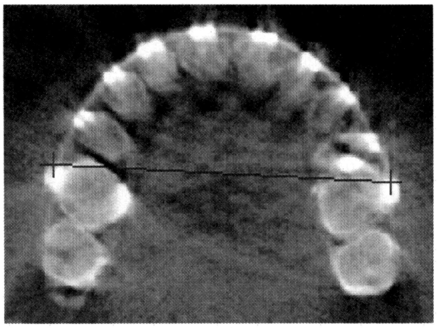


Figure 2h (Level 3, Figure 2b)

Intermolar width. Measurement made from most anterior point of the right and left molar tubes at center of wire slot.

Anterior Retraction – Crown/Root Movement:

The amount of retraction was determined by measuring both canine and incisor movement. The midpoint between the right and left pterygoid depths (MPD) was marked. Four sagittal slices were then made, each originating from the MPD and extending to the center of the root canals of the four teeth being measured: right and left canines and right and left central incisors (Figure 2i). From the resulting sagittal image, measurements were then made from the incisal tip (IT) and apical tip (AT) of each of the four teeth to the pterygoid midpoint marker (Figure 2j). In this manner, both crown movement and root torque could be determined.

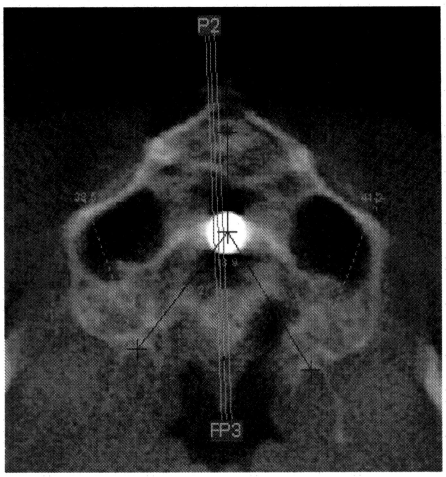


Figure 2i. (Level 1, Figure 2b). Anterior retraction measurement preparation. Sagittal cut through center of right incisor root and midpoint of pterygoid depths.

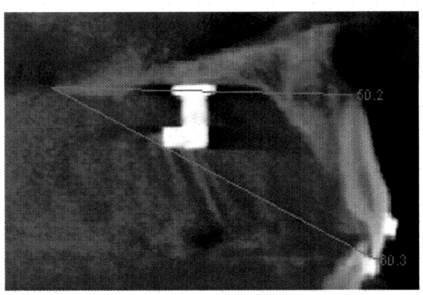


Figure 2j: Resulting sagittal image from Figure 2i.
Incisal and apical tips of anterior teeth measured to midpoint of pterygoid depths.

Palatal Dimensions

A. Surgical Interpalatal Width:

The skeletal interpalatal width and the palatal depth were measured in an effort to discern if there were any correlation between palatal dimensions and OnPlant failure. At the cross-sectional level of the superior portion of the OnPlant body, a transverse cut was made through the center of the OnPlant (Figure 2k). From the resulting frontal image, the interpalatal width was measured across the most superior skeletal surface of the palatal vault (Figure 2l)

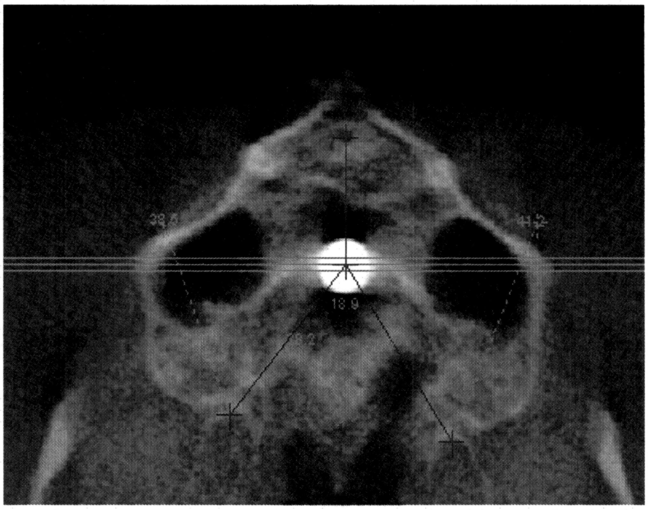


Figure 2k. (Level 1, Figure 2b). Skeletal interpalatal width measurement preparation.
Transverse cut through the center of the superior surface of the OnPlant.

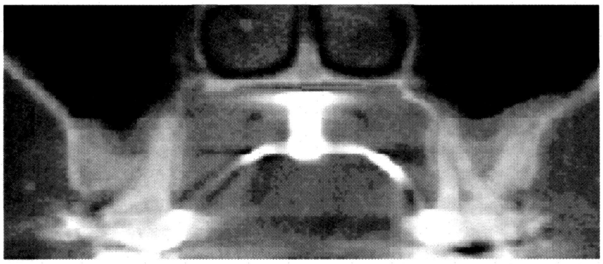


Figure 2l. Resulting frontal image of OnPlant from Figure 2k.
Skeletal interpalatal width. Measured from the most superior skeletal surface of palatal vault.

B. Palatal Depth:

To measure the interpalatal depth, a line was drawn connecting the cemento-enamel junctions of the first molars. A measurement was then made at a 90-degree angle from this line to the palatal vault crest (Figure 2m).

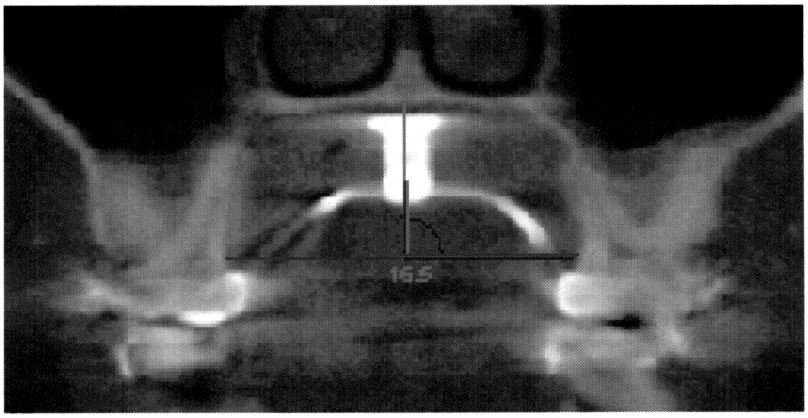


Figure 2m. Resulting frontal image from cut made in Figure 2k. Palatal depth. Measured at a ninety-degree angle from a line connecting the cementoenamel junctions of the first molars to the palatal vault crest.

Statistical Analysis

The reproducibility of the initial and final measurements taken on the NewTom over three trials was evaluated using intra-class correlation coefficients with absolute agreement. Initial and final data for the measurements describing OnPlant movement, molar movement, anterior tooth crown retraction and anterior tooth root retraction were evaluated with an Omnibus test to determine if there were any significant differences among the measurements. A series of post hoc tests were then run between the individual variables to more specifically identify where the effects were located. Last, palatal dimension was compared to both molar movement and OnPlant movement using Pearson's analysis to test for linear associations.

RESULTS

The reproducibility of the initial and final measurements made on the NewTom over three trials was evaluated using intra-class correlation coefficients with absolute agreement. All but one measurement demonstrated reliability coefficients in excess of 0.99. The measurement from the incisal tip of the left canine to the midpoint of the left pterygoid depth displayed a reliability coefficient of 0.95. Due to the high reproducibility between the scores, all subsequent analyses were conducted on the average of the three measures. Table 1 lists the means and standard deviations for the changes in absolute values of the individual measurements during treatment (Pre to Post).

An Omnibus test performed at a significance level of 0.05 on OnPlant movement, molar movement, anterior crown retraction and anterior root retraction found significant differences among the measurements. To further distinguish where these effects were located, a post hoc test was performed, also at a significance level of 0.05. The results of this test indicated that the crown and root movement of the anterior teeth affected both OnPlant and molar movement ($p < .001$). No significance was found between OnPlant movement and molar movement, however.

Pearson's analysis found no linear correlation between palatal dimension (surgical interpalatal width and palatal depth) and OnPlant movement. Likewise, palatal dimension had no effect on molar movement.

Data representing absolute values of OnPlant movement, molar movement, anterior crown retraction and anterior root retraction was plotted for each of the seven subjects individually (Graph 1, Tables 1 and 2). In this way, an understanding of the OnPlant and molar performance could be evaluated in conjunction with the particular treatment circumstances of each patient. The results for the seven subjects represented in

Graph 1 can be better understood when examined simultaneously with the case histories (see addendum). The crown and root retraction for each patient was dependent on several factors including the amount of crowding present initially. The absolute mean amount of accumulated OnPlant movement over the three measurements taken was less than 0.9 millimeters for all patients. This falls beneath clinical relevance and error of the method. Only two subjects displayed significant molar movement. Subject 6's absolute mean molar movement was 2.1 millimeters and Subject 4, whose OnPlant failed near the end of treatment, displayed an absolute mean molar movement of 3.3 millimeters. Graph 2 compares the absolute movement in treatment of all seven patients to further illustrate the difference in OnPlant and molar movement as compared to crown and root movement.

Table 1. Descriptive statistics (absolute values) for the change in individual measurements during treatment (Pre to Post)

MEASUREMENTS	MEAN	STD DEV
ONPLANT MOVEMENT		
SCO to CIC	0.18	0.08
SCO to PD-R	0.22	0.19
SCO to PD-L	0.34	0.19
MOLAR MOVEMENT		
Intermolar width	0.20	0.15
AMT-R to PD-R	0.38	0.58
AMT-L to PD-L	0.75	0.65
AT-R of palatal root of 1st molar to PD-R	0.43	0.36
AT-L of palatal root of 1st molar to PD-L	0.44	0.33
ANTERIOR CROWN MOVEMENT		
IT-R of central incisor to MPD	2.12	1.84
IT-L of central incisor to MPD	2.27	1.91
IT-R of canine to MPD	2.75	1.79
IT-L of canine to MPD	2.96	1.26
ANTERIOR ROOT MOVEMENT		
AT-R of central incisor to MPD	2.12	1.52
AT-L of central incisor to MPD	1.94	1.38
AT-R of canine to MPD	0.63	0.45
AT-L of canine to MPD	1.32	0.91

Graph 1. Absolute Values of Movement in Treatment. Collective values of OnPlant, molar, anterior crown and anterior root movement are composed of measurements listed in Table 1.

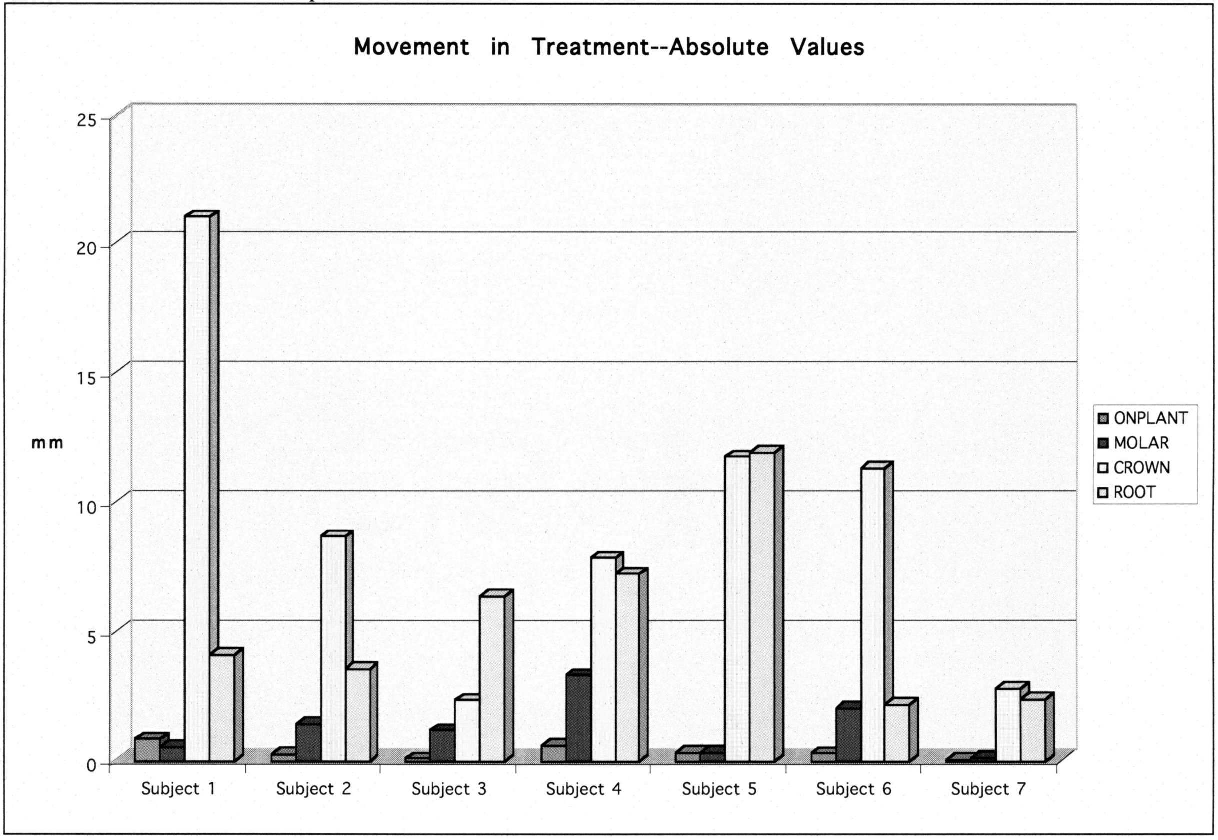
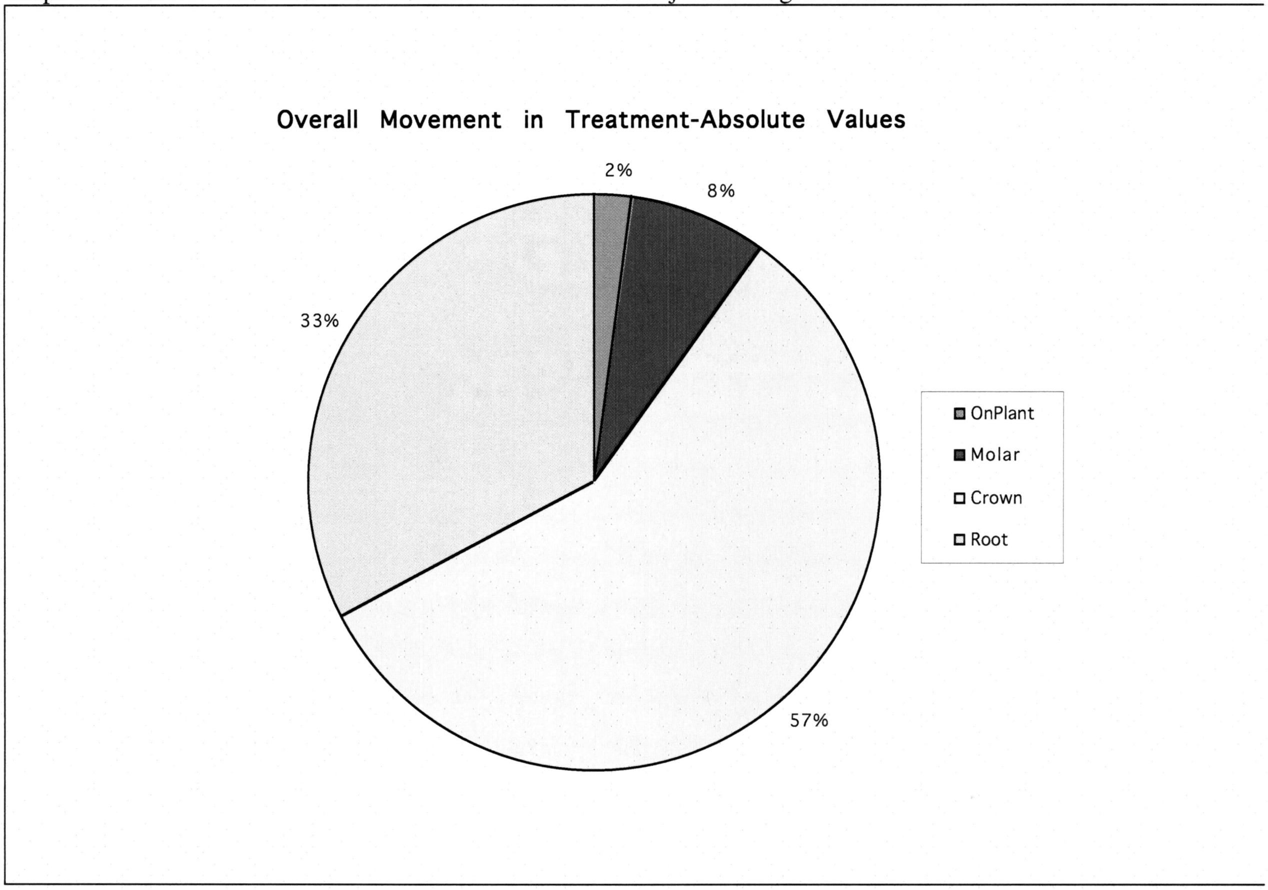


Table 2.
Absolute values of movement in treatment as plotted in Graph 1. Means and standard deviations included

	ONPLANT MVMT	MOLAR MVMT	CROWN MVMT	ROOT MVMT
Subject 1	0.87	0.53	21.07	4.10
Subject 2	0.27	1.43	8.70	3.57
Subject 3	0.10	1.20	2.37	6.37
Subject 4	0.60	3.33	7.87	7.23
Subject 5	0.33	0.33	11.77	11.97
Subject 6	0.30	2.07	11.33	2.20
Subject 7	0.07	0.13	2.80	2.40
Mean ± std dev	0.36 ± 0.28	1.29 ± 1.13	9.41 ± 6.34	5.40 ± 3.46

Graph 2. Absolute values of overall movement of the seven subjects throughout treatment.



DISCUSSION

Study design

The decision to reconstruct the data from the NewTom parallel to the OnPlant body was made in an effort to create consistent reference points from the initial and final records for each subject. It is conceivable that tilting or flexure of the OnPlant body could have occurred in the event of OnPlant failure; however, movement in this direction by the OnPlant would be minimal unless osseointegration did not occur at the start of treatment. In addition, the skeletal landmarks (center of the incisive canal and depths of the pterygoid plates) would remain consistent in the case of OnPlant flexure alone. Therefore, the easily discernable, radioopaque OnPlant body was considered to be the most accurate reference point for data reconstruction.

No effort was made to standardize the method of retraction or amount of force delivered during retraction between the different subjects. Three different clinicians treated the subjects, each using individual methods. Orthodontic retraction technique is not under investigation in this study.

Whereas the method used here to evaluate incisor retraction was thought to be fairly accurate, the same technique employed to measure canine retraction was not as reliable. Canine movement was measured along a straight path, however, true canine retraction occurs along a curved arc, the exact path depending upon the individual patients arch form. Despite the slight error in measurement of canine retraction, this method of measurement was thought to provide adequate information to compare the amount of retraction to molar anchorage loss.

Limited time allowed only partial treatment of three of the subjects. The premature, final records taken on these patients were able to provide valuable information about the performance of the OnPlant thus far. Future data gathered from these three subjects following completion of OnPlant use will be included in studies designed to evaluate other skeletal anchorage devices.

Results

The molar movement present in Subject 4 can be explained by the fact that the OnPlant failed near the end of the retraction phase of treatment. No appreciable movement of the OnPlant occurred in this same patient, however. It is possible that a pure tipping of the OnPlant-transpalatal bar unit occurred following OnPlant failure, resulting in a mesial movement of the molars. The tipping motion alone of the OnPlant body would not be revealed when measuring from the superior center of the OnPlant to the skeletal landmarks.

The molar movement revealed in Subject 6 is more difficult to explain. No obvious loss of molar anchorage was detected clinically in this patient. It is possible that at the seating of the OnPlant-transpalatal bar unit, a perfect fit between both the molar bands and the hexagonal attachment interface of the OnPlant abutment did not occur. Even a slight torquing action of the transpalatal bar to gain alignment of the hexagonal interface could result in orthodontic movement of the molars.

The lack of significance between OnPlant movement and molar movement can be supported by previously discussed explanations: 1.) The possible tipping action (versus pure mesial migration) of the OnPlant-transpalatal bar unit at appliance failure and 2.) torquing of the OnPlant-transpalatal bar to gain alignment of the hexagonal interface at the time of appliance cementation.

Future Research

The NewTom has the capability of demonstrating gray-scale measurements. With the 8-bit technology of the NewTom the gray scale values are represented in the range of 0 – 256. Once calibrated this may prove to be useful. These gray-scale values, or contrast comparisons, may represent a fairly accurate estimate of bone density. As an adjunct to the measurements taken for this study, gray scale values were collected of the bone through which the canine was retracted. Some clinical consistencies in gray-scale averages to bone density were noted - for instance, a particularly high gray-scale average was found in an area where clinically the extraction space was difficult to close; however, ongoing research will reveal whether or not this method of evaluating bone density is reliable.

CONCLUSIONS

The conclusions from this study are as follows:

1. Clinically, the OnPlant provided the maxillary molars sufficient stability, or anchorage, to withstand the forces of retraction of the anterior teeth following maxillary premolar extraction.

2. Sufficient anchorage was provided by the OnPlant to help prevent any unwanted molar movement during torquing of the maxillary incisors.

3. Analysis of the measurements taken on the NewTom revealed a loss of molar anchorage in two of the patients, however retraction of the anterior teeth was not jeopardized.

4. The NewTom proved to be a consistent and reliable tool to measure the effects of the OnPlant during treatment.

Due to the advantages the NewTom holds over the lateral cephalogram in patient analysis (i.e. the ability to measure right and left sides individually and the ability to view all structures in three dimensions), it should be considered a standard evaluation method for future research in this area. Use of the OnPlant and other such absolute anchorage devices during orthodontic treatment is likely to become more widespread as exposure to the benefits of such appliances is gained throughout the orthodontic community.

ADDENDUM

Case Histories

RETRACTION/TORQUE COMPLETE

Patient 1:

Patient 1, a 19-year-old Caucasian male, presented to the Orthodontic clinic with a full-step Class II molar relationship, an overbite of 85%, and a 10-millimeter overjet. There was no crowding in the mandibular arch and 7 millimeters of spacing in the maxillary arch, partially due to the presence of peg laterals. The patient had a relatively straight profile.

Following maxillary first premolar extractions and placement of the OnPlant anchorage device, the canines and incisors were fully retracted, leaving spacing mesial and distal to the laterals for future bondings. The OnPlant was removed after 12 months when no further retraction or torquing of the incisors was necessary. The treatment was detailed with vertical elastics for three months and debanded. No loss of molar anchorage was detected clinically.

Patient 2:

Patient 2, a 21-year old Caucasian female presented to the Orthodontic clinic with a full-step Class II molar relationship, an overbite of 10%, and a 7 millimeter overjet. Her soft tissue profile was mildly concave. She had 4 millimeters of crowding in the mandibular arch and 8 millimeters of crowding in the maxillary arch. The patient refused the option of orthognathic surgery.

Following extractions and placement of the OnPlant anchorage device, canines and incisors were fully retracted. During the retraction process, undesirable lingual tipping of the incisors occurred. An auxiliary torquing archwire was placed and allowed to act for a period of 4 months. The OnPlant was removed after 11 months of active retraction and torquing of the maxillary incisors. No loss of molar anchorage was detected clinically.

Patient 3:

Patient 3, a 13-year old Caucasian female, presented to the orthodontic clinic with a Class II molar relationship, an overbite of 5%, and a 9 millimeter overjet. She had 3 millimeters of crowding in the mandibular arch and none in the maxillary arch. Her soft tissue profile was moderately convex.

Following extraction of the first premolars, the patient was instructed to wear headgear for maximum anchorage control. The patient was not cooperative and the decision was made to use the OnPlant to eliminate the need for patient compliance. Active retraction ceased until the OnPlant anchorage device could be cemented. The canines were retracted the remaining distance and the incisors were fully retracted. The OnPlant anchorage was used for an additional 3 months while inter-arch elastics were used to shift the mandibular arch to correct the 3 millimeter mandibular midline discrepancy. The OnPlant was removed after 7 months when all retraction was complete and the mandibular midline was 1 millimeter overcorrected. The patient is in the finishing stage of treatment. An initial 2 millimeter loss of molar anchorage occurred due to noncompliance with the headgear, however no further loss of anchorage was noted following placement of the OnPlant anchorage device.

Patient 4:

Patient 4, a 19-year old Caucasian male, presented to the orthodontic clinic with a full-step Class II molar relationship, an overbite of 20%, and an overjet of 7 millimeters. There was 4 millimeters of crowding in the mandibular arch and 8 millimeters of crowding in the maxillary arch. The soft tissue profile was straight.

Following extraction of maxillary first premolars and placement of the OnPlant anchorage device, the canines and incisors were fully retracted. The retraction phase of treatment was 6 months in length. The OnPlant failed after 5 months of treatment and a 1 millimeter loss of molar anchorage was noted clinically. The OnPlant was removed, and Class II elastics were used to correct the anchorage loss. The patient is in the final finishing stages of treatment.

RETRACTION/TORQUE INCOMPLETE

Patient 5:

Patient 5, a 34-year-old Hispanic female, presented to the Orthodontic clinic with missing mandibular right first and second molars and the mandibular left first molar. She had a Class II cuspid relationship, an overbite of 60% and an overjet of 4 millimeters. There was 3 millimeters of crowding in the mandibular arch and no crowding in the maxillary arch. She had a full profile with mentalis strain.

A pin implant was placed in the mandibular right molar region to use as a fulcrum for intrusion of the mandibular incisors. Following extraction and placement of the OnPlant anchorage device, the canines were fully retracted and the incisors were retracted 2 millimeters. Treatment is still in progress and further incisor retraction will be necessary once proper intrusion of the mandibular incisors is obtained. No loss of molar anchorage has been detected clinically.

Patient 6:

Patient 6, a 47-year-old African-American female, presented with a Class II, Subdivision right molar relationship, an overbite of 5% and a 2 millimeter overjet. She had no crowding in either arch. The mandibular midline was 6 millimeters to the right. Non-extraction orthodontic treatment had been performed previously, but the patient was not satisfied with her resulting protrusive profile. The decision was made to extract the maxillary first premolars and the mandibular left premolar.

Following extractions and placement of the OnPlant anchorage device, the maxillary canines were fully retracted into the extraction space. The incisors were retracted 2 millimeters. The treatment is still in progress. No loss of molar anchorage has been detected clinically.

Patient 7:

Patient 7, a 55-year-old Hispanic female, presented to the Orthodontic clinic with multiple restorations, a full-step Class II molar relationship, an overbite of 60% and an overjet of 6 millimeters. There was no crowding in the mandibular arch and 3 millimeters of crowding in the maxillary arch. The soft tissue profile was full.

The decision was made to extract the maxillary second premolars due to their deteriorating restorative condition. Following placement of the OnPlant anchorage device, retraction of the first premolars into the extraction space continued for 4 months. The treatment is still in progress. No loss of molar anchorage has been noted clinically

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