The number of adult patients in orthodontic practices is increasing. 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.

**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.

**Factors to be taken into consideration when formulating treatment plan for lingual orthodontic treatment.**

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. Patients with narrow arches are more likely to have difficulty in adapting to the appliance. Starting treatment with only one of the two arches may help the adaptation. Transient tongue irritation often occurs and can be relieved by the use of orthodontic wax. 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-Parker 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.

The bite planes on the maxillary incisor brackets cause rapid bite opening making the lingual appliance most effective in deep bite cases. 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. 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.

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 maintenance. Subsequently, short clinical crown is a contraindication for lingual appliance. However, if crown height is inadequate, crown lengthening procedures could be considered.
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 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 teeth. For the inexperienced operator, it is better to start with less complex cases such as nonextraction cases without severe sagittal, vertical or transverse problems. Some operators start their first few cases with maxillary lingual brackets and mandibular labial appliances.

The ideal cases for lingual orthodontic treatment are:
- low angle deep bite
- diastema
- Class I minor crowding
- upper premolar extractions for Class II cases.

The difficult cases for lingual orthodontic treatment are:
- 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.

The Current State of Clinical Applications

Objections to the concept of lingual orthodontic treatment are still occasionally raised, often by non-practitioners of the technique. For example, there is a perception that the length of treatment with lingual appliances is excessive compared with that for labial appliances. Students of orthodontic history may recall analogous debates beginning in the 1930s between the radical non-extraction lobby led by Dr. Edward Angle and the group under Dr. Charles Tweed, which advocated judicious selection of extraction patterns. Despite the acrimony of the time, the latter faction’s work led directly to the development of standard edgewise mechanics, which in turn laid the groundwork for the modern straight wire appliance. In other quarters, the efficacy and nature of functional appliances has also been, and occasionally continues to be, hotly debated.

Despite early resistance, “new” techniques such as these have eventually become proven and have moved from the margin to the mainstream. There seem to be only rare instances in which candid admissions have been made exposing the convenience of the standby “old excuse that treatment time would be considerably longer.”

While pundits may attempt to deflect patient interest in many a new clinical method in this fashion, there is no objective evidence to suggest that lingual orthodontic treatment should take any longer for a given case than labial orthodontic treatment.

Is Treatment Quality Comparable to Labial Orthodontics?

Despite some early trepidation, the direct bonding of ceramic brackets quickly became accepted practice. As a further note, because the advent of early ceramic brackets (e.g., the Starfire ceramic system [Sybron Dental Specialties], among others) coincided roughly with the arrival of early lingual appliances, many clinicians at that juncture turned away from primordial lingual appliances in favour of labial ceramic brackets, not withstanding short-lived objections such as that cited above.

Precision of bracket placement (and, therefore, final clinical results) has been addressed primarily by the use of indirect lingual bonding. The laboratory protocols for fabrication of transfer trays have been a standard feature of most lingual orthodontic styles of practice since the beginnings of the discipline. Direct bonding is possible, but rarely implemented.

Another commonly held misconception centres around the assumed problem of bracket interference in cases of deep overbite. The earliest lingual bracket designs incorporated a built-in bite plane within the body of the upper anterior brackets. Some clinical cases show the initial “propping open” effect elicited by the presence of lingual upper appliances against lower incisors, with subsequent posterior bite closure.

The Lingual Edgewise Appliance

Different kinds of lingual bracket systems have been manufactured, for example, Fujita, Ormco, Forestadent and Creekmore Enterprise. The Kurz-Ormco 7th generation lingual brackets are Edgewise brackets specifically designed for the lingual surface of the teeth.
Figure 2: Forestadent lingual bracket.

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 tooth brushing. 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 cap. 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 time. 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 combined.

**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[2] 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.

**Technique: Explained in successive pictures. (Figure 3)**

Figure 3 A: accurate impressions recorded.
Figure 3 B: Models are poured in diestone.

Figure 3 C: Casts are duplicated.
Figure 3 D: Duplicates are dried in oven.
Figure 3 E: Teeth are sectioned to fabricate diagnostic set up.

Figure 3 F & G: Individual teeth are placed on preformed set up base. Overall archform must be coordinated.

Figure 3 H: The final set up is checked.
Figure 3 I: Lingual surfaces must be completely cleaned using a wax solvent.

Figure 3 J: Set up is dried in oven at approximately 100 degrees F. for 1 hour.
Figure 3 K: Model is placed in model holder and set with the occlusal plane parallel to a fixed horizontal plane.
Figure 3 L: Brackets are bonded to the set-up model using a two-part heavy body paste such as Phase II from Reliance Orthodontic Products.
Figure 3 M: Adhesion is applied to mesh pads of each bracket.

Figure 3 N: Ideal template blade is made of 0.018 or 0.022 stainless steel.
Figure 3 O: Anterior brackets are placed.

Figure 3 P: Anterior brackets are set
Figure 3 Q: Excess adhesive is trimmed using dental explorer.

Figure 3 R: Photocopy is made using a camera or a copying machine.
Figure 3 S: Acrylic caps are constructed.
Figure 3 T & U: Small strip of acrylic is cut & laid over the top of each bracket.

Figure 3 V & W: Each bracket is removed from the set up tooth & transferred to its individual duplicate on malocclusion model.

Figure 3 X & Y: Brackets are secured to the malocclusion model using water soluble adhesive.

Figure 3 Z: A copying machine is used to make a second occlusal record. AA: The clinician can bend the Bioplast tray as needed to gain initial placement.
Figure 3 AB & AC: Trays are sectioned in two or three pieces per arch.

Figure 3 AD: Injectable silicone is used in plastic syringe.

Figure 3 AE: Model release is painted on the surfaces of the cast. AF: Biostar machine.

Figure 3 AG: Trays are removed from the model soaking the cast in warm water for approximately 30 min. Figure 3AH: Bracket bases are abraded using a micro etcher.
The TARG system\textsuperscript{2} 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 improved the machine so tooth labio-lingual thickness could be measured reducing the first-order bends in the archwire.

Advantages
- It is an accurate and quantified two dimension system.
- Allows accurate placement of the brackets on the cast without having to cut the tooth and place in the wax.

Disadvantages
- The system does not take into account the labio-lingual thickness of teeth. Hence correct alignment can only be obtained by adding a great number of first order bends.
- The distance of the bracket base and the labial surface varies according to the level of bonding.

Recent developments to improve bracket positioning include the Hiro Laboratory Procedure and the Ray Set Biaggini Bracket positioned.

The Hiro System\textsuperscript{10,11} 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 advantages:
1. no electronic equipment is required for bracket positioning;
2. no need to transfer brackets from the set-up model to the original malocclusion model;
3. the accuracy of bonding is improved because of the rigid individual trays;
4. bonding can take place at any time as the trays are not affected by positions of other teeth and
5. rebonding is quick and accurate with the ideal archwire and the set-up model.

The Ray Set System\textsuperscript{2} 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 bonding. 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 surface. 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 placement.

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 one\textsuperscript{12}. Scuzzo and Takemoto 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 intrusion.

As far as the upper molars are concerned, the axis passing to 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 increased. 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. 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 malocclusion.

iii) Anchorage considerations
It is generally said that a lingual approach gives a greater amount of anchorage than a labial approach. 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 bone.

Treatment Sequence
Scuzzo and Takemoto 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 molar.

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 x .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 mass retraction. The wires for torque leveling are .0175 x 0.175-inch or .017 x .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 x .025-inch TMA archwire, the closed helical loop with .017 x .025-inch TMA archwire and the closing loop with .0175 x .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 x .025-inch TMA. In the lower arch, .016 x .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 X .0175-inch TMA archwires are used.

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 removal.

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 base plate 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 Takemoto 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.

Keys to Success in Lingual Therapy
Smith and coworkers reported 12 keys to success in lingual therapy. They were.

1. patient selection
2. bracket placement accuracy
3. indirect bonding
4. vertical and transverse control of segments
5. double-overlies on anterior teeth
6. buccal and lingual molar attachments
7. correcting rotations
8. arch form and archwire sequence
9. archwire stiffness and torque control
10. en masse retraction
11. light, resilient wire for detailing and gnathologic
12. positioner and retention.

REFERENCES