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THE EDITOR'S CORNER

Analog Meets Digital

Most practicing orthodontists, like me, tend to be rather conservative, sticking with time-proven techniques and procedures rather than jumping on board every new development that comes along. Of course, if all of us waited until new techniques had been accepted into general use before trying them out for ourselves, very little progress would be made in the profession.

JCO has always been a leader in clinical innovation. We were the first to publish an article proposing the use of intraosseous anchorage (Creekmore and Eklund's landmark, "The Possibility of Skeletal Anchorage", April 1983), almost 20 years before the first miniscrew appeared on the market. The eventual acceptance of this technique has opened possibilities for treatment outcomes that, in years past, could only have been accomplished through surgical intervention. Likewise, many of the myriad Class II correctors available today were introduced to the profession in the pages of JCO. While there is no doubt in my mind that a dedicated doctor who believes strongly in traditional techniques such as headgear and biteplates can still achieve excellent results in all but the most recalcitrant of patients, the widespread availability of non-compliance-dependent Class II correctors must be viewed as an advance for the clinical practice of orthodontics. The results speak for themselves.

Clinical innovation extends to diagnostic techniques as well. Giorgio Fiorelli, Enrico Pupilli, and Biagio Patanè described the advantages of digital photography and radiography in JCO as early as November 1998. I doubt that there are many old-fashioned cephalometric tracing boxes around any more; at this point, there is sufficient published research to validate the use of computerized cephalometric analysis in comparison to radiographic films and acetate tracing paper.

Of course, there are times when the latest innovation turns out to have significant flaws. Who can forget—at least among those of us old enough to remember—the debonding disasters of the first generation of all-ceramic brackets? That is clearly one situation in which caution proved to be a sensible approach. Today, cone-beam computed tomography seems to have fallen off from its initially enthusiastic level of reception around the world, most notably in the European Union, due to reservations about the cost-benefit ratio of the radiation doses involved. The jury still seems to be out on this one, and it may yet be a few years before a decision is reached.

In the current issue of JCO, Dr. David Paquette addresses a problem that has been created by a relatively new, and otherwise useful, orthodontic diagnostic technology. As Dr. Paquette points out, proprietary software programs now allow clinicians to examine and modify virtual models on their computer screens without having to resort to time-consuming impressions and painstaking setups of plaster models on gnathologic articulators. Dr. Sheldon Baumrind, a pioneer in occlusal analysis, recalls in an e-mail that "the gnathostatic method of preparing study casts, which was originally introduced in the 1920s, disappeared by the '40s as clinicians came to rely upon the lateral cephalometric x-ray. Incidentally, one of the technical problems in keeping gnathostatic study casts was that if you put them on a shelf, they would take up too much room. Another problem was that the upper cast would tend to slide down the lower cast along the sloped occlusal plane and fall off the shelf when the cabinet door was opened."

Although manipulation of virtual models is certainly easier and cleaner than gnathostatic mountings, these digital models seem to have a fundamental flaw, as noted by Dr. Paquette: improper orientation of the occlusal plane. I explored the clinical problems associated with the occlusal plane in an earlier Editor's Corner (JCO, September 2006). In this month's article, Dr. Paquette explains and illustrates the diagnostic errors that can result as a consequence of improper orientation of the occlusal plane in virtual treatment projections. Software designers will likely resolve this issue in the not-too-distant future, but in the meantime, Dr. Paquette presents a simple and reliable solution based on the time-tested, old-fashioned technique of facial photography. Innovative orthodontists who are already well advanced in virtual treatment planning will surely find Dr. Paquette's blend of digital and analog methodology to be ingenious. RGK

Efficient Tooth Movement with Early Full-Size Archwires

K. HERO BREUNING, DDS, PHD

Smaller stainless steel wires are traditionally used in the early stages of orthodontic treatment because of the need for flexibility, reduced friction, and lighter forces. These small round wires have a limited capability of correcting tooth positions in three dimensions, however, since close contact between the wire and the bracket slot is required for precise control (Table 1).

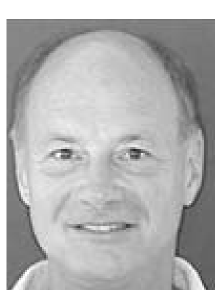
More than 30 years ago, Burstone introduced “variable-modulus orthodontics”, describing it as “a new approach to force control”. While the system “allows wire size to remain relatively constant”, “the material of the wire is selected on the basis of clinical requirements. When the material instead of the cross section is varied, superior orientation should be achieved with fewer wires during tooth alignment. . .”[1] Both Burstone[1] and Garrec and Jordan[2] suggest that the use of full-size starting wires will not necessarily increase forces or alter the biomechanics of orthodontic treatment.

Today, heat-activated superelastic rectangular wires with large cross-sections (such as the currently available Neo Sentalloy* and a new wire under development, Ultra Therm**) can deliver much lighter forces than smaller stainless steel wires (Fig. 1).[3] Therefore, it should be possible to use a full-size, .018" × .018" initial wire in an .018" slot when a force of 100g is adequate to move teeth and the wire deflection is less than 2.5mm. If an .022" slot size were used, the force of a full-size wire (.022" × .022") would be more than 100g, which would increase the likelihood of root resorption or at least patient discomfort. An .020" × .020" wire could be used, but that would create about 18° of play between the wire and the bracket slot, resulting in less three-dimensional control during the initial phase of treatment. Therefore, we prefer to use an .018" bracket system for early full-size wires.

Because we use self-ligating brackets, a square wire allows the bracket clips to be closed easily while still providing early torque control.[4] Starting with a larger rectangular wire would not only increase the force, but make it difficult to fit the wire in the bracket slots.

TABLE 1
ESTIMATED PLAY OF ARCHWIRE IN .022" BRACKET SLOT

Wire Size	Degrees of Play
Round	360°
.014" × .025"	65°
.016" × .025"	46°
.017" × .025"	39°
.018" × .025"	32°
.019" × .025"	24°



Dr. Breuning is an Assistant Professor in 3D Imaging, Department of Orthodontics and Dentofacial Biology, Radboud University, Nijmegen Medical Centre, Nijmegen, The Netherlands; e-mail: h.breuning@dent.umcn.nl.

*Trademark of GAC International, 355 Knickerbocker Ave., Bohemia, NY 11716; www.gacintl.com.

**Registered trademark of Ultimate Wireforms, Inc., 200 Central St., Bristol, CT 06010; www.ultimatewireforms.com. An .018" square Ultra Therm wire is under development.

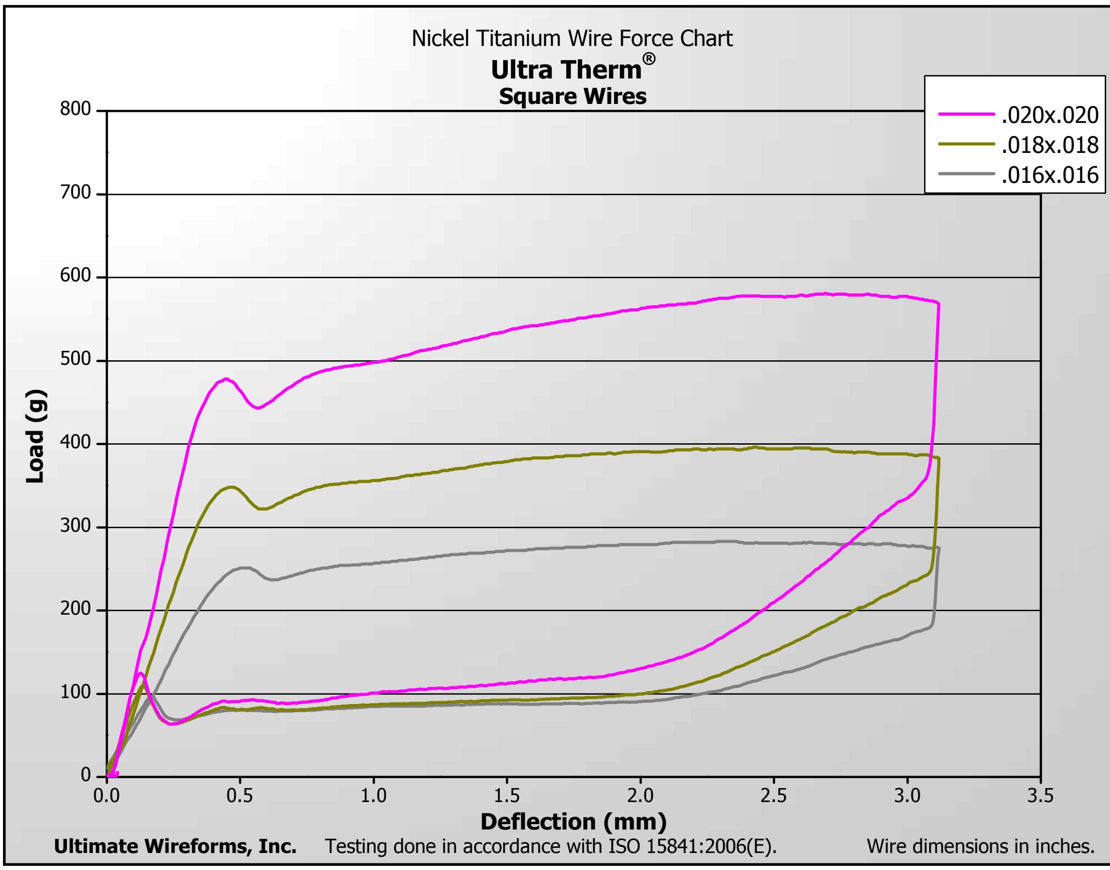


Fig. 1 Ultra Therm superelastic nickel titanium wires exert constant deflection (tooth-moving) force of about 100g if bending distance does not exceed 2.5mm. Near-horizontal orientation of upper (ligating force) and lower (tooth-moving force) graph line segments demonstrates superelasticity of wire. Forces begin and end at point 0, indicating that these wires have shape memory and will return to original archforms. (Image courtesy of Ultimate Wireforms, Inc.)

Fig. 2 Combination of traditional and early full-size wires in case using .018" Damon* self-ligating brackets: .014" flexible round wire in mandibular arch and .018" square wire in maxillary arch.**

Fig. 3 Patient with initial .018" square archwires in .018" interactive, self-ligating ceramic System C* brackets.

The two patients shown here are being treated with different self-ligating brackets. With passive brackets such as the Damon*** system, a super-flexible .018" square wire can be inserted in an .018" slot at the start of treatment (Fig. 2), with a cooling spray used to reduce the stiffness of the wire if necessary. If the clip cannot be closed over an .018" square wire, a super-flexible .016" square wire could be used, but its smaller cross-section will reduce the effectiveness of tooth movement and increase the number of wires needed during treatment. Full-size rectangular archwires can also be used at the beginning of treatment with .018" interactive self-ligating brackets such as the ceramic System C* (Fig. 3).

Discussion

The concept of early rectangular wires is not new: Alpern introduced a square-wire technique using full-size wires in .018" slots in 2008.[4] Unfortunately, at that time, the debate regarding friction in traditional vs. self-ligating brackets was in full swing, and the wires recommended by Alpern delivered higher forces than those described here. Considering that recent studies seem to indicate no difference in the rate of tooth movement between traditional and self-ligating brackets,[5] it appears that friction plays only a minor role. Of course, friction between the wire and the bracket slot increases with the size of the wire, but no clinical study to date has shown a reduction in sliding due to the use of rectangular wires. In one recent investigation, an increase in wire size did not increase friction in passive self-ligating brackets.[6]

It would be reasonable to expect that the amount of force delivered should affect the rate of tooth movement. In a systematic review, however, Ren and colleagues concluded that optimum force levels could not be determined from the literature.[7] Therefore, it seems unnecessary to select wires with incremental forces or to change archwires to increase the speed of tooth movement.

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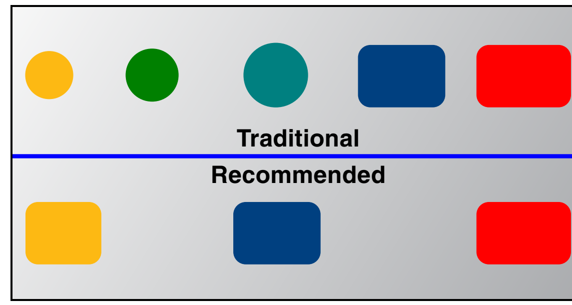

Fig. 4 Traditional wire sequence, with increasing cross-section, and recommended approach, using full-size wires of increasing stiffness to achieve superior results with fewer wire changes.

In our proposed treatment approach, the stiffness of the archwires is increased during treatment without changing the wire dimensions. According to Kusy, an .019" × .025" TMA*** wire has about one-third the stiffness of a stainless steel wire of the same size.[8] Increasing the wire stiffness will increase the force delivered, but as noted above, more force will not necessarily result in faster tooth movement.[4] In fact, Ren and colleagues found that increasing the frequency of reactivation (thus increasing the force) actually slows tooth movement.[9] As Burstone[1] and Alpern[4] have suggested, when stiffness is varied instead of the cross-section of the wire, superior results can be achieved with fewer wires (Fig. 4).

Orthodontists should recognize the advantages of the new heat-activated superelastic alloys, which are specifically designed to produce light and constant tooth-moving forces with outstanding resiliency. These wires can be used early in treatment because they are soft at room temperature, allowing easy ligation. Early use of full-size superelastic rectangular archwires with forces as low as possible (to avoid root resorption) and no reactivation should not only produce optimal tooth movement, but reduce complaints about post-reactivation pain. Longer appointment intervals and fewer wire changes should also be possible without losing three-dimensional control or extending treatment time.

This technique will improve the efficiency of treatment with preadjusted, self-ligating, and lingual brackets, as well as recently introduced customized systems such as Incognito† and Insignia.*** It seems illogical to start with a digital treatment plan, order custom brackets and wires, and then start treatment by using round archwires with 360° of play. In addition, when adjuncts such as elastics are used, compensating torque is often needed to counteract the forces of the elastics. Because the customized bracket systems do not allow compensating torque, early full-size wires are imperative.

It will soon be possible to present finished cases using our protocol for early rectangular wires, including both the currently available Neo Sentalloy and the newly developed Ultra Therm super-flexible rectangular wire. In any case, the efficacy of this new approach should be studied in randomized clinical trials.

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A Three-Dimensional Setup Model with Dental Roots

HONGMING GUO, DDS, PHD
JING ZHOU, DDS
YUXING BAI, DDS, PHD
SONG LI, DDS, PHD

Proper root alignment, an important standard in the evaluation of orthodontic treatment outcomes, is significantly affected by the accuracy of bracket placement. Adverse consequences such as non-parallel roots, fenestration, and dehiscence are difficult to prevent when the clinician plans only for alignment of the dental crowns.[1]

Indirect bonding can improve the accuracy of bracket placement, as can the use of three-dimensional study models and computer-aided design. Currently available digital models show only the dental crowns, however, without the roots. Of course, 3D images from cone-beam computed tomography (CBCT) include the dental roots, but they cannot provide the same accuracy in terms of crown surface detail as a digitized plaster model.

We have developed a method for accurately superimposing CBCT-based digital maxillofacial models and digitized study models. This article describes the procedure and illustrates its use in indirect bonding of lingual brackets.

Preparing the Digital Model

A CBCT scan was taken of the maxillofacial region of a patient scheduled for lingual orthodontic treatment, using a NewTom VGi scanner* with the following settings.
Volume: 15cm × 15cm
Settings: 1.2mA, 110kV
Scanning time: 3.6 seconds
Axial slice thickness: .25mm (600-610 images)
Radiation (dose area product): 33 micrograys/m^2
Voxel size: .3mm

*QR srl, via Silvestrini 20, 37135 Verona, Italy; www.qrverona.it. Distributed by ImageWorks, 250 Clearbrook Road, Suite 240, Elmsford, NY 10523; www.imageworkscorporation.com.


Dr. Guo


Dr. Zhou


Dr. Bai


Dr. Li

Dr. Guo is an Assistant Professor, Dr. Zhou is a resident, and Drs. Bai and Li are Professors, Department of Orthodontics, Beijing Stomatological Hospital, Capital Medical University, 4 Tiantanxili, Dongcheng District, Beijing 100050, China. Dr. Zhou is also a staff orthodontist, Department of Orthodontics, Benq Hospital, Nanjing, China. Contact Dr. Guo or Dr. Li at hongming_guo@yahoo.com.cn.

The images were saved in DICOM format, and maxillofacial models were reconstructed using Mimics 10.0** software (Fig. 1). The upper and lower dental arches were digitally separated from the rest of the skeleton.

A two-phase polyvinyl siloxane impression was taken of each arch, and plaster casts were poured. The casts were scanned with a 3D Shaderlight scanner*** at a resolution of .02mm, and digital dental models were reconstructed using Mimics software and viewed with OrthoDS 4.6**** (Fig. 2).

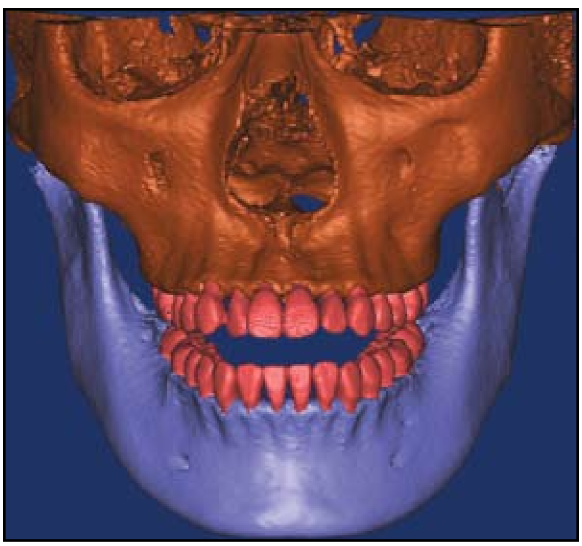

Fig. 1 CBCT-generated maxillofacial model.

Before merging with the CBCT-generated maxillofacial models, the digitized dental models were modified using Mimics 10.0. The third molars were eliminated (since they would not be included in the bonding trays), and the excess base material was removed along a plane defined by the three highest gingival apices of the remaining teeth (Fig. 3). The modified dental model was merged with the 3D maxillofacial model by aligning the three gingival points, which defined the cutting plane in each digital version (Fig. 4). The CBCT-generated crowns were then eliminated, so that the resulting model was composed of CBCT-generated roots and the crowns from the digitized dental model (Fig. 5).

**Materialise, Technologielaan 15, 3001 Leuven, Belgium; www.materialise.com.

***Breuckmann GmbH, Torenstrasse 14, 88709 Germany; www.breuckmann.com.

****EA, Inc., 1139 Lane, Pudong Ave., Shanghai, China; www.aibraces.com.

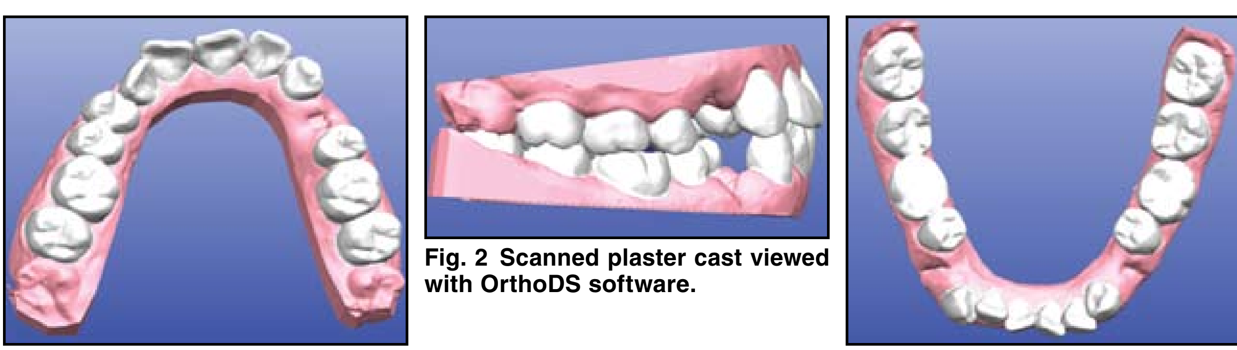

Fig. 2 Scanned plaster cast viewed with OrthoDS software.

Fig. 3 Modification of digitized maxillary dental model using Mimics software. A. Original model. B. After removal of third molars and excess base material.

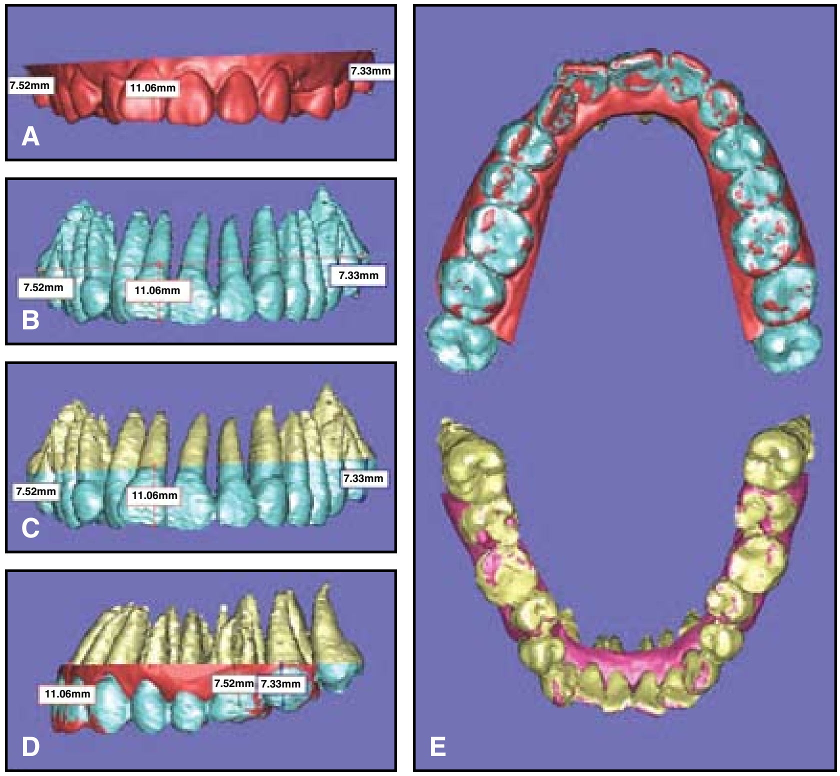

Fig. 4 Integration of digitized dental model with CBCT-generated maxillofacial model. A. Distances measured between three reference teeth, defining cutting plane of digital model. B. Measurements transferred to CBCT-generated model to duplicate cutting plane. C. Sections of CBCT model above and below cutting plane displayed in different colors. D. Superimposition of two models. E. Occlusal views after superimposition.

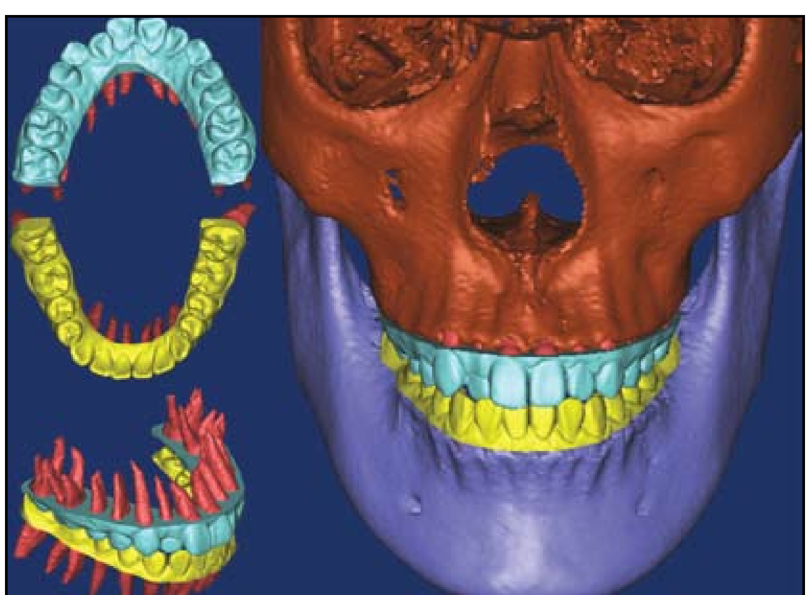

Fig. 5 CBCT-based crowns eliminated from merged models; occlusal relationship generated by software.

To confirm the accuracy of this method, we measured the discrepancies between the digital dental models and 3D maxillofacial models of 10 patients after integration, using Rapidform 2006 software.† Differences were measured at all points along the fused plane on the integrated model. The average discrepancy was .159mm (± .0265mm) in the maxilla and .151mm (± .0337mm) in the mandible (Fig. 6).

After model integration, each tooth was digitally separated to enable individual movement using OrthoDS (Fig. 7). The resulting 3D setup allows the teeth and roots to be viewed with or without the jaws, so that both bone mass and root parallelism can be evaluated (Fig. 8).

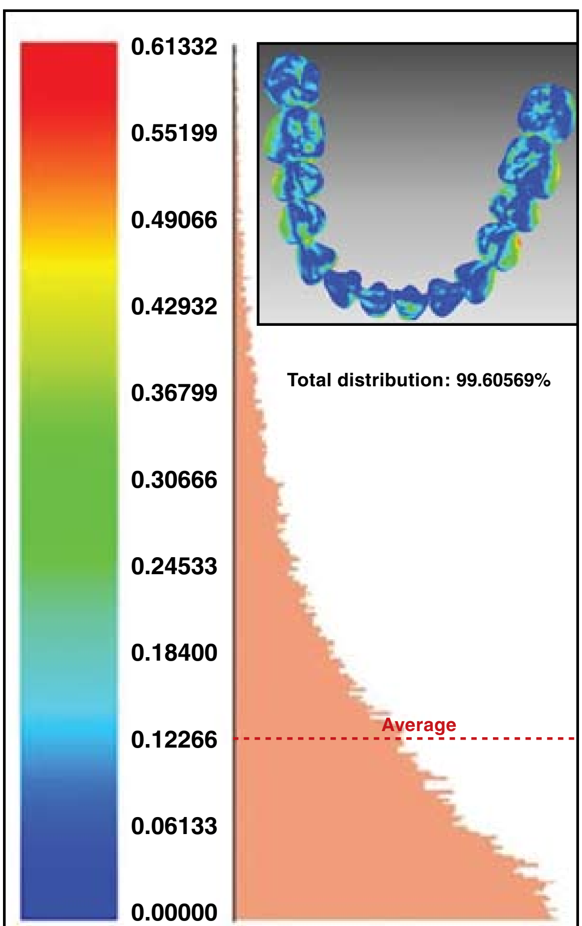

Fig. 6 Average discrepancies between digitized dental and CBCT models (lower arch) in 10 patients after model integration, with differences ranging from 0mm (blue) to .55mm (red).

Indirect Bonding Procedure

We designed a virtual lingual bracket‡ body and .022" × .016" lingual wire using SolidWorks CAD software.†† After the lingual archwire was positioned in the 3D setup, the virtual brackets were placed so that the slots and archwire were fully engaged, with the bracket centered on the horizontal plane of each tooth (Fig. 9).

Each tooth was digitally bonded to its corresponding bracket, and the entire dentition was moved back into the original malocclusion (Fig. 10). From this data, an acrylic model was fabricated using laser rapid-prototyping technology, and vacuformed dual-layer bracket transfer trays were produced (Fig. 11). The inner layer is 1mm Bioplast,‡‡ which has enough flexibility and soft-

†Registered trademark of Rapidform, Inc., 1185 Bordeaux Drive, Suite A, Sunnyvale, CA 94089; www.rapidform.com.

‡3D lingual bracket, Forestadent USA, 2315 Weldon Parkway, St. Louis, MO 63146; www.forestadentusa.com.

††Dassault Systèmes SolidWorks Corporation, 300 Baker Ave., Concord, MA 01742; www.solidworks.com.

‡‡Registered trademark of Scheu Dental, Iserlohn, Germany. Distributed by Great Lakes Orthodontics, Inc., 200 Cooper Ave., Tonawanda, NY 14150; www.greatlakesortho.com.

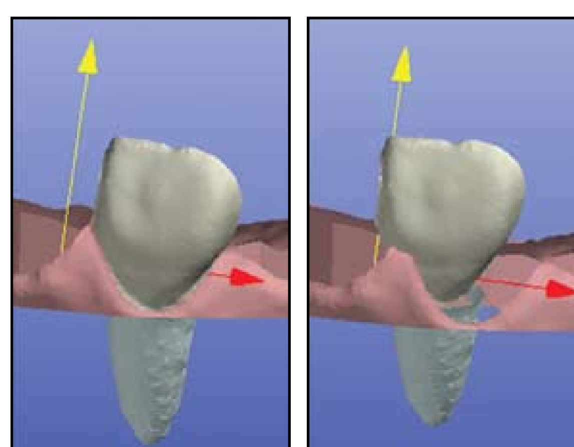

Fig. 7 Individual movement of central incisor after model integration.

ness to wrap the bracket tightly; the outer layer is 1mm Biocryl,‡‡ which is hard enough to prevent deformation and shifting of the inner layer.

At the bonding appointment, after routine tooth preparation, brackets were placed in the upper and lower transfer trays and coated with adhesive, and the trays were placed in the patient's mouth (Fig. 12A). After light-curing, the trays were cut into three sections to avoid dislodging the brackets during removal (Fig. 12B).

Progressive bonding can be used if indicated by crowding or rotations, as in the patient shown here. In such a case, digital models and transfer trays are produced for two different points in treatment. Crowded or severely rotated teeth remain unbonded until after leveling (Fig. 10A), when a

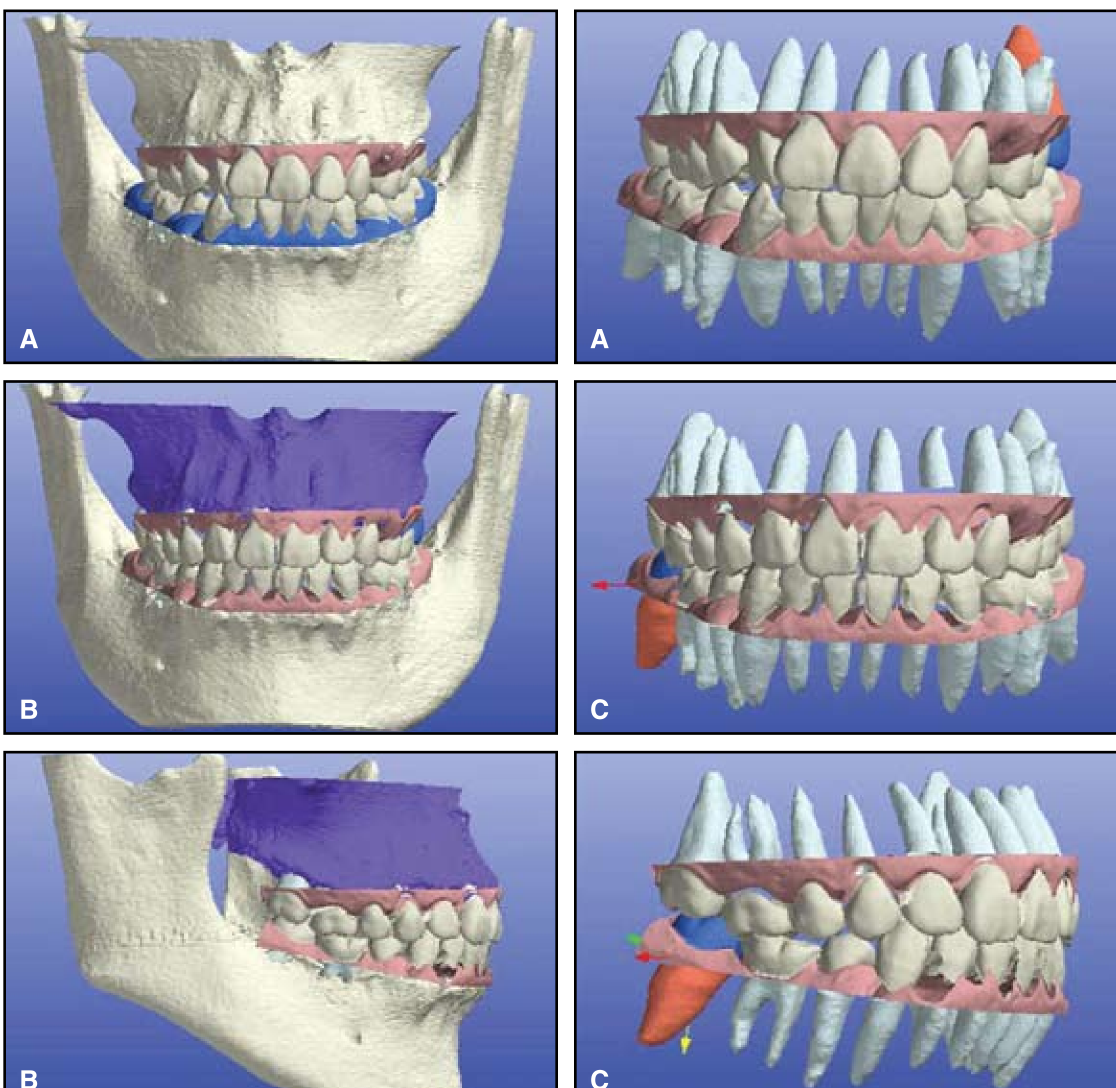

Fig. 8 Three-dimensional setup procedure. A. Original 3D model with and without jaws. B. Digital setup with jaws retained to evaluate alveolar bone mass after tooth movement. C. Jaws eliminated to allow assessment of post-treatment root parallelism.

second set of transfer trays is fabricated with brackets only for the unbonded teeth (Fig. 10B).

Discussion

Although the theory of straightwire appliances holds that crowns and roots will align properly as long as the bracket positions are accurate, this is not always the case.[2] Non-parallel roots increase the risk of periodontal damage and undesirable tooth movement under occlusal loads.[1] They can negatively affect long-term stability and may increase the possibility of space reopening, especially when there are non-parallel roots on both sides of an extraction site.[3]

Shpack and colleagues found that indirect bonding was significantly more accurate than direct bonding of both labial and lingual brackets.[4] Because precise bracket positioning is especially critical in lingual orthodontics,[5] many recent innovations have focused on improving transfer techniques.[6,7] Developments in computer-aided design and 3D modeling now make it possible to avoid time-consuming tooth separation, mounting of casts, bracket positioning, and light-curing.[5,8] In addition, a digital setup model can easily be moved back into the original malocclusion, and transfer trays can be fabricated for any point in treatment.

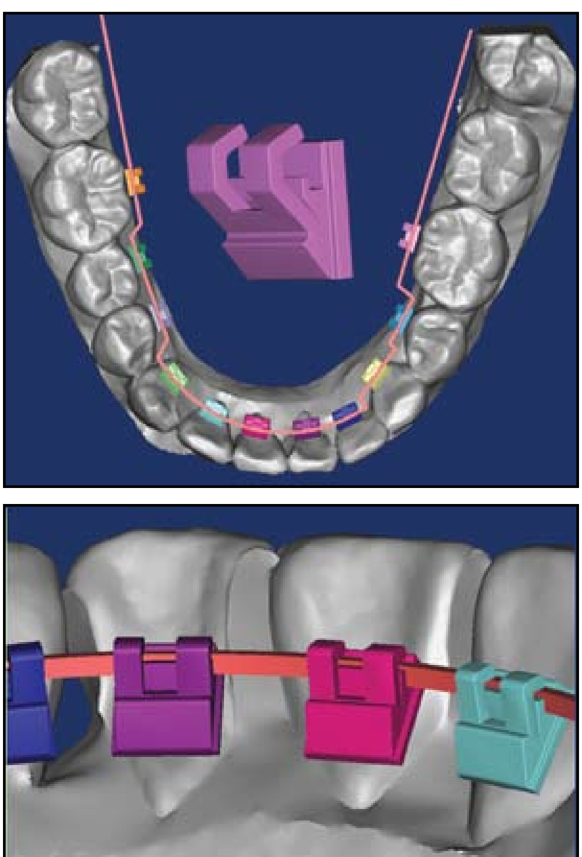

Fig. 9 Virtual lingual brackets and wires placed on digital setup models.

We used OrthoDS software, which was originally designed for the manufacture of invisible aligners, to align the arches and determine bracket positions in our digital setup. While commercial systems such as OraMetrix,§ OrthoCAD,§§ and Incognito§§§ can perform the same function,[9-11] currently available 3D study models do not include the roots.

Considering the accuracy of 3D digital systems,[12-16] it should not be difficult to incorporate 3D root and jaw data into the diagnostic design. Cevidanes and colleagues superimposed CBCT-generated skulls of the same patient, taken at different times, along the bone surface.[17] Enciso and colleagues superimposed separate OrthoCAD-scanned crowns over CBCT skeletal data.[18] Macchi and colleagues integrated entire laser-scanned models with CT images.[19] We followed the latter approach, although we superimposed the digitized dental model along a single plane on the CBCT-generated maxillofacial model instead of placing each tooth separately, which could cause unpredictable deviations. Landmarks of the remaining gingival-tissue data in the destructive-scanned models can also be used as references for model alignment. For consistency of measurement, we first superimposed the vertical plane, then adjusted the horizontal plane, and finally performed vertical fine-tuning. Our evaluation of 10 patients'

§Trademark of OraMetrix, Inc., 2350 Campbell Creek Blvd., Suite 400, Richardson, TX 75082; www.suresmile.com.

§§Trademark of Cadent, Inc., 640 Gotham Parkway, Carlstadt, NJ 07072; www.cadent.biz.

§§§Trademark of 3M Unitek, 2724 S. Peck Road, Monrovia, CA 91016; www.3Munitek.com.

integrated models confirmed that this superimposition method is reliable and accurate.

Although studies of radiation dosimetry are not directly comparable,[20] patient exposure from CBCT is within the same range as traditional dental imaging[21] and can be significantly lower than the radiation exposure from a complete series of radiographs.[20] The usual radiation dose of the NewTom CBCT unit used in our clinic is 33 micrograys/m^2, which is 20-50 times less radiation than that produced by a conventional medical CT, according to the manufacturer. Still, since there is some uncertainty and controversy regarding the use of CBCT in orthodontics, scanning should not be performed without good reason.

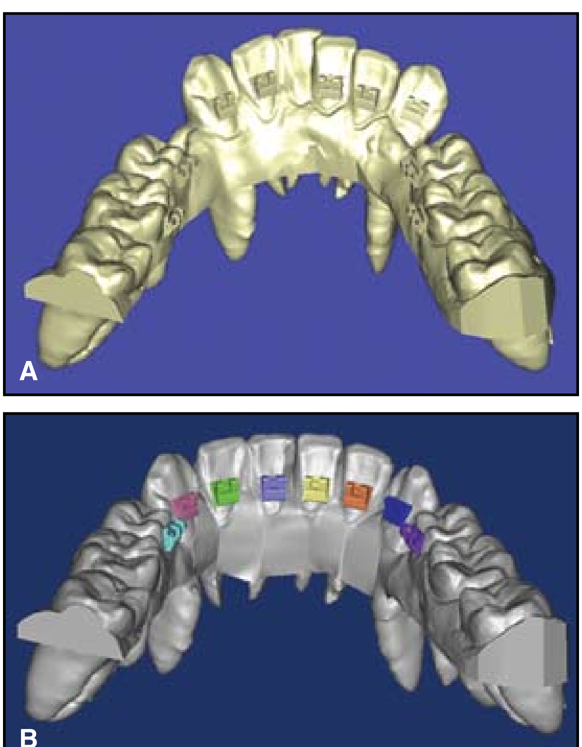

Fig. 10 A. Teeth and brackets moved back into original malocclusion (central incisor not included in initial bonding). B. Mid-treatment virtual setup for placement and bonding of central incisor bracket.

Conclusion

Treatment planning that accounts for positions of the roots and jaws can help ensure root parallelism and adequate alveolar bone thickness, thus avoiding root exposure and ultimately improving the orthodontic outcome. Our digital setup technique provides a clear view of the teeth, roots, and surrounding bone on the integrated digital model. Post-treatment root alignment and the anatomic relationships of surrounding bone are therefore easy to predict.

The bonding method shown here is applicable to either labial or lingual appliances.

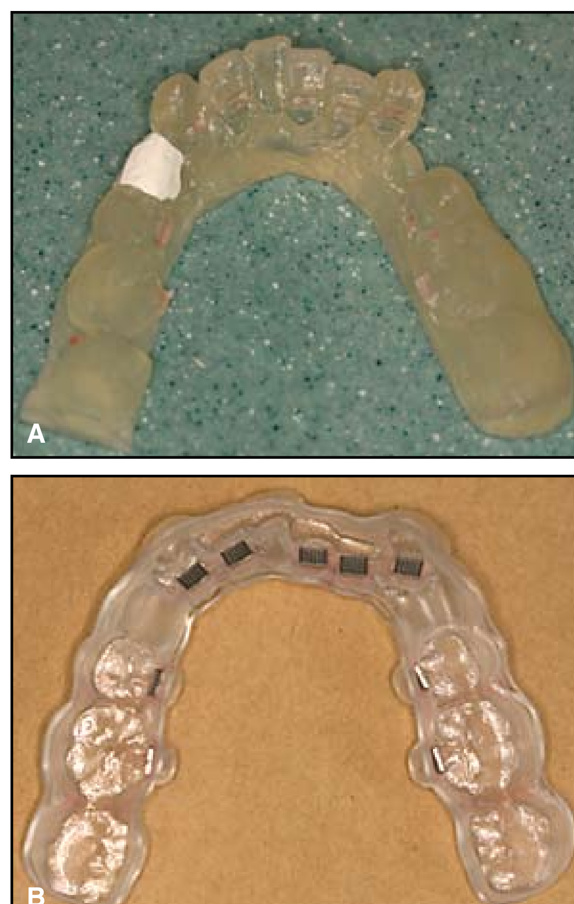

Fig. 11 A. Acrylic model of lower arch fabricated by laser rapid prototyping. B. Dual-layer transfer tray.

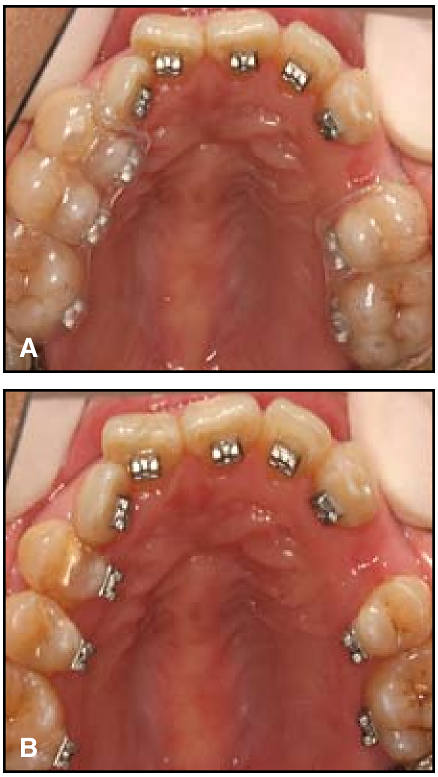

Fig. 12 A. Indirect bonding of upper arch. B. After removal of transfer tray in three sections.

Considering the precision required in bonding lingual brackets, we have found the technique particularly useful in lingual orthodontics.

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Importance of the Occlusal Plane in Virtual Treatment Planning

DAVID E. PAQUETTE, DDS, MS, MSD, FACD

Orthodontic diagnosis and treatment planning have recently moved into the digital realm, to the extent that virtual treatment projections have become commonplace. Several proprietary software platforms, including Invisalign ClinCheck,* OrthoCAD iQ,** and Ormco Insignia,*** allow clinicians to modify virtual models that are suspended in space on their computer screens. But there is a significant shortcoming in the basic design of the most commonly used programs: improper orientation of the occlusal plane. That is the fundamental flaw in the current process of virtual smile design.

For many years, when an orthodontist trimmed diagnostic study models, the bases of the models were trimmed parallel to the Frankfort horizontal plane, and the resulting occlusal plane was thus oriented to be a true representation of the patient's actual occlusal plane angle relative to Frankfort horizontal (Fig. 1). According to Downs, that angle ranges from 2° to 17°, with a mean of about 9° (Fig. 2).[2-7]

At some point, however, the standard changed so that study models were trimmed with the occlusal plane parallel to the floor (or desktop). That was because the upper model would frequently fall off the lower model and break if they were trimmed in the original manner. The new

Dr. Paquette is in the private practice of orthodontics at 8430 University Executive Park Drive, Suite 605, Charlotte, NC 28262; e-mail: davep@paquetteortho.com.

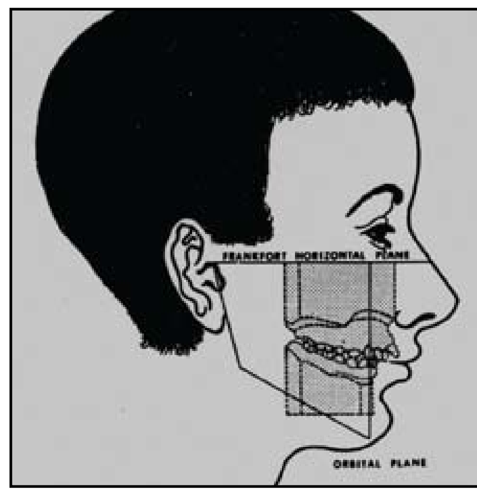

Fig. 1 Historic orientation of study models, with occlusal plane related to Frankfort horizontal (reprinted by permission[1]).

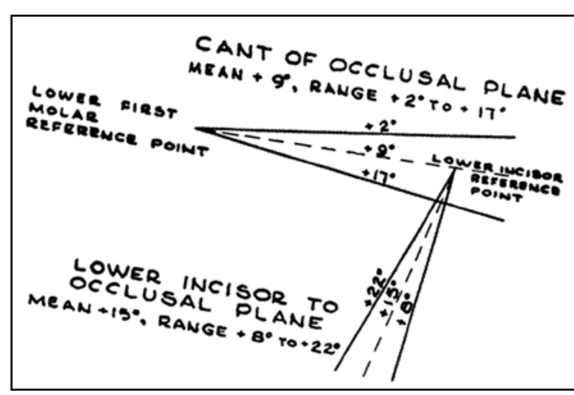

Fig. 2 Range of occlusal plane angles to Frankfort horizontal (reprinted by permission[4]).

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Fig. 3 Contemporary ABO standard for trimming study models.

Fig. 4 Contemporary virtual model orientation.

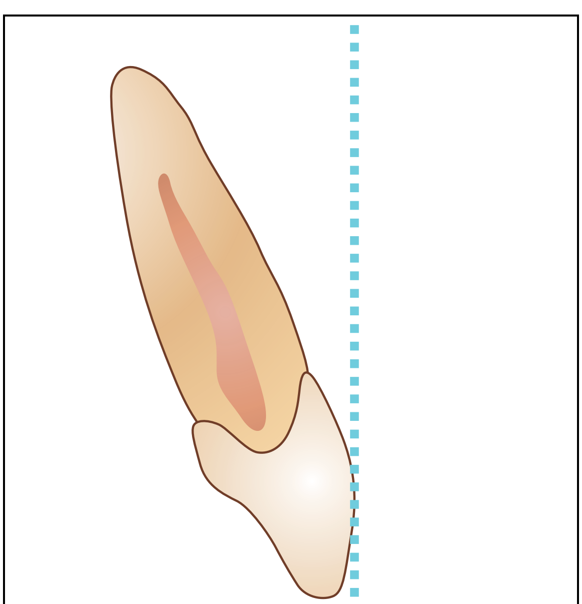

Fig. 5 Most esthetic incisor torque, with tangent to FA point perpendicular to floor.

method of trimming orthodontic models is now the standard for ABO case presentations (Fig. 3).[7]

Unfortunately, when software engineers designed the currently used virtual interfaces, they based the presentation of the virtual model on the contemporary method, with the occlusal plane parallel to the floor (Fig. 4). This results in a significant loss of information about the patient's torque requirements, smile arc, and axial inclinations.

Incisor Torque

To avoid the argument about whether Frankfort horizontal is the correct reference plane for torque calculations, let us stipulate that the most esthetic position of the upper central incisor is with a tangent to FA point perpendicular to the floor (Fig. 5).[8-10] This shows just how misleading the current virtual orientation can be in terms of the occlusal plane (Fig. 6). If the occlusal-plane-to-FA tangents for different occlusal plane angles are reoriented so that each occlusal plane is flat, it becomes obvious how much the torque of the incisors is affected (Fig. 7). If we reverse the process and set the incisor torque as desired and then reorient the virtual model to the correct occlusal plane, it is apparent that the end result is not going to be the desired result (Fig. 8).

By using the common virtual method of analysis, we are simply evaluating the intended end

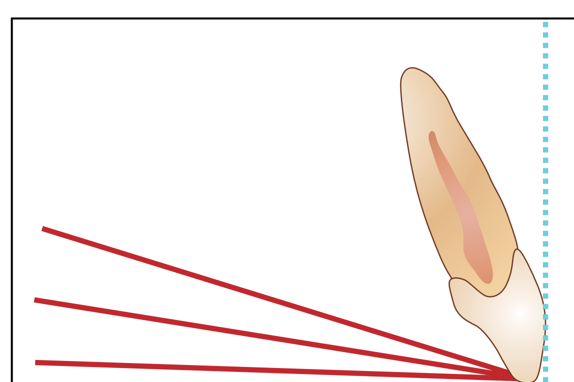

Fig. 6 Most esthetic incisor torque relative to three orientations of occlusal plane (flat, 8°, and 16°).

result independent of appliances or mechanics. For example, if we were treating a patient with a 16° occlusal plane angle with Invisalign (Fig. 9), we might conclude from the retroclined orientation of the incisors at the end of treatment that the aligners were unable to express torque correctly. In reality, the aligners probably delivered the requested torque, but that torque was incorrect due to the incorrect orientation of the virtual model during treatment planning. If we were using either OrthoCAD iQ or Insignia, the recommended torque in the brackets would be incorrect, but we would have the opportunity to place additional torque in the archwire. After treatment, we might draw the invalid conclusion that the software calculated the torque incorrectly, when it was actually the virtual treatment projection that was incorrect (Fig. 10).

The Smile Arc

Sarver and others have called our attention to the importance of the smile arc as a component of an attractive smile.[11,12] Parekh and colleagues have confirmed that both orthodontists and patients prefer a smile arc that is consonant with the lower lip.[13] When one views the typical virtual model

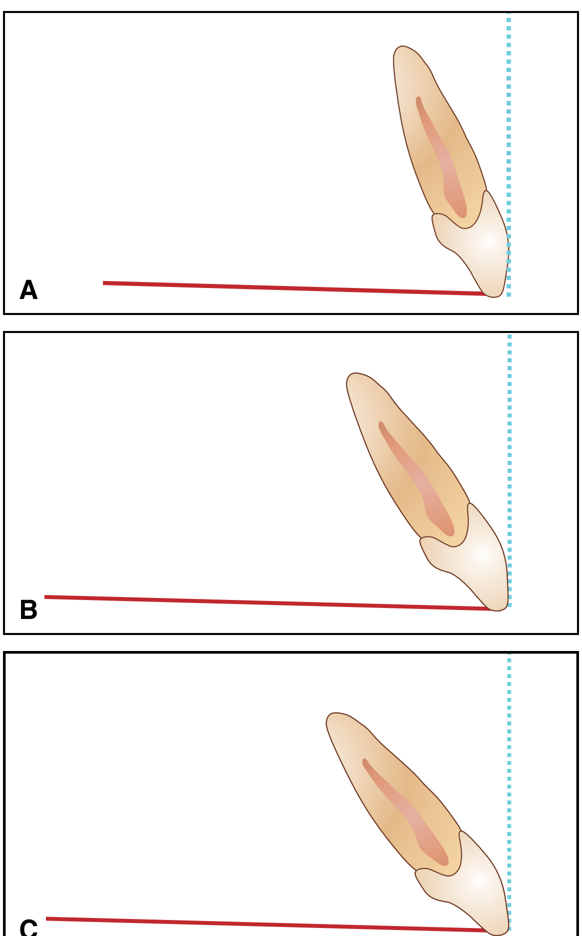

Fig. 7 Differences in incisor torque after reorientation of tangent to FA point, based on different occlusal plane angles. A. Flat. B. 8°. C. 16°.

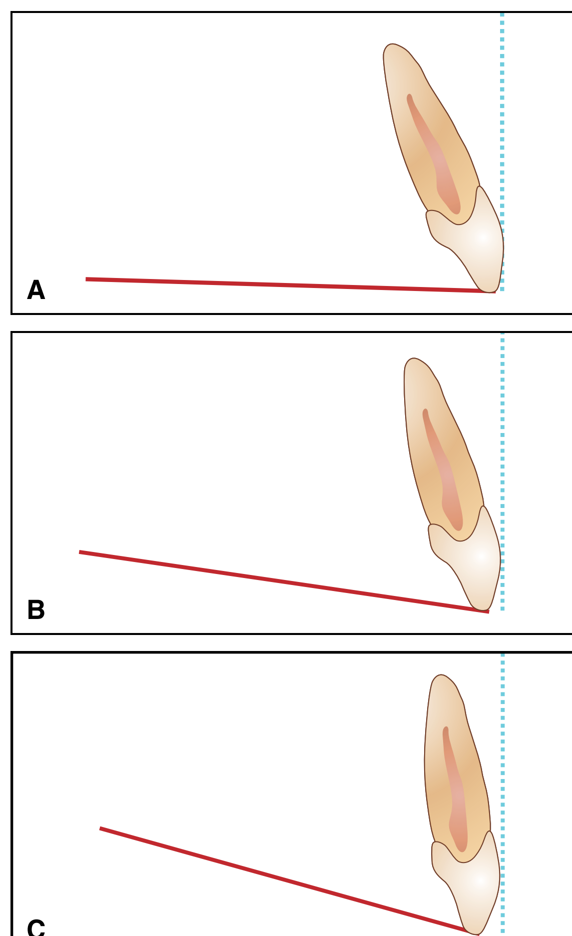

Fig. 8 Differences in incisor torque after reorientation of virtual treatment projections to actual occlusal plane angles. A. Flat. B. 8°. C. 16°.

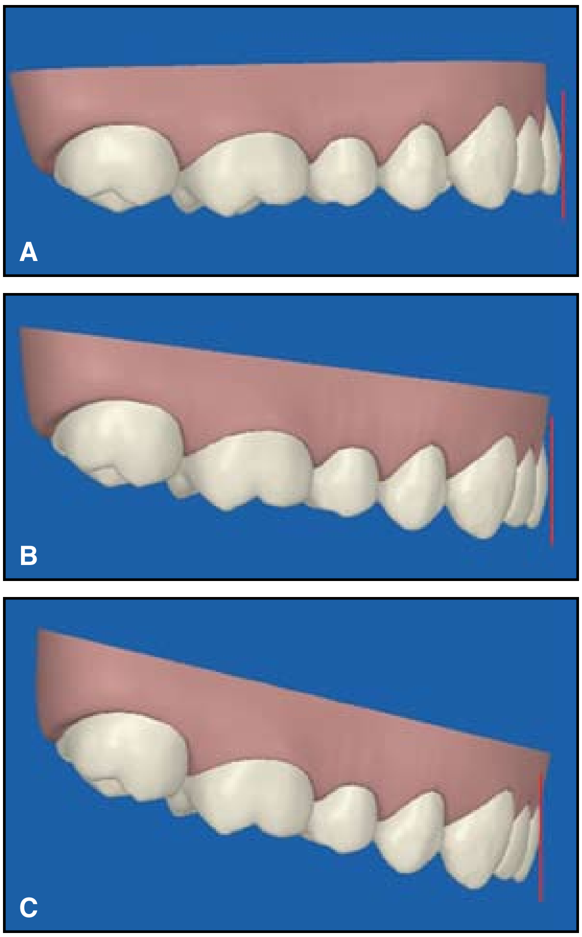

Fig. 9 Differences in incisor torque after reorientation of Invisalign ClinCheck* projections to actual occlusal plane angles. A. Flat. B. 8°. C. 16°.

setup from the anterior, it becomes obvious that the orientation of the occlusal plane directly affects the resulting smile display. For instance, if the orthodontist tried to adjust the smile arc according to a virtual setup with a flat occlusal plane, but the patient actually had a 16° occlusal plane angle, the result would be an overly accentuated smile arc (Fig. 11).

Axial Inclinations

Another area in which improper virtual model orientation can detrimentally affect treat-

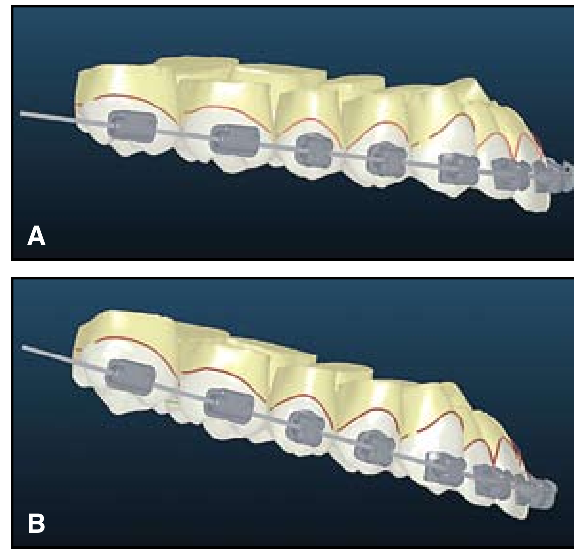

Fig. 10 Differences in Insignia*** system bracket torque with 8° (A) and 16° (B) occlusal plane angles.

ment outcomes is related to the cant, or what Ackerman and colleagues have called "roll".[12] If the "roll" of the virtual model is incorrect, then the axial inclination of the incisors may be inappropriately adjusted to the wrong position.

A Temporary Solution

Until software vendors are able to orient virtual models to the true occlusal plane— through the integration of a cone-beam or cephalometric radiograph, or at least by using the mean occlusal plane angle as a default—clinicians can use a simple and straightforward method for diagnosis. With the patient's smiling facial photograph as a reference, the virtual model should be reoriented so that the cusp tips of the canines and the first molars are in the same relationship as in the photograph (Fig. 12). Although not a perfect solution, it is a much better starting point for diagnosis than the current method of virtual orientation.

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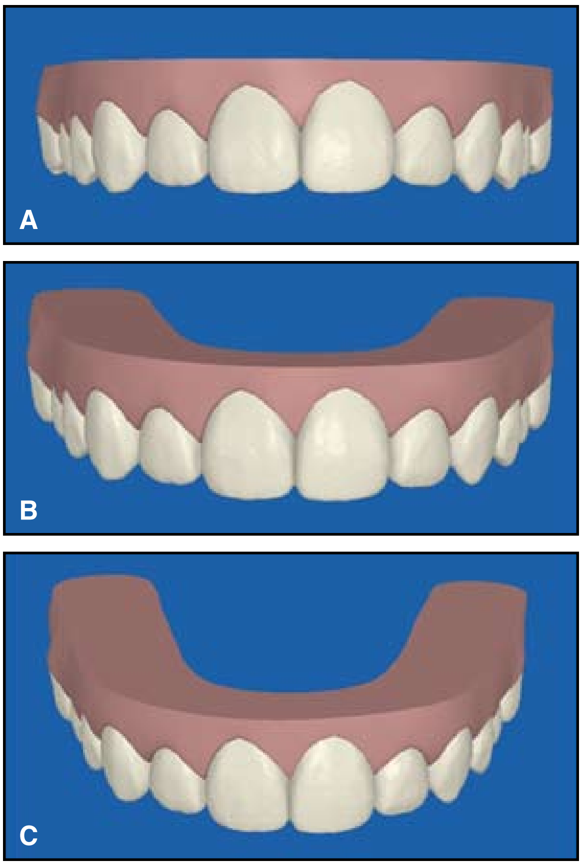

Fig. 11 Differences in smile arc in ClinCheck projections with different occlusal plane angles. A. Flat. B. 8°. C. 16°.

Fig. 12 A. Relationship of patient's canine and first molar cusp tips noted on smiling facial photograph. B. Orientation of ClinCheck virtual model corrected to match occlusal plane in photograph (compare Figure 4).

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CASE REPORT

Mandibular Molar Protraction with the Twin Force Bite Corrector in a Class II Patient

AMIRPARVIZ R. DAVOODY, DDS, MDS
JONATHAN FELDMAN, DDS, MS
FLAVIO A. URIBE, DDS, MDS
RAVINDRA NANDA, BDS, MDS, PHD

Nonextraction approaches to Class II treatment involve either distalization of the maxillary dentition or the use of functional appliances or elastics to achieve a Class I occlusion.[1,2] Extraction of mandibular teeth is not usually considered in a Class II case, since it makes treatment even more complex. In a Class II patient missing one or more mandibular molars, however, the orthodontist must decide whether to open space for a prosthodontic restoration or to protract the molar or molars distal to the edentulous space. Retraction of the teeth anterior to the edentulous space is generally ruled out because it would worsen the disto-occlusal relationship and overjet.

Mandibular molar protraction is one of the most difficult orthodontic movements to achieve, due to both anatomical factors and the problem of anchorage preservation. Although Coelho Filho's Mandibular Protraction Appliance has been one option,[3] many orthodontists have turned to temporary anchorage devices in recent years for treatment of such cases.[4,5] Another alternative is to use a push-type intermaxillary appliance such as the Twin Force Bite Corrector (TFBC)* to simultaneously correct the Class II malocclusion and serve as anchorage for protraction of a mandibular molar into the edentulous space.[6,7]

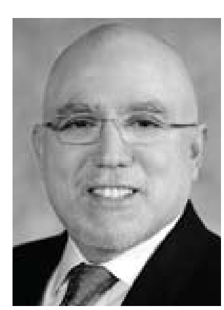
Each TFBC unit comprises

*Registered trademark of Ortho Organizers, 1822 Aston Ave., Carlsbad, CA 92008; www.orthoorganizers.com.


Dr. Davoody


Dr. Feldman


Dr. Uribe


Dr. Nanda

Dr. Davoody is a Clinical Instructor, Dr. Feldman is an Assistant Clinical Professor, and Dr. Uribe is an Associate Professor and Program Director, Division of Orthodontics, and Dr. Nanda is Professor and Head, Department of Craniofacial Sciences, Alumni Endowed Chair, School of Dental Medicine, University of Connecticut, Farmington, CT 06030. Dr. Uribe is a Contributing Editor and Dr. Nanda an Associate Editor of the *Journal of Clinical Orthodontics*. E-mail Dr. Nanda at nanda@uchc.edu.

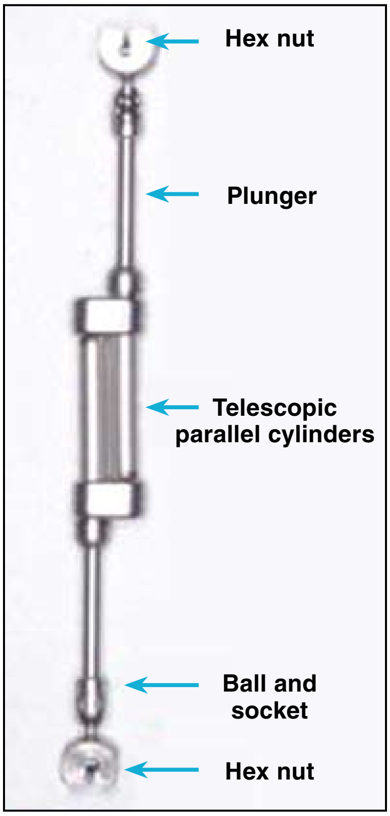


Fig. 1 Components of Twin Force Bite Corrector.

two parallel 15mm cylinders housing nickel titanium coil springs, with a plunger incorporated into each cylinder at opposite ends (Fig. 1). Hex nuts at the free ends of the plungers fix the appliance to the archwires mesial to the upper molars and distal to the lower canines. At full compression, the TFBC produces 210g of force at each end and postures the mandible forward into an edge-to-edge position. Considering the design and the amount of force delivered, it requires stiff base archwires, usually .019" × .025" or .021" × .025" stainless steel. To prevent spaces from opening, either the archwires must be cinched at the ends or the teeth must be tied together with stainless steel ligatures.

TABLE 1
CEPHALOMETRIC DATA

	Pretreatment	Post-TFBC	Post-Treatment
SNA	82.0°	80.0°	80.0°
SNB	81.0°	81.7°	81.0°
ANB	0.3°	–1.7°	–1.5°
Occ-FH	8.3°	5.6°	4.4°
SN-GoGn	16.8°	18.7°	17.6°
FMA	19.7°	22.2°	23.0°
U1-SN	105.4°	116.0°	108.0°
U6-PP	17.5mm	20.0mm	19.0mm
L1-APog	–1.3mm	2.6mm	0.0mm
IMPA	95.8°	96.9°	95.8°
L6-MP	24.4mm	24.4mm	24.4mm
G'-Sn-Pg	10.8°	9.4°	10.1°
UL-SnPg'	0.9mm	2.8mm	1.5mm
LL-SnPg'	0.0mm	0.8mm	0.2mm

This article illustrates the use of the TFBC for simultaneous Class II correction and anchorage for molar protraction in a growing patient.

Diagnosis and Treatment Planning

A 14-year-old male presented to our orthodontic clinic with a chief complaint of the appearance of his maxillary canines (Fig. 2, Table 1). The patient's mandibular left first permanent molar had been lost due to caries, and the second molar was tipping mesially. Extraoral analysis revealed a brachyfacial, symmetrical face and a convex soft-tissue profile with a slightly retrognathic mandible. No incisor display was observed at rest, but the entire maxillary incisors were evident upon smiling. All teeth were present except for the unerupted third molars and the missing mandibular left first molar. The malocclusion was classified as Class II, division 2, with a Class II occlusal relationship at the canines and the right molars. In addition to mild crowding in the maxilla and about 6mm of space in the mandible (due to the missing first molar), the patient had a deep bite with normal overjet.

Four treatment alternatives were considered:

- Nonextraction treatment involving protraction of the mandibular left second molar.
- Nonextraction treatment with opening of the mandibular left first molar space for prosthodontic restoration.
- Extraction of the maxillary first premolars and protraction of the mandibular left second molar.
- Extraction of the maxillary first premolars and opening of the mandibular left first molar space for prosthodontic restoration.

Records analysis indicated that the nonextraction option involving protraction of the lower left second molar would be the best choice. After leveling and alignment, a TFBC would be used

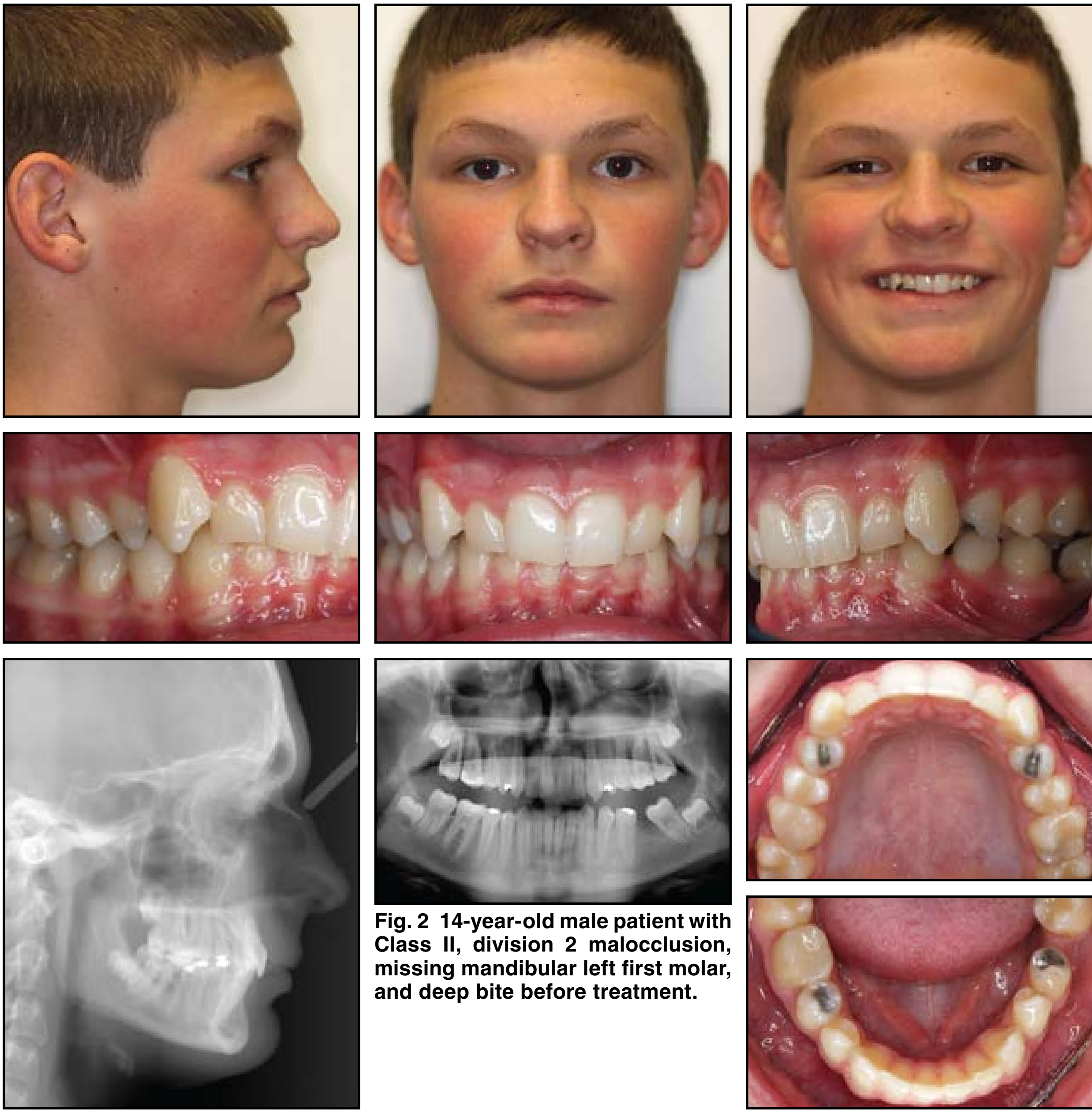


Fig. 2 14-year-old male patient with Class II, division 2 malocclusion, missing mandibular left first molar, and deep bite before treatment.

to correct the Class II malocclusion while serving as anchorage for protraction of the mandibular left second molar into the edentulous first-molar space. We expected that the apparently healthy third molar would drift mesially and erupt into an acceptable position once the second molar had been protracted.

Treatment Progress

An .022" preadjusted appliance was bonded, with −6° of mandibular incisor torque to reduce the risk of flaring. Initial alignment was achieved with a series of nickel titanium archwires, increasing in size to .019" × .025" stainless steel over 12 months of treatment. At this point, the mandibular left second molar had been fully uprighted.

Upper and lower stainless steel archwires were then cinched distal to the second molars, and a TFBC was attached bilaterally to the maxillary wire, mesial to the first molar bands, and to the mandibular wire, distal to the canines

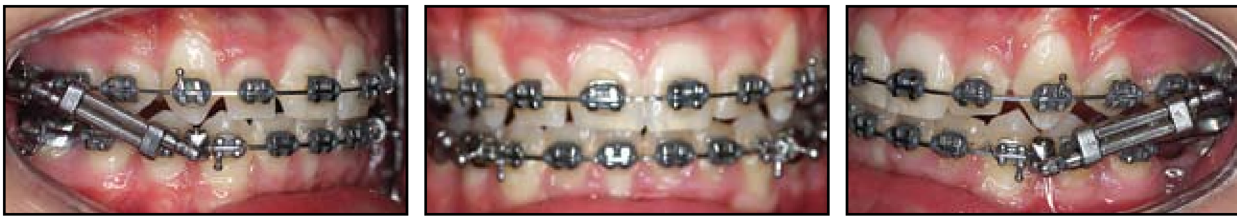


Fig. 3 Twin Force Bite Corrector placed bilaterally after 12 months of leveling and alignment.

Fig. 4 Closed-coil spring and elastomeric chain used during Class II correction with TFBC to protract lower left second molar into first-molar space.

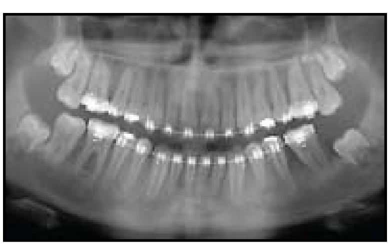


Fig. 5 Progress panoramic x-ray shows eruption of lower left third molar after eight months of second-molar protraction.

(Fig. 3). At the same time, a nickel titanium closed-coil spring was placed between the mandibular left canine and the mandibular left second molar to initiate molar protraction.

Five weeks later, an elastomeric chain was added to increase the protraction forces to approximately 300g (Fig. 4). Forces of this level have been previously reported in cases of molar protraction using miniscrew anchorage.[5] Although crown-level protraction forces will often cause mesial tipping and rotation of the molar, such undesirable movements were minimized by using an .019" × .025" stainless steel archwire.

The TFBC remained in place for eight months, until the lower left second molar had been moved into the edentulous first-molar space and a Class I occlusion had been achieved. The TFBC was then removed, and seating elastics were prescribed for retention of the Class I occlusion. Tip and torque were controlled by the use of .019" × .025" stainless steel archwires, despite the heavy forces of the TFBC.

Because the lower left third molar had penetrated the gingival tissue by this time (Fig. 5), a bracket was bonded and a nickel titanium overlay wire was used to bring it into the arch. The maxillary second molars and right mandibular second molar were also bonded to control the clockwise rotation of the occlusal plane that often occurs with the TFBC, as evidenced by a marginal-ridge step distal to the first molars (Fig. 5). During the finishing stage, the maxillary canines were recontoured to reduce the prominence of their incisal thirds.

Total treatment time was 30 months (Figs. 6,7; Table 1). After debonding, minor gingival recession was seen at the mesiobuccal aspect of the protracted lower left second molar, but no periodontal pocket or bone defect was observed. An .017" × .025" stainless steel wire was bonded buccally from the lower left second premolar to second molar to retain the protracted molar's position.

Discussion

Protraction of mandibular molars is complicated by thick cortical bone plates and dense trabecular bone, in addition to the

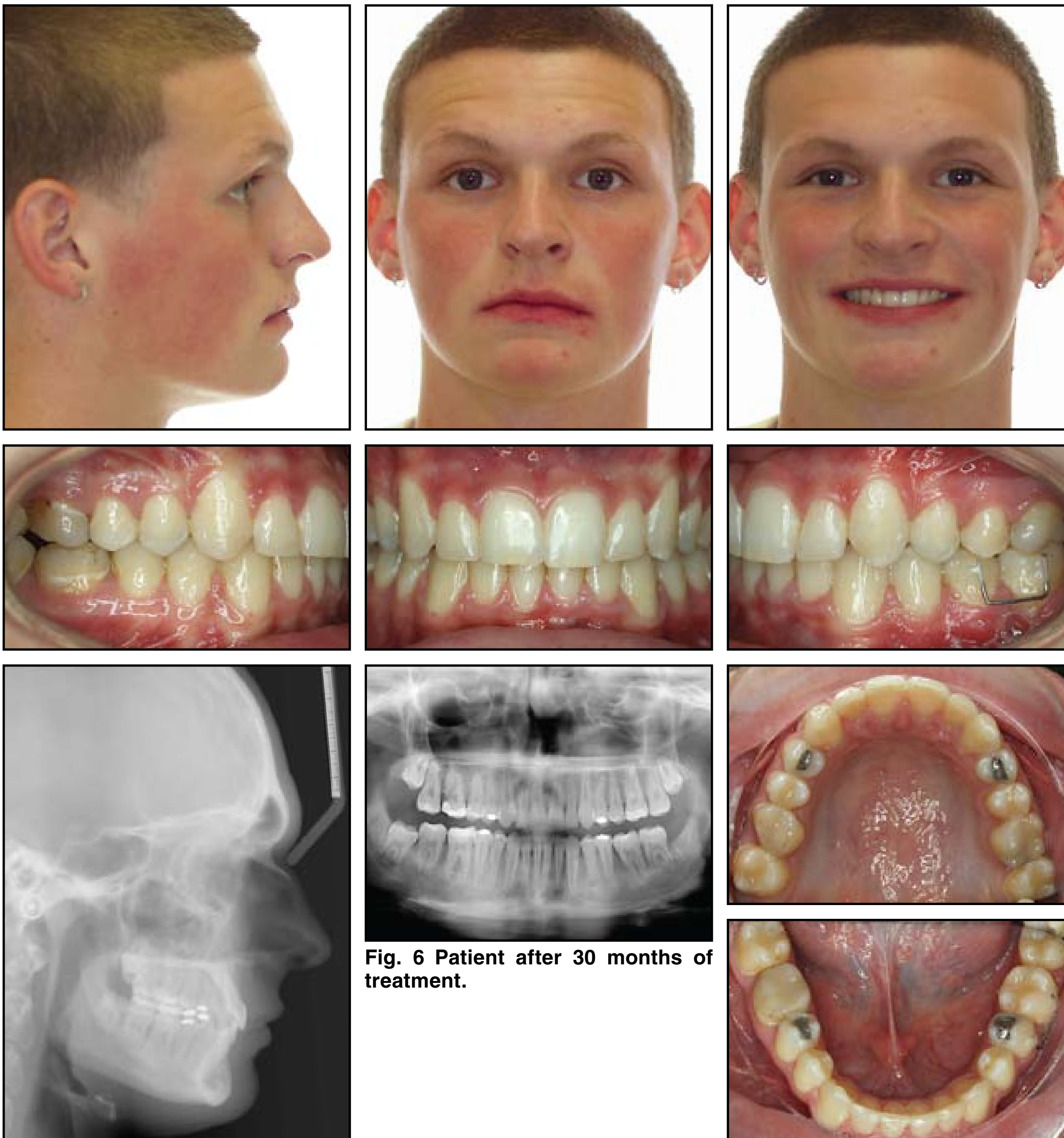


Fig. 6 Patient after 30 months of treatment.

buccolingual width of the molar roots.[8] When an intermaxillary push-type appliance such as the TFBC is already being used for Class II correction, however, the need to insert miniscrews[4,5] can be avoided by taking advantage of the appliance as a toothborne anchorage unit.

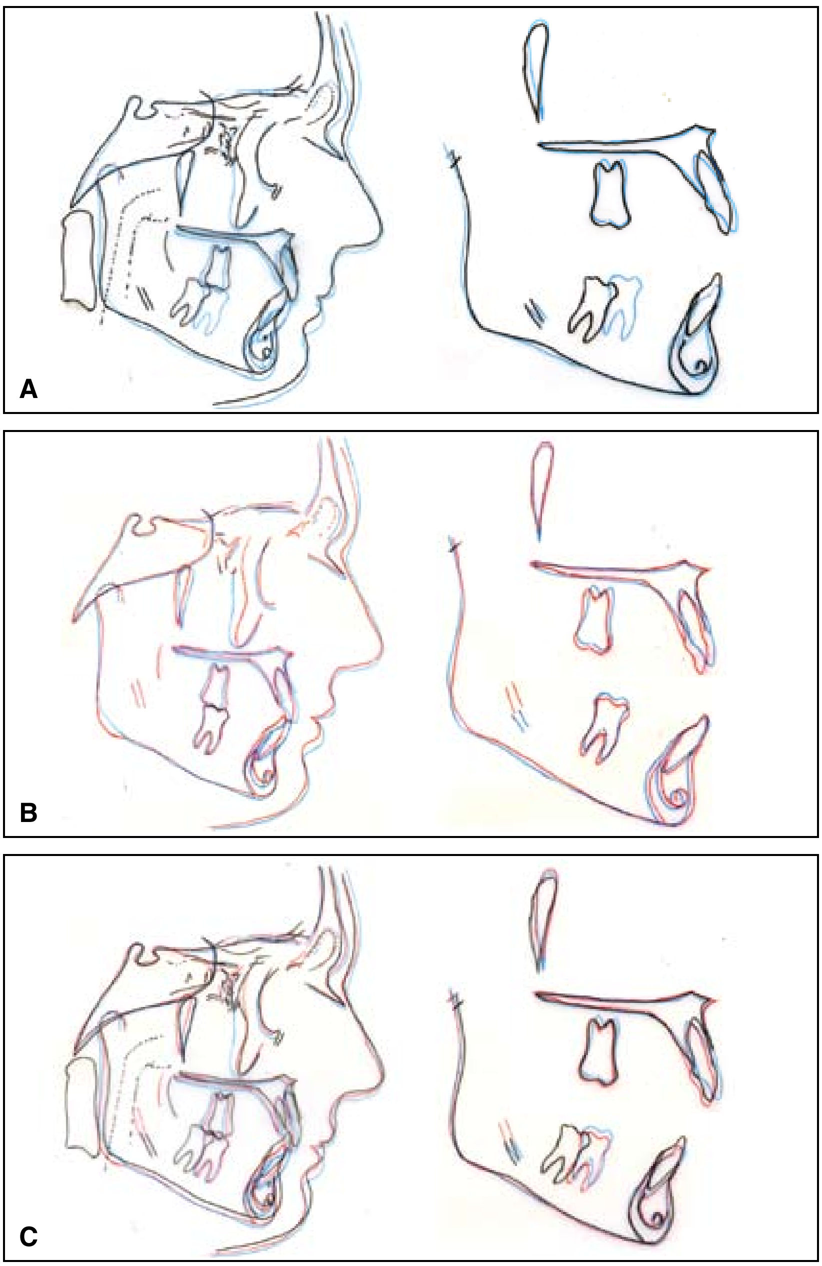


Fig. 7 Superimposition of cephalometric tracings. A. Pretreatment (black) and immediately after removal of TFBC, 20 months into treatment (blue). B. Post-TFBC (blue) and post-treatment (red). C. Pretreatment (black) and post-treatment (red).

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TECHNIQUE CLINIC

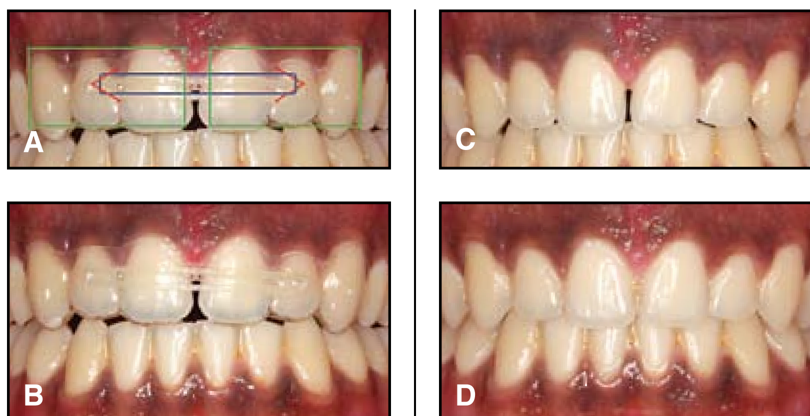
Closure of a Minor Midline Diastema Using Essix Trays

We have successfully used a sectioned Essix* appliance to close a relapsed maxillary midline diastema in an adult patient. The procedure is as follows:

1. Fabricate an upper canine-to-canine Essix tray (type ACE) as usual. Section the tray at the mesial third of each central incisor to create separate left and right trays. Round off the mesial edges for patient comfort.
2. Using a scalpel, create arrow-shaped attachment points for an elastic ($\frac{1}{8}$", 4oz) in the lateral incisor regions. In Figure A, the green boxes indicate the outline of the Essix trays, the red arrows show the location and orientation of the attachment points, and the blue box represents the elastic. The finished appliance is fairly inconspicuous (B).
3. Ask the patient to wear the trays with the elastic as close to full-time as possible.
4. Perform interproximal reduction if required by the tooth morphology, crown tip, gingival contour, or attachment level. In the patient shown here, stripping was performed on the mesial-occlusal third of the central incisors after four weeks of treatment (C) to eliminate a midline black triangle.

In this case, after closure of the diastema (D), a bonded 2-2 retainer (.0175" Wildcat** twisted wire) was placed to prevent relapse. Total treatment time was 10 weeks. Our patient lost his Essix trays halfway through treatment; otherwise, a single set of trays would probably have been adequate for the entire procedure. Interproximal contacts distal to the upper canines opened slightly, but tightened spontaneously during retention. A wraparound retainer may be worn at night to close such spaces if necessary.

To avoid excessive crown tipping, we do not recommend using this technique in a patient with a midline diastema wider than 2mm.



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DANIEL CASSARELLA, DMD
cassarella@ucla.edu

JASON PAIR, DDS
Section of Orthodontics
University of California-Los Angeles
10833 Le Conte Ave.
CHS 20-140
Los Angeles, CA 90095

An In-Office Wire-Bending Robot for Lingual Orthodontics

ALFREDO GILBERT, DDS, MS

Although precisely made archwires are crucial to the success of lingual orthodontics, the irregular lingual dental anatomy and small interbracket distances make manual wire-bending difficult, especially in cases involving anterior crowding. Lingual archwires require numerous offsets, often asymmetrical,[1] and minor inaccuracies in wire design or manufacture can produce undesirable clinical consequences. For example, the distal bends of an overlong lingual archwire may act as a kind of "trigger point", sending the anterior segment forward and opening the bite, or an inadequate offset in the premolar region can displace the buccal segment (Fig. 1).

Fig. 1 Upper left first premolar incorrectly positioned by lingual archwire without adequate offset.

This article introduces a system for designing and bending archwires more precisely and rapidly, called LAMDA* (Lingual Archwire Manufacturing and Design Aid, Fig. 2). The software was devel-

*Lancer Orthodontics, Inc., 2330 Cousteau Court, Vista, CA 92081; www.lancerortho.com.

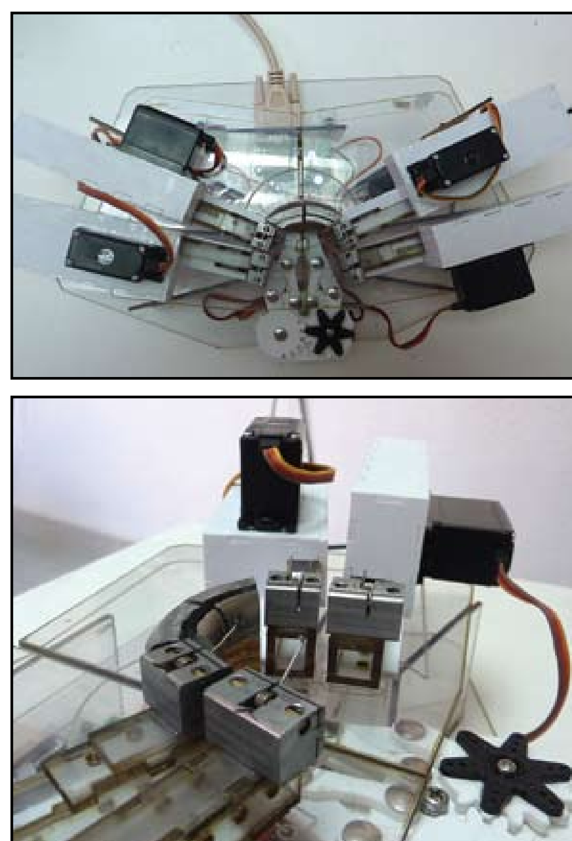
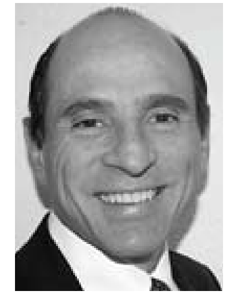


Fig. 2 Top and lateral views of LAMDA wire-bending robot.



Dr. Gilbert is coordinator of lingual orthodontics courses, Facultad de Estudios Superiores, Universidad Nacional Autónoma de México, Campus Zaragoza, Mexico City, Mexico. He is also Head of the Research and Innovation Program, Smile Center Institution, National Board of Science and Technology of Mexico, and in the private practice of orthodontics at Tampico #8 Colonia Roma, Mexico City, Mexico. He is the inventor of the LAMDA system. E-mail him at alfredogilbert@gmail.com.

oped in the Research and Development Department of Smile Center Dental Specialties in Mexico City, using the Microsoft Visual Studio 2008 Express integrated environment and Visual C# programming language.** The third-generation wire-bending robot[2] is designed to be used in the office, either before or after brackets are bonded, thus eliminating both external laboratory fees and the delay in waiting for wires to be shipped. This robot makes only 1st-order bends; the other two dimensions are accommodated by using the familiar Hiro bonding system.[3]

Lingual Archwire Design Using LAMDA

To design an archwire for a patient with no brackets in place, take a digital occlusal photograph of the study cast, then load the digital image (in either JPG or BMP format) into the LAMDA software. Click on the location of the wire's distal end and continue around the arch, clicking on each location where a bend is needed (Fig. 3). Allow sufficient space for the desired bracket depth. In the example shown, the widths of the canine and premolar differ by about 2mm in each arch, requiring accurate offsets in the lingual archwire to avoid lingual or labial movement of neighboring teeth. The position of any point is easily modified by right-clicking on the point and dragging it to the desired position.

The LAMDA software assigns *x* and *y* coordinates to each point, using pixels as the unit of measurement.[4] To convert the distances to centimeters for the wire-bending robot, the program must be calibrated by carefully marking two points 1cm apart next to the cast and including these two points in the occlusal photograph (Fig. 3). As the cursor is moved over various line segments and

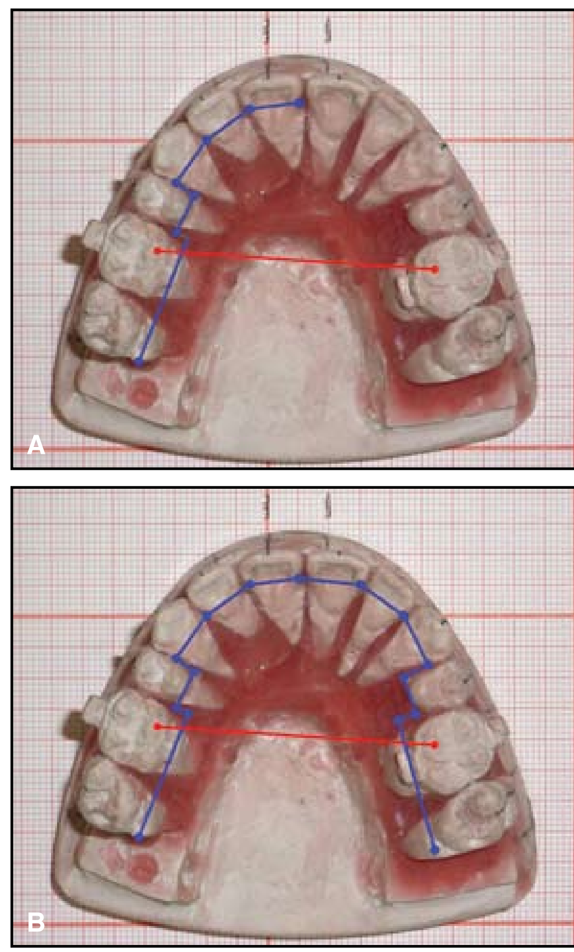


Fig. 3 A. User clicks on image at distal end of archwire and at each point where wire will be bent by robot. B. Completed virtual archwire. Program tools can be used to make interdental measurements (intermolar width in these images).

**Registered trademark of Microsoft Corporation, Redmond, WA; www.microsoft.com.

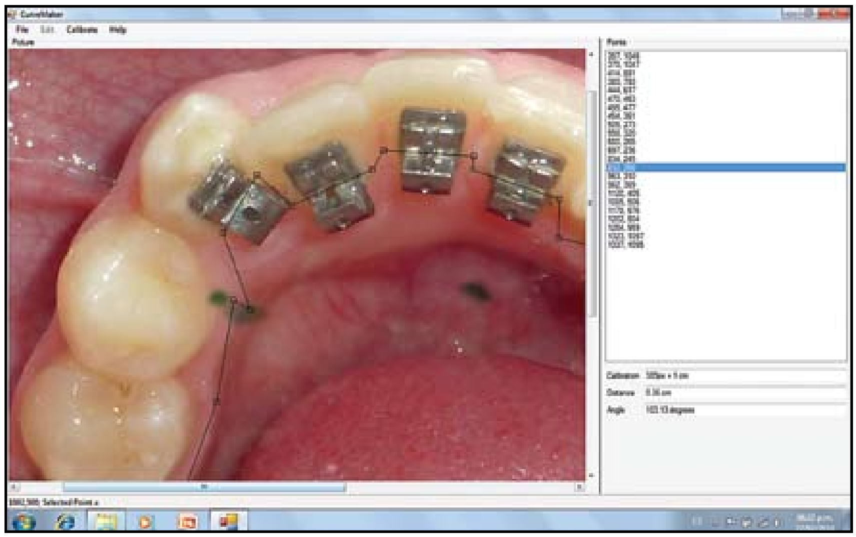


Fig. 4 Archwire designed for bonded brackets, with two green marks made on occlusal mirror for calibration. Photo enlarged in program screen to assist in precise placement of bends.

connecting points on the digital archwire, the program displays the distances between any two points and shows angles as positive (bends to the left) or negative (bends to the right).

A similar protocol is followed in a patient with brackets already bonded, but a single occlusal photograph is used instead of a photograph of the plaster cast. Calibration from pixels to centimeters is accomplished by marking a 1cm space on the occlusal mirror before taking the photograph (Fig. 4). A passive archwire can be designed by tracing the exact positions of the brackets, or an active archwire can be made with appropriate adjustments.

LAMDA can also be used to accurately measure intercanine and intermolar widths during treatment from either cast (Fig. 3) or occlusal photographs. Although interdental distances are more accurately measured from the study casts with a digital caliper, the LAMDA program can be used to monitor changes during treatment and to confirm that an archwire is not too wide or too narrow without taking new impressions at every archwire change.

Data files in the LAMDA system, in .DAT format, contain references to the working photos and information concerning the calibration distances and the coordinates of the points used to define the archwire shapes. The program can export text files listing all the lengths and angles used to design the archwire, and the user can print out an image of the finished design with the "Print Screen" option.

Occlusal photographs should be taken at each appointment, so that LAMDA can be used to determine the caliber and design of the next archwire. As a general rule, if the line drawn on the screen does not adapt perfectly to the virtual bracket slots, an increase in wire size is not needed; alternatives such as half-boots (with stainless steel wires) or memory wires (with prescription brackets) may be advisable.

The Wire-Bending Robot

Gantry robots like the one used in the LAMDA system have the ability to move an end effector (the device or tool at the end of a robotic arm) in multiple planes of space with great precision, though with limited degrees of freedom. These are also known as "cartesian coordinate robots" because their axes of control are linear and at right angles to each other. They are often used to span relatively extended workspaces and act on objects with vertical planes of symmetry.[3,5,6] Because the LAMDA robot works only on the *x* and *y* axes, it is relatively simple, compact, and inexpensive to manufacture.

The LAMDA robot incorporates a heater that can raise the temperature of a nickel titanium archwire to 600°F, making it possible to bend the wire without losing its capacity to transform reversibly between the austenitic and martensitic phases[7] (Fig. 5). The robot manufactures stainless steel archwires in about five minutes and nickel titanium archwires in about six minutes.

Figure 6 shows lingual treatment of a female patient who presented with four missing upper premolars. The difference in buccolingual thickness between the canines and first molars makes wire-bending especially difficult in this kind of case. Using the LAMDA system, I was easily able to design and fabricate appropriate wires to treat the patient efficiently. Treatment time was seven months.

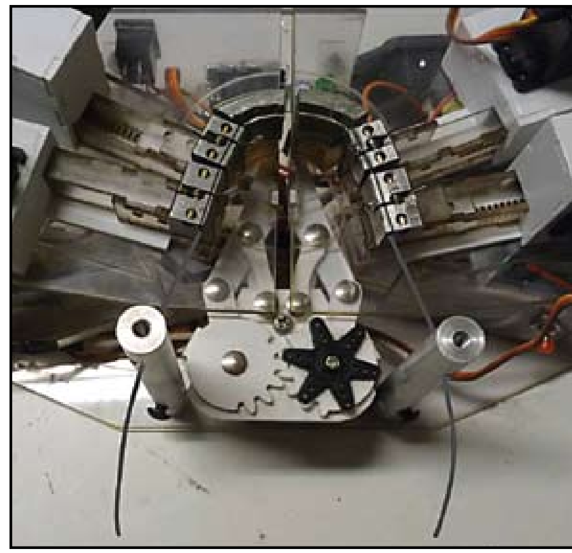


Fig. 5 Heat-tempering of nickel titanium archwire.

Comparison of Manually vs. Robot-Bent Lingual Wires

To test the fit of lingual archwires produced with the LAMDA system, 15 lingual orthodontic specialists were presented with a single patient's pretreatment plaster cast and occlusal photograph and asked to bend one archwire manually and one using the LAMDA system (Fig. 7). The participants had no prior training or experience with the

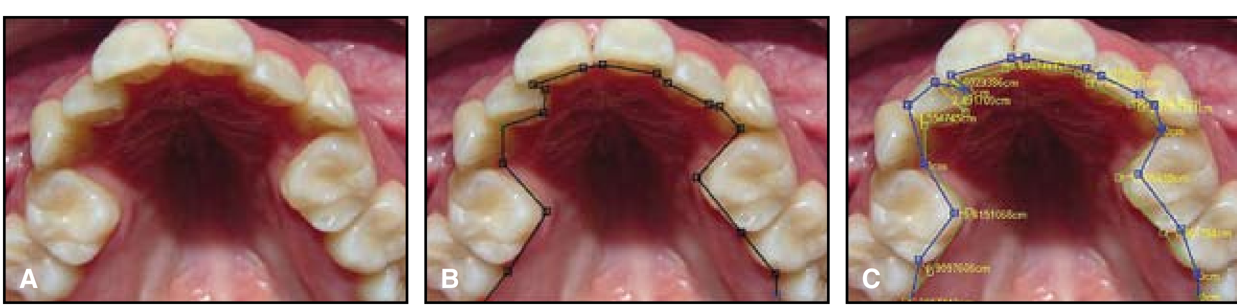


Fig. 6 A. Adult female patient with four missing upper premolars before treatment. B. Design of passive lingual archwire. C. Design of passive (green) and active (blue) archwires. D. .016" × .022" stainless steel wire used for finishing. E. Patient after seven months of treatment.

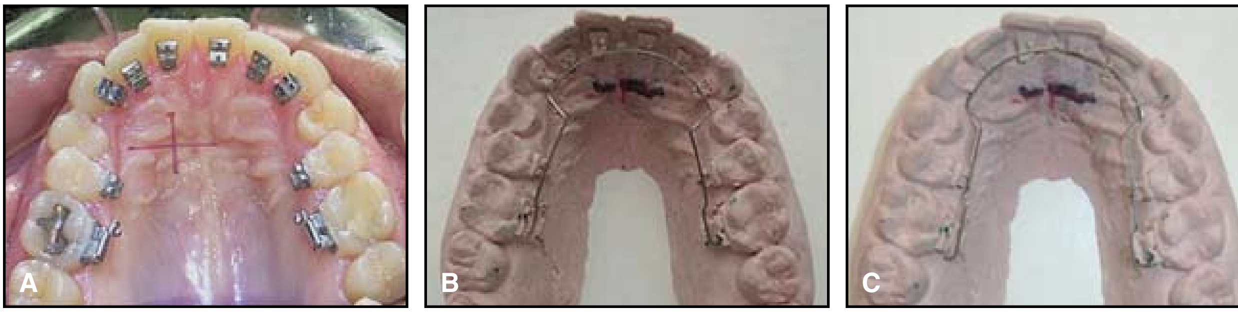


Fig. 7 A. Occlusal photograph used in test of LAMDA system. B. Sample archwire fabricated in traditional manner. C. Sample archwire designed and fabricated using LAMDA system.

TABLE 1
ARCHWIRE ADAPTATION SCORES

	Score (10 Possible Points)	
Orthodontist No.	Manual Fabrication	LAMDA System
1	6	8
2	7	10
3	5	9
4	7	10
5	6	8
6	8	9
7	5	9
8	8	9
9	7	9
10	8	9
11	6	9
12	6	9
13	8	9
14	8	9
15	8	9
Mean	6.9	9.0

LAMDA software or robot.

A 16th orthodontist performed a blind evaluation of the 30 archwires, assigning a score between zero and 10 to each wire based on how well it adapted to the cast. The mean score for the 15 manually bent archwires was 6.9; the mean score for the 15 archwires designed and manufactured with the LAMDA system was 9.0 (Table 1).

Discussion

Successful lingual orthodontic treatment demands careful control of laboratory procedures and fine details.[8] Designing the archwire over a digital image reduces the possibility of errors caused by mirror angles and off-axis viewing of the arches from within the mouth.

The choice of a bracket-positioning and transfer system is particularly important. The LAMDA wire-bending robot is much simpler than the robots used in commercially outsourced systems, since it manufactures only 1st-order bends. Although this requires the use of the Hiro bracket-positioning system[3] for 2nd- and 3rd-order bends, it makes the unit affordable for a solo practitioner. In addition, the orthodontist is able to regulate the process at any time with more flexibility than in outsourced systems.

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PRODUCT NEWS

Esthetic Wires

G&H Wire has introduced a polymer-coated esthetic archwire in either G4 nickel titanium or S304 stainless steel. The flake-resistant, durable polymer coating does not change the dimensions or force values of the wire, according to the company. Tooth-colored and bleach-white shades are available in Trueform I, Europa I, and Europa II archforms.

For more information, contact G&H Wire Company, 2165 Earlywood Drive, Franklin, IN 46131. (800) 526-1026; www.ghwire.com.

Patient Education

Ortho2's Edge Animations videos use cutting-edge rendering techniques that produce extremely high-quality images and animations to educate and instruct patients about miniscrew and surgical techniques, expanders and Damon brackets, placement of wax and elastics, and other topics, according to the company. A user-friendly interface allows customization with drawings, annotations, or audio narration. The program is available for Ortho2 Edge and ViewPoint or as a stand-alone product.

For more information, contact Ortho2, 1107 Buckeye Ave., Ames, IA 50010. (800) 678-4644; www.ortho2.com.

Liquid Dispenser

Whip Mix's automatic system for accurate measurement of powders and liquids used in fabrication of plaster models is now capable of handling two separate liquid ingredients simultaneously. The AquaSpense SL automatically calculates the powder weight and dispenses the appropriate amount of water and any other necessary liquid, such as a gypsum hardener, ensuring accurate and predictable results, according to the company.

For information, contact Whip Mix Corporation, P.O. Box 17183, Louisville, KY 40217. (800) 626-5651; www.whipmix.com.

Power Toothbrush

Mouth Watchers' power toothbrush features bristles impregnated with antibacterial nano-silver particles, including special "flossing bristles" with 1-micron tips to reach into crevices and interproximal spaces, according to the company. The brushhead is designed to oscillate 5,000 times per minute with an up-and-down motion that improves access around brackets, bonded retainers, and bridges.

For more information, contact Mouth Watchers, LLD, 293 Humphrey St., Swampscott, MA 01907. (866) 941-8478; www.mouthwatchers.net.

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