

Lingual Orthodontics – A Review

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ABSTRACT The addition of lingual appliances to the world of aesthetic orthodontic appliances has provided the ultimate in aesthetics because they are not visible. Patients with high aesthetic demands seem more interested in this approach and enjoy having confidence in their smile *before* their braces are removed. This article attempts to review the development and current principles and techniques of lingual orthodontics.

Development of Lingual Appliances

The number of adult patients in orthodontic practices is increasing¹. The decision taken by adults to commit themselves to orthodontic treatment is a more complex matter than for the younger age groups, as they have the demands of their work and broader social needs to consider. Of those who would accept all other aspects of treatment there is a group that is not prepared to display their orthodontic appliances and lingual orthodontics has become the aesthetic solution for meeting the needs of these patients^{2, 3}. When Miura *et al*⁴ presented an acid etch bonding system in 1971, it was possible for the first time that the total orthodontic appliance could be placed on the palatal or the lingual surfaces of the dental arches so that it would not be seen. Fujita^{5, 6} began to work on the development of a specific lingual bracket technique and published a few case reports using his method in 1979. The addition of lingual appliances to the world of esthetic orthodontic appliances has provided the ultimate in esthetics⁷.

Kurz and coworkers⁸⁻¹⁵ in cooperation with the Ormco Company developed an edgewise bracket for lingual

application and they tested these new brackets in approximately 80 cases in 1980. In 1981, 6 prominent American orthodontists formed the Lingual Task Force with a mission to promote lingual orthodontics. Since then courses have been given all over the world and many universities have integrated lingual orthodontics into the curriculums of their post-graduate orthodontic programs.²

Both Fujita and Kurz with their coworkers^{5, 8-15} adapted the edgewise mechanism for use on the lingual surfaces. However, Paige¹⁶, who preferred the Edgewise appliance labially, recognized that a round archwire technique would be more suitable when applied lingually. The greater variation of lingual surface anatomy meant that a round archwire compared with a rectangular wire was less liable to cause undesirable torque, and therefore the positioning of brackets at precise angulations was less critical. As distinct from labial approach, the ribbon arch bracket was positioned with the vertical slot directed towards the occlusal surface to facilitate archwire placement.

The Lingual Task Force members and others provided many reports on the continuing development of the lingual appliance^{8, 11, 13-15, 17-25}. In many places of the world there have been limited acceptance of lingual technique by orthodontists because of problems encountered in the early evolution of the appliance. Many have considered the lingual technique difficult to employ^{13, 20} and more time consuming²⁶ for the patient and for the orthodontist. However, technological advancements in materials and processes are creating renewed interest in lingual protocols²⁷. Patients who have been offered the lingual orthodontic option are very enthusiastic in their acceptance²⁸. Patients with aesthetic demands, especially those with acting, singing, modeling or entertaining goals seem more interested in this approach. They enjoy having confidence in their smile *before* their braces are removed⁷. As the patient's profile and lip position are not distorted by the brackets, a true cosmetic evaluation during treatment is possible⁶.

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Figure 1 Before treatment (left) and after aligning and leveling (right). Courtesy Dr. Franklin She.

Moreover, contrary to the popular myths about lingual appliances, good results can be achieved equivalent to that of labial appliances with proper patient and case selection, and a sound treatment plan.

The Lingual Edgewise Appliance

Different kinds of lingual bracket systems have been manufactured, for example, Fujita, Ormco, Forestadent and Creekmore Enterprise^{29, 30}. The Kurz-Ormco 7th-generation lingual brackets are Edgewise brackets specifically designed for the lingual surface of the teeth⁷. The maxillary anterior brackets have a built-in bite plane which helps minimize accidental debonding from the lower incisors. The bite plane effect also allows for efficient bite opening in deep bite cases. The mandibular anterior brackets are designed to minimize interference with oral hygiene maintenance. The ball hook extends away from the tissue to allow access during toothbrushing. The wider bicuspid bracket has been designed for better rotation and tip control of the bicuspids. The interbracket width is now more uniform throughout the arch. The ball hook has been shortened and flattened for easy ligation, increased patient comfort and minimal gingival irritation. The twin bracket is recommended for the first molars when both the first and second molars are bonded or banded. When a transpalatal bar may be required, the twin bracket with an auxiliary tube is used. The hinge cap is an ideal attachment for the terminal tooth. Using a hinge cap opening tool, the cap is easily opened, exposing the archwire slot. The archwire is inserted with the end of the archwire already bent at the appropriate angle. Then the hinge cap is closed, using a utility plier. Finally, the terminal tube is used when the clinical crown height of the terminal teeth is too short to accommodate a hinge cap⁷. New lingual brackets and bracket systems are continuously being developed. The self ligating brackets solve the problem of ligation in lingual orthodontics and greatly reduce chair time³¹. With the latest in CAD/

CAM technology, Wiechmann described an individualised lingual bracket system in which the processes of bracket production and bracket positioning are combined³².

Keys to Success in Lingual Therapy

Smith and coworkers^{20, 21} reported 12 keys to success in lingual therapy. They were patient selection; bracket placement accuracy; indirect bonding; vertical and transverse control of segments; double-overties on anterior teeth; buccal and lingual molar attachments; correcting rotations; arch form and archwire sequence; archwire stiffness and torque control; en masse retraction; light, resilient wire for detailing and gnathologic positioner and retention. Other authors also published different keys to success^{7, 33}.

Patient and Case Selection

Majority of the patients seeking lingual orthodontic treatment are adults with high demand in aesthetics. Many of them have been treated with labial fixed appliances at a young age. These adult patients often present with complex restorations, multiple missing teeth or compromised periodontal conditions. These factors must be taken into consideration when formulating treatment plan for lingual orthodontic treatment^{7, 34}.

Patients must be informed of initial speech difficulties after placement of the lingual appliance. Usually the problem will last for a few weeks only but different patients will adapt at different rate^{5, 34-36}. Patients with narrow arches are more likely to have difficulty adapting to the appliance. Starting treatment with only one of the two arches may help the adaptation³⁴. Transient tongue irritation often occurs and can be relieved by the use of orthodontic wax^{7, 34, 37}. Oral hygiene maintenance is more difficult with the lingual appliance, especially in cases with short clinical crowns. It is

important to educate the patient on proper cleaning techniques and a typodont with lingual brackets should be used for demonstration. Garland-Parker⁷ recommended specific oral hygiene techniques for the lingual appliances including the use of interdental brushes, floss threaders, angled toothpicks, oral irrigators, etc. It has been reported that salivary flow rate increases in the lingual orthodontic patient, thereby reducing the caries rate^{34, 38}.

The bite planes on the maxillary incisor brackets cause rapid bite opening making the lingual appliance most effective in deep bite cases^{11, 20, 34}. However, in excessive deep bite or large overjet cases the bite plane may hinder the anterior-posterior movement of teeth causing loss of anchorage. The bite plane may also increase the clockwise rotation of the mandible thereby worsening the Class II relationship^{5, 10, 13, 17, 39-42}. The posterior open bite as a result of the bite plane also causes mastication difficulty during the initial treatment period. Some authors suggested using occlusal build-up on the labial cusps of lower molars and gradually reduced with treatment^{7, 34}.

The clinical length of the crown determines the amount of lingual enamel surface area available for bonding. Brackets must be positioned 1mm away from the gingiva to allow for cement removal and oral hygiene maintenance¹³. Subsequently, short clinical crown is a contraindication for lingual appliance. However, if crown height is inadequate, crown lengthening procedures could be considered¹³.

As mentioned before, the lingual orthodontic patients are extremely demanding in aesthetics and are concerned with visible extraction spaces. Temporary resin teeth or aesthetic pontics^{7, 43} can be used to fill the extraction spaces and are gradually reduced as the spaces become smaller. The aesthetic pontics must not interfere with tooth movement or healing of the sockets.

Cases that can be treated with labial appliance are also treatable with lingual orthodontics. In lingual orthodontics, larger amount of anchorage is available, especially in the lower arch, resulting in greater retraction of anterior teeth⁴³. For the inexperienced operator, it is better to start with less complex cases such as non-extraction cases without severe sagittal, vertical or transverse problems⁷. Some operators start their first few cases with maxillary lingual brackets and mandibular labial appliances⁷.

The ideal cases for lingual orthodontic treatment^{13, 33} are low angle deep bite, diastema, Class I minor crowding and upper premolar extractions for Class II cases. The difficult cases for lingual orthodontic treatment are those with 4 premolar extractions, posterior crossbite, high mandibular plane angle, anterior open bite, surgical or orthognathic cases. The contraindicated cases for lingual orthodontic treatment are short clinical crown cases; severe periodontal problems and cases with severe temporomandibular problems. A number of case reports demonstrating difficult and contraindicated cases have been published⁴⁴⁻⁴⁹.

Laboratory Procedures for Indirect Bonding

It is extremely difficult to visualize and accurately position the lingual brackets if they are directly bonded. Indirect bonding is therefore the standard in lingual orthodontics. Several techniques have been developed and the two major ones are the TARG (Torque/Angulation Reference Guide) and the CLASS (Custom Lingual Appliance Set-up Service) system.

In the CLASS method^{7, 50}, an ideal diagnostic set up is constructed which reflects the position of all teeth in the proposed finished case. Brackets are placed on this diagnostic set-up and a custom composite base is constructed for each to compensate for irregular tooth morphology, torque, angulation, in-out and rotation overcorrections. The brackets with their custom bases are then transferred from the diagnostic set-up back to the malocclusion model on which a silicone transfer tray is made for indirect bonding.

The TARG system^{7, 50} utilizes a special electronic machine to position the lingual brackets directly onto the malocclusion model with high precision and accuracy. The original TARG machine was developed by Ormco in 1984. In 1987, Fillion^{51, 52} improved the machine so tooth labio-lingual thickness could be measured reducing the first-order bends in the archwire.

Recent developments to improve bracket positioning include the Hiro Laboratory Procedure and the Ray Set Biaggini Bracket positioner. The Hiro System⁵³⁻⁵⁵ is a modified CLASS technique invented by Hiro and improved by Takemoto and Scuzzo. The technician shapes an ideal arch on the set-up with a full-size rectangular archwire. The lingual brackets were transferred onto this wire and secured with elastic ligatures. Single rigid transfer trays are then fabricated for each tooth. The archwire is then removed and custom bases for the brackets are made. Compared to the TARG and CLASS techniques, the Hiro System has several advantages⁵⁴⁻⁵⁵: no electronic equipment is required for bracket positioning; no need to transfer brackets from the set-up model to the original malocclusion model; the accuracy of bonding is improved because of the rigid individual trays; bonding can take place at any time as the trays are not affected by positions of other teeth and rebonding is quick and accurate with the ideal archwire and the set-up model.

The Ray Set System⁵⁰ utilizes a 3-dimensional goniometer for analysis of the first-, second- and third-order values of each individual tooth. Both pre- and post- set-up values of individual teeth are evaluated and the amount of orthodontic tooth movement for each tooth on the set-up model is calculated.

Special Considerations in Clinical Bonding

As the lingual side of the arch is more susceptible to

moisture contamination, extra precautions are necessary to ensure a dry field during bonding⁵⁶. Teeth with short clinical crowns, porcelain or metal crowns or large restorations are more liable to bond failure. Before bonding to porcelain or metal crowns, the surface should be sandblasted with a micro etcher and a metal or porcelain primer should be used as directed. If necessary, a window may be cut in the lingual surface of the crown and composite resin placed to provide a bondable surface⁷. The patient should be informed that this procedure would reduce the life of the crown and that replacement might be needed after the orthodontic treatment. If the CLASS system is used, the brackets should be bonded as soon as possible after the working model has been made. Placement of separators and extractions must be carried out after bonding as any tooth movement taken place after the impression is taken will compromise the fit of the transfer tray and hence the accuracy of bracket placement⁵⁶.

Comparative Biomechanics between Lingual and Labial Techniques

i) Force actions

As the force of application is on the lingual side, the mechanics of tooth movement for lingual orthodontics has different characteristics from the labial one⁵⁷. Scuzzo and Takemoto⁵⁸ summarized the effects of different forces imposed on teeth by the lingual and labial techniques in the three planes of spaces.

Sagittal plane

From a sagittal view, when the same amount of force is applied to anterior teeth in both systems so that the intrusion force equals the retraction force, the net force vector points directly towards the center of resistance with the labial system and lingual to the centre of resistance with the lingual system, producing a lingual tipping force and vertical bowing effect. Therefore, during en masse retraction in lingual orthodontics, the retraction force should be minimized and more intrusion and palatal root torque is needed.

Vertical plane

The effect of intrusive forces on the lingual and labial sides of the upper incisors differs between cases of normal, labial or lingual inclination. In normally inclined incisors, vertical force applied on both the labial and lingual side lies mesial to the center of resistance (CR) in the horizontal plane, thereby producing a counterclockwise moment. The moment is greater when force is applied on the labial side because of greater distance from the CR as compared to that when the force is applied on the lingual side. In proclined incisors, both the labial and lingual intrusive forces produce counterclockwise moments but the magnitudes are greater than that of normal incisor inclination because of increased distances of the points of application of

the forces from the CR. In upright incisors (as in a Class II division 2 malocclusion), labial intrusive force will produce a counterclockwise moment but the same amount of vertical force on the lingual side will produce a clockwise moment and this increases the lingual inclination of the crowns. This is due to the point of application of the force lies distal to the axis passing through the CR of incisors. In such cases, it is advised to advance the crowns first and then to perform the intrusion⁵⁸.

As far as the upper molars are concerned, the axis passing through the CR is closer to the lingual surface. This implies that whenever an intrusive force is applied to the lingual brackets, the crowns of the teeth will rotate in a lingual direction; the opposite will occur whenever an intrusive force is applied to the labial brackets: crown rotation will take place in a labial direction.

In the lower arch with normal incisor inclination, the lingual bracket slot is closer to the axis passing through the CR when compared with that on the labial side. For this reason, lingual application of force allows easier intrusion coupled with less proclination of the crown, as compared with labial force application. This will also generate more distal inclination of the lower molar crowns and more lingual tipping of the lower incisors during leveling.

Horizontal plane

In the horizontal plane, the interbracket distance in lingual orthodontics is shorter than that in the labial one. Also, the point of application of force is closer to the tooth axis in lingual orthodontics. Therefore the rotation moment is less than on the labial side and it is more difficult to have an efficient coupling of forces during rotational movement. The short interbracket distance means that the archwire stiffness is also increased⁵⁹. A more flexible archwire is needed, especially in crowded cases. All these factors make correction of rotations more difficult with the lingual appliance.

ii) Choice of extractions

With its unique biomechanics, extraction choices in lingual orthodontics often differ from those in labial orthodontics^{43, 60, 61}. In lingual orthodontics the strong molar anchorage, especially in the lower arch, makes mesial movement of the lower molars difficult. Also, the lower molars tip distally as the arch is leveled in lingual orthodontics and this changes the molar relationship from Class I to Class II. Therefore in Class I cases, the extraction of the upper first premolars and lower second premolars may be necessary rather than the extraction of the four first premolars. In Class II cases, it is desirable to avoid extraction in the lower arch as much as possible and rather to advance and/or slice anterior teeth if the amount of crowding is minimal. If crowding in the lower arch is severe, extraction of

one or more lower incisors may be considered. In Class III cases, premolar extraction facilitates the lingual tipping of lower anterior teeth. The distal tipping of lower molars during leveling also improves the Class III molar relationship. All these facilitate the correction of a Class III malocclusion⁴³.

iii) Anchorage considerations

It is generally said that a lingual approach gives a greater amount of anchorage than a labial approach⁴³. In lingual orthodontics, distally tipping forces are constantly applied to posterior teeth through the archwire, which makes posterior teeth more resistant to anchorage loss than in labial orthodontics. As brackets are placed on the lingual surfaces, it is easier to control the vertical height of the lingual cusps through the constant application of buccal root torque, which tips molars lingually. This is particularly helpful in controlling the lingual cusps of the upper second molars, which are most likely to be extruded and cause interference. The control of molar extrusion also prevents the clockwise rotation of the mandible and the resultant adverse effects such as anterior open bite and deterioration of a Class II relationship. Removal of tongue pressure with a lingual appliance further reinforces molar anchorage, especially in a lower dental arch with narrow bone⁴³.

Treatment Sequence

Scuzzo and Takemoto⁴³ recently summarized the contemporary recommendations of treatment sequence and selection of archwires in a typical extraction case using the lingual appliance. The archwires, in general, are mushroom in shape with insets between the canine and premolar and between the premolar and molar⁴³.

In the anterior leveling stage, .016-inch titanium molybdenum alloy (TMA) archwire with loops or a lingual arch is used for partial canine retraction. When there is little anterior crowding, or when partial canine retraction has been accomplished, a full archwire of .016-inch Copper Nickel Titanium (Cu-NiTi) or .017×.017-inch Cu-NiTi is used for alignment of the anterior teeth.

When anterior leveling has been achieved, torque establishment of the anterior teeth is necessary prior to en masse retraction. The wires for torque leveling are .0175×.0175-inch or .017×.025-inch TMA archwires.

In the en masse retraction stage, both sliding mechanics and loop mechanics can be used. Loop mechanics is mainly used in the upper arch. There are 3 types of loops that can be used and they are the T-loop with .017×.025-inch TMA archwire, the closed helical loop with .017×.025-inch TMA archwire and the closing loop with .0175×.0175-inch TMA archwire. The loops should be activated about 1mm every 8 weeks. When sliding mechanics are used in the upper arch, the appropriate wire is .017×.025-inch TMA. In the lower

arch, .016×.022-inch stainless steel (SS) archwire is used for sliding mechanics. Loop mechanics is used when active lingual tipping of the lower anterior teeth is needed for space closure or when maximum anchorage is required. Both vertical and transverse bowing effect can occur during space closure, especially in the upper arch. Compensating curves and gable bends should be placed in the archwires to counteract the bowing effects. In addition, the retraction force should be light and adequate lingual root torque should be placed in the anterior segment before space closure. In the detailing stage, .016-inch TMA or .0175×.0175-inch TMA archwires are used.

Treatment of anterior open bite

Although anterior open bite is not an ideal case for treatment with the lingual appliance¹³⁻³³, Geron and Chaushu⁶² described a technique for treatment of anterior open bite using the lingual technique. They concluded that the factors that contributed to successful results were firstly, an extrusive force on the incisors and an intrusive force on the molars, produced by extra torque in the anterior brackets. The use of a flat archwire for space closure, contrary to the usual curve of Spee in lingual extraction treatment, allowed full expression of the extrusive force on the incisors. Secondly, an undersize wire in the slots of the posterior lingual brackets and the use of light forces reduced friction and anchorage requirements thus eliminating the need for intermaxillary elastics and thirdly, a possible tongue-crib effect of the lingual brackets.

Segmented mechanics in lingual orthodontics

Fontenelles²⁶ pointed out that only segmentation could solve the contradiction of conflicting requirement in lingual orthodontics: low load-deflection rate, constant moment-to-force ratios, and keeping strict control. The appliance was divided into three components, namely, the passive appliance, the active appliance and the guiding component. The passive appliance provided a high load-deflection rate, ensuring maximum stiffness to control the relationships between the teeth included. Because passive systems were intended to provide enough stiffness to tie the teeth into a unit, any sufficiently stiff device could be used, for example, .018×.025-inch SS archwire, bonded cast chrome-cobalt splint and bridgework. The active appliance should have a low load-deflection rate giving a high degree of force constancy, and should produce the moment-to-force ratio necessary for the tooth movement intended and maintain it as constant as possible. The guiding component was to guide the tooth in its progress along the dental arch, from its initial position to its final

location. Anchorage could be provided by varying the line of action of the force. Case reports of different segmental techniques have been published^{27, 63-65}.

Lingual straight-wire technique

With conventional lingual brackets, mushroom-shaped archwires are required with insets between the canine and the premolar and between the premolar and the molar. Vertical steps between the canine and the premolar are often needed. In a study in which the crowns on a plaster model were trimmed to the gingival margins, parallel to the occlusal plane, a few in-out differences on the lingual side were revealed⁶⁶. This study has led to the development of a lingual straight-wire (LSW) technique based on the cervical lingual arch form^{66, 67}. The LSW-brackets are provided with various degrees of torque, angulation and bracket thickness for individual tooth. The bracket slots are positioned so that the direction of archwire insertion is opposite to the Kurz 7th generation appliance. The bracket stem of the LSW-appliance is positioned more gingivally relative to the bonding base and is longer labio-lingually and the bracket is shorter vertically.

With the use of straight wires, wire-bending is minimized and chair-time is reduced. With no inset between the canine and the premolar, there is no variation in the amount of inset associated with archwire changes and the lateral occlusion remains stable once established. Preformed archwires can be used and sliding mechanics can be simplified. Vertical control of the teeth is possible from an early stage of treatment because vertical steps are not needed^{66, 67}.

Lingual light-wire techniques

In 1982, Paige¹⁶ described a lingual light-wire technique using Unipoint combination brackets with slots oriented in the occlusal-incisal direction and with vertical slots for use of auxiliaries and horizontal slots in unravelling of crowding incisors. There is a gingival 'wing' to place elastic modules on continuous elastic chains. The problem of short interbracket distance was partially overcome. Using this technique, the lingual tooth contours are much less a variable factor because torque control can be achieved by properly shaped torquing auxiliaries and placement of brackets is sensitive only to the incisal-gingival placement. Therefore indirect bonding is not required.

Jenner and McLean² also showed that the Begg Appliance, based on the use of ribbon arch brackets and round archwires, provides a relatively simple conversion from labial to lingual mechanics. During bracket placement, the bracket is turned upside down for lingual mechanics. Unlike the edgewise techniques, bracket placement is simplified because torque is not built into the bracket. This removes the need to involve the services of

commercial laboratories to place pre-angulated brackets on the model prior to indirect bonding. There was also less difficulty with subsequent rebonding of individual brackets if they were dislodged. It is possible to use standard labial bracket bases on the lingual⁶⁸. Archwires for lingually placed brackets required modifications to accommodate the lingual anatomy of the incisors, canines, bicuspid and molars. However, the original three stages of Begg treatment sequences were retained.

Retention in lingual orthodontics

Patients who have chosen to have lingual braces are often esthetically demanding and do not like visible retainers. Due to social restrictions, they have limited time to wear retainers. Clear retainers made of 0.4-0.5mm thick thermoplastic material are easy to fabricate and can be delivered on the same day of appliance removal⁶⁹. They are also comfortable to wear and cause little speech interference. However, they break and deform easily so they are not suitable for long term use. A modified Begg retainer with the anterior part made of transparent retainer wire is esthetically pleasing but the baseplate may cause some discomfort and speech difficulty. The retainer also has to be fabricated in the laboratory. It has been recommended that clear retainers should be used during day time and a Begg or Hawley retainer for long term night wear. For lower incisors with reduced periodontal support, a fixed lingual retainer is used to stabilize the teeth. Scuzzo and Takemoto⁶⁹ prefer the .012-inch Australian wire because the finer wire causes little discomfort and the resilience of the wire allows individual movement of the incisors and encourages periodontal fibre rearrangement. This passive retainer can be transformed into an 'active' retainer to correct minor incisor malalignment or for finishing a case.

Conclusion

In this article we have tried to sum up the current developments of the lingual appliances. Since its inception more than twenty years ago, a lot of work has been done in the developments of the lingual orthodontic appliances. Many orthodontists today are not routinely practicing lingual orthodontics, possibly because of the increased time and effort required. Nevertheless, once the orthodontists see the confident smiles of their patients from the start of the treatment to the end, they will agree that their foresight, care and efforts to their patients have been amply rewarded.

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