A study of the effects of playing a wind instrument on the occlusion

By

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Abstract

Objectives

To investigate the effects of playing a wind instrument on the occlusion.

Subjects and method

This was a cross-sectional observational study. One hundred and seventy professional musicians were selected from twenty-one classical orchestras and organisations. The subjects were subdivided according to the type of instrument mouthpiece and included thirty-two large cup-shaped mouthpiece brass players (group A.L), forty-two small cup-shaped mouthpiece brass players (group A.S), thirty-seven single reed mouthpiece woodwind players (group B) and fifty-nine string and percussion instrument players (control group). Impressions were taken for each subject and various parameters were assessed from the study casts. Statistical analysis was undertaken for interval variables with one-way analysis of variance and for categorical variables with Chi-square tests.

Results

No statistically significant differences were found in overjet, overbite, crowding, Little's Irregularity Index and prevalence of incisor classification between the wind instrument players and the control group, $p>0.05$. However, group A.L had a significantly higher prevalence of buccal crossbites than all the other groups, $p<0.05$.

Conclusions

Playing a wind instrument does not significantly influence the position of the anterior teeth and is not a major aetiological factor in the development of malocclusion. However, playing a brass instrument with a large cup-shaped mouthpiece may predispose to buccal crossbite development.

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Chapter 1

Literature Review

1.1 Introduction

Dentists and orthodontists are often asked by patients and their parents whether playing a wind instrument may affect the position of their teeth. Indeed, amongst wind instrument players and teachers it has been popular belief that playing a wind instrument leads to malocclusion.

1.2 The wind instruments

A wind instrument is a musical instrument that comprises a resonator, which is usually a tube, in which a column of air is set into vibration by the player blowing into or over a mouthpiece. The pitch of the vibration is determined by the length of the tube and by manual modifications of the effective length of the vibrating column of air.

Wind instruments are divided into brass instruments and woodwind instruments. Brass instruments are made of metal and have a cup- or funnel-shaped mouthpiece. In brass instruments sound is produced by vibration of the lips as the player blows into the mouthpiece. This creates waves of vibrating air which travel through the instrument and come out of the bell at the end as sound. Hence, brass instruments are often also referred to as labrosones, literally meaning "lip-vibrated instruments". The pitch, which refers to the height of the tones, depends on how fast the lips vibrate, the length of the tube and contraction of the diaphragm. In most brass instruments, the length of the resonator may be altered by a piston or rotary valves so that a variety of tones are produced. The waves of vibrating air may be diverted by pressing the valves and therefore the path of air is sent into separate loops before it is expelled through the bell of the instrument.

Woodwind instruments typically comprise a resonator with holes and a single reed mouthpiece, double reed mouthpiece or an aperture where the wind instrument player blows into. Blowing air into the resonator creates waves of air, which come out at the other end as sound. Covering and uncovering the holes allows the production of a variety of different tones. The tones are also dependent on the length of the resonator; the longer the resonator, the lower the tone.

Although brass instruments were originally made of brass and woodwind instruments were originally made of wood, nowadays, the material which is used to make the body of the instrument is not always a reliable guide to its family type. For example, although the saxophone and the flutes are made of metal, they belong to the woodwind family.

A more accurate way to determine whether an instrument is classified as brass or woodwind is to examine how the player produces sound and observe how the embouchure is formed. The term embouchure alludes to the manner in which the lips and mouth are applied to the mouthpiece of the wind instrument. The word is of French origin and is related to the root "*bouche*" which means mouth. A correct embouchure allows the instrumentalist to play the instrument at its full range with a full, clear tone and without strain or damage to the muscles.The greatest determinant of embouchure is the type of mouthpiece an instrument possesses. In brass instruments, the player's lips vibrate, causing the air within the instrument to vibrate. In woodwind instruments the player blows either onto a reed (clarinet), across a hole (flute), or down a hole (recorder).

1.3 Aetiology of malocclusion

A malocclusion is defined as an appreciable deviation from the ideal occlusal relationship that may be considered aesthetically or functionally unsatisfactory (Houston et al. 1992). Malocclusion is due to the interplay of a variety of different environmental and genetic factors (Mossey 1999).

The following aetiological factors of malocclusion have been suggested:

- A disproportion in the size of the maxilla and mandible - Lundström (1984), Proffit et al. (2007)
- Dentoalveolar disproportion - Proffit et al. (2007)
- Abnormality in the number and shape of the teeth - Van der Linden (1974), Proffit et al. (2007)
- Soft tissue behaviour e.g. lip trap - Proffit et al. (2007)
- Localised dental pathology or trauma - Proffit et al. (2007)
- Early loss of primary teeth - Proffit et al. (2007)
- Lack of attrition in modern society’s soft diet - Begg (1954)
- Various muscular dystrophies - Proffit et al. (2007)
- Mouth breathing - Linder-Aronson (1973), Harvold et al. (1981)
- Habits e.g. thumb sucking and tongue thrust - Larsson (1987)
- Playing a wind instrument - Pang (1976), Gualtieri (1979), Brattström et al. (1989)

1.3.1 Dental equilibrium theory

Weinstein et al. (1963) were the first authors to propose the equilibrium theory with respect to tooth position. The authors proposed that the forces exerted by the surrounding soft tissues may be sufficient to cause tooth movement in the same manner as that produced by orthodontic appliances. Therefore, the surrounding musculature envelops and consequently shapes the dental arch forms.

Proffit (1977) revisited the equilibrium theory and concluded that that the position of the teeth is dependent on forces exerted from the tongue and lips, forces from the dental occlusion, forces from the periodontal membrane and habits such as thumb-sucking. Respiratory needs may also influence the head, jaw and tongue posture and therefore may also affect the force equilibrium.

1.3.2 Digit sucking

The effects of digit and thumb sucking on the occlusion are well documented in the medical literature.

Proffit and Fields (2004) suggested that the effects of digit or thumb sucking are due to the alteration of the force equilibrium on the teeth. Digit sucking may cause proclination and spacing in the maxillary incisor teeth, anterior open bite and a narrow and V-shaped upper arch. The anterior open bite is due to a combination of interference with normal eruption of incisors and excessive eruption of posterior teeth.

Proffit and Fields (2004) suggested that the duration of the habit is more important than the magnitude of the force. Thus, the detrimental effects of thumb sucking on malocclusion in a child that sucks vigorously but intermittently will be less than in a child that sucks the thumb for 6 hours or more, even if the child places the thumb or fingers passively between the teeth whilst sleeping, without actively exerting pressure.

Graber (1959) suggested that the duration, frequency and the intensity of the habit are all important factors. In some children, the intensity is high with active perioral muscle function and audible accompaniment, whereas in others the habit only involves passive insertion of the digit in the mouth.

Larsson (1987) suggested that the vertically directed component of the force obstructs vertical growth of the maxilla, the dental arch becomes lengthened and the anterior teeth of the upper arch become anteriorly displaced. The lower incisors may become retroclined, as a result of the force by the digit, or may become proclined when the force that the tongue exerts on the lingual surfaces of the lower incisors during thumb sucking is higher than the force exerted by the digit.

Moore and McDonald (1997) in a cephalometric evaluation of patients presenting with persistent digit sucking habits concluded that, other than the dentoalveolar effects documented by previous authors, the sucking habit also caused minor effects on the skeletal pattern. In comparison to the control group, children with a thumb sucking habit had a significantly higher maxillary prognathism, increased maxillary anteroposterior length, and the maxillary plane was rotated downwards posteriorly and upwards anteriorly.

1.3.3 Mouth breathing

Previous research studies have suggested that mouth breathing, caused by nasopharyngeal obstruction associated with enlarged adenoids, results in a typical facial appearance described as the “long face syndrome” or “adenoid facies”. Mouth breathing results in the development of a retrognathic mandible, increase in lower anterior face height, high maxillary mandibular planes angle, narrow alar bases, a narrow or V-shaped maxillary arch, lip incompetence and retroclination of upper and lower incisors (Harvold et al., 1981, Linder-Aronson 1973, Linder-Aronson 1974, Linder-Aronson et al., 1986, Linder-Aronson et al., 1993).

It has been suggested that mouth breathing results in the tongue adopting a more inferior and anterior position in the oral cavity. This inferior position of the tongue does not exert lateral (buccal) forces on the maxillary dentition and therefore the medial pressure exerted by the lips and cheeks is not counteracted, leading to narrowing of the maxilla (Linder-Aronson 1974, Harvold et al., 1981).

However, the relationship between mode of breathing and facial morphology and malocclusion still remains unclear (O’Ryan et al., 1982).

1.4 Magnitude and duration of force required for tooth movement

Tooth movement requires the application of force, of adequate magnitude and adequate duration.

Weinstein et al. (1963) concluded that various levels of forces, even when low in magnitude, if applied over a considerable period of time can cause significant changes on tooth position.

Proffit (2004) suggested optimal forces for orthodontic tooth movement ; 70-120g for bodily movement, 50-100g for root uprighting, 10-20g for intrusion and 35-60g for rotation, extrusion and for tipping movements. These values depend on the size of the tooth, with incisors requiring lower magnitude of forces and multi-rooted teeth higher forces. Ideal efficiency of tooth movement is achieved by continuous application of forces as opposed to with intermittent application of forces. However, it is possible to produce tooth movement with a shorter duration of force application, with the threshold of force duration being 6 hours. However, these figures provided are anecdotal as they are not the product of research.

Ren at al. (2003) undertook a systematic review to ascertain the optimal forces required to achieve orthodontic tooth movement. The authors found very few experiments relating the rate of tooth movement to the magnitude of the applied force. Due to variation in the results from primary studies, no evidence regarding the optimum force required for orthodontic tooth movement could be extracted from the literature. The authors concluded that more well controlled clinical studies and standardised experiments in the orthodontic field are required in order to define the relationship between magnitude of applied force and rate of tooth movement.

Animal studies have been conducted to ascertain whether continuous or intermittent forces are superior at initiating tooth movement.

Konoo et al. (2001) examined the tooth movement, osteoclast recruitment at compression sites and root resorption of rats' teeth with the application of continuous force and intermittent forces applied for 1 hour daily. They concluded that, although the application of a force of 1 hour daily does not stimulate tooth movement, it is enough to stimulate recruitment of osteoclasts at compression sites.

Hayashi et al. (2004) compared the tooth movement of rats' molar teeth with continuous and intermittent forces applied for 8 hours daily. Although there was no difference in initial tooth movement, less movement was observed with intermittent forces on days 7 and 13.

Yoo et al. (2004) assessed the initial response of nitric oxide synthetase when light continuous orthodontic force was applied on rats' maxillary first molars for 1, 3 and 6 hours per day. Nitric oxide is a marker of signal transduction relating to bone remodelling. The authors concluded that as little as 1-3 hours may be the threshold duration of force required for tooth movement to occur when a light continuous force is applied.

Kumasako-Haga et al. (2009) compared the effects of intermittent and continuous forces on the rate of tooth movement of rats' molar teeth. It was found that intermittent forces, acting for 8 hours per day, were sufficient to stimulate the recruitment of osteoclasts at compression sites, leading to tooth movement, whilst causing minimum root resorption.

1.5 The orthodontic-wind instrument interface

The orthodontic-wind instrument interface has been the focus of debate in the medical literature for over 70 years. The majority of the work in this area has been done by dentists and orthodontists interested in this field, often by virtue of being musicians themselves. For instance, Edward Ray Strayer was an orthodontist and a professional bassoonist with the Philadelphia Orchestra and Ernest Herman was an orthodontist and a violin and trumpet player.

A study of the published literature reveals a large range of expert opinions including:

1. Playing a wind instrument can be used as an aid in the treatment of malocclusion - Strayer (1939), Porter (1952), Dunn (1982)
2. Playing a wind instrument may delay or adversely affect orthodontic treatment - Herman (1974), Green and Green (1999)
3. Careful selection of wind instruments may be used to assist in the retention of teeth in subjects who have undergone orthodontic treatment - Strayer (1939)
4. Certain malocclusions and occlusal features are more compatible with playing certain types of wind instruments - Engelman(1965) , Porter (1967), Herman (1974), Green and Green (1995)
5. Certain dental and occlusal features, such as proud restorations, may interfere with a comfortable embouchure - Nixon (1963), Porter (1967), Lovius and Huggins (1973), Herman (1974)

6. Orthodontic appliances may interfere with the correct embouchure and therefore adversely affect the performance - Porter (1967), Herman (1974), Green and Green (1999)
7. Variations in the peri-oral and facial structures can influence wind instrument playing - Lamp and Epley (1935), Nixon (1963), Porter (1967), Herman (1974), Green and Green (1999)
8. Brass and woodwind instruments are helpful in developing muscle tonicity Parker (1957)

Most of the above statements were based on anatomical assumptions, logic and anecdotal evidence rather than evidence-based research. Based on research studies, other authors have drawn the following conclusions:

1. Playing a wind instrument at professional level requires a sound dentition with minimal malocclusion - Lovius and Huggins (1973)
2. Orthodontic appliances may interfere with the correct embouchure and therefore adversely affect a wind instrument player's performance - Raney (2005)
3. There is no correlation between dental irregularities and the ability to excel in playing a wind instrument - Lamp and Epley (1935)
4. The pressure exerted by brass instruments on the teeth may be as high, or even higher, with respect to thumb sucking - Engelman (1965)
5. Playing a wind instrument may affect the position of the teeth and occlusion - Pang (1976), Gualtieri (1979), Herman (1981) and Brattström et al. (1989)

The aspect of the orthodontic- wind instrument interface that research has particularly focused on is the debate of whether playing a wind instrument may affect the position of teeth. From the preceding overview of the potential aetiological factors of malocclusion, it is possible to question whether playing a wind instrument may interfere with the dental equilibrium balance and therefore may influence the position of the player's teeth or cause a malocclusion.

1.6 Strayer's classification of wind instruments

Strayer (1939), who was a professional Bassoonist with the Philadephia Orchestra as well as an orthodontist, was one of the first authors to publish articles on the orthodontic-wind instrument interface. Strayer suggested the theoretical effects of playing various wind instruments on the position of the teeth, depending on the mouthpiece that the instrument contains and the embouchure that is involved. Strayer, based on observation, proposed that wind instruments may be used as an aid in the treatment of malocclusions and in improving facial musculature.

Strayer described the embouchure and the muscles that are used for playing each wind instrument and concluded that playing all types of wind instruments are useful in subjects with hypotonic facial muscles. He classified instruments into four categories depending on their mouthpiece and the embouchure involved, as follows:

<u>Class A instruments</u> (Figures 1.1 and 1.2)

This group of instruments has cup-shaped mouthpieces and comprises the following, named in order of increasing size of the instrument's mouthpiece;

1. Trumpet
2. Bugle
3. Fluegel horn
4. French horn
5. Trombone
6. Baritone
7. Bass horn
8. Tuba

The mouthpieces are typically made of metal. There is a significant variation in the size, width of the rim and shape and depth of the cup depending on the size and type of the instrument. Whilst playing these wind instruments, the mouthpiece is placed tightly against the lips causing the face to assume “tenseness” and air is directed into the instrument through a small aperture formed between the tensed lips. Higher tones require the musculature to be more tensed than lower tones. Strayer suggested that playing a Class A instrument would be useful in subjects with general hypotonicity of the facial musculature and flabby lips, in subjects with a Class II division 1 malocclusion and in subjects with protruding upper incisors. Strayer also suggested that Class A instruments are useful in mouth breathers, as the deep regular breathing required to play the instrument stimulates the narrow and constricted nasal passages to develop into normal size and contour, thus allowing free passage of air.

Class B instruments (Figures 1.3 and 1.4)

This group of instruments has single reed mouthpieces and comprises the following, named in order of increasing size of the reed mouthpiece and size of the instrument;

1. Clarinet
2. Saxophone

The mouthpiece is wedge-shaped with a single reed in the lower surface of the mouthpiece. Whilst playing the wind instrument, the upper lip touches the upper surface of the mouthpiece, whilst the lower lip acts as a cushion for the reed. Strayer suggested that playing a Class B instrument is useful for subjects with a Class III malocclusion, as the action of the musculature in forming the embouchure causes an anterior restraining force, which prevents the mandible from protruding. Furthermore, Strayer suggested that these instruments are contraindicated in all subjects with protruding upper anterior teeth, in subjects with Class II division I and Class II division 2 malocclusions as the instrument exerts an anterior restraining force on the mandible.

Class C instruments (Figures 1.5 and 1.6)

This group of instruments has double reed mouthpieces and comprises the following, named in order of increasing size of reed and instrument;

1. Oboe
2. English Horn
3. Bassoon
4. Contra-bassoon
5. Sarusophone

At the time of writing, double reed instruments had a mouthpiece comprising two pieces of reed bound together with wire and binding cord. Whilst playing a Class C instrument instrument, the double reed is placed between the lips, forming a cushion for the mouthpiece. Strayer suggested that Class C instruments are not contraindicated for any type of malocclusion, as there is no strong tension involved in forming the embouchure. However, he suggested that this class of instruments is excellent for stimulating hypotonic tissues , elongating lips, and for retruding the lips in subjects with a characteristic curl or protrusion of the lips, where the upper lip is turning upwards and outwards and the lower lip is turned downwards and outwards.

Class D instruments (Figure 1.7)

This group of instruments have an aperture at the head of the instrument and comprises the following, named in order of increasing size;

1. Piccolo
2. Flute

Playing this type of wind instrument requires the lower lip to be rolled over the side of the head of the instrument, whilst the upper lip is stretched or drawn downwards to create a small hole to direct the airflow into the mouthpiece's aperture. Variation in tone is produced by increasing and decreasing the tension of the upper lip whilst the lower lip remains inactive.

Strayer suggested that playing a Class D instrument is useful in subjects with a class I class III malocclusions, in subjects who have a short upper lip and “unruly” mentalis muscle action. Strayer suggested that playing a class D instrument should be avoided in subjects with a Class II division 1 and class II division 2 malocclusions.

Strayer also suggested that playing any class of wind instruments may either act as an adjunct or may be detrimental to the orthodontic treatment, depending on the instrument that is played and the malocclusion that the orthodontist is aiming to correct. Furthermore, Strayer suggested that playing a wind instrument is useful in assisting retention after the orthodontic appliances are removed, provided that the instrument is not contraindicated for the original malocclusion, and the orthodontist should be consulted if somebody who has completed his/her orthodontic treatment is interested in playing a wind instrument.

Finally, Strayer described in detail the physiology and muscles involved in voice production. He concluded that singing is beneficial for those subjects with hypertonicity of the facial, supra- and infrahyoid musculature as it requires the entire facial, throat and the chest muscles to be under delicate control. He stated, therefore, that singing is not contra-indicated for any type of malocclusion.

Figure 1.1 Professional trombone player and embouchure with a large cup-shaped mouthpiece (Class A).

Figure 1.2 Professional French horn player and embouchure with a small cup-shaped mouthpiece (Class A).

Figure 1.3 Professional clarinet player and embouchure with a single reed, clarinet mouthpiece (Class B).

Figure 1.4 Professional saxophone player and embouchure with a single reed, saxophone mouthpiece (Class B).

Figure 1.5 Professional oboe player and embouchure with a double reed, oboe mouthpiece (Class C).

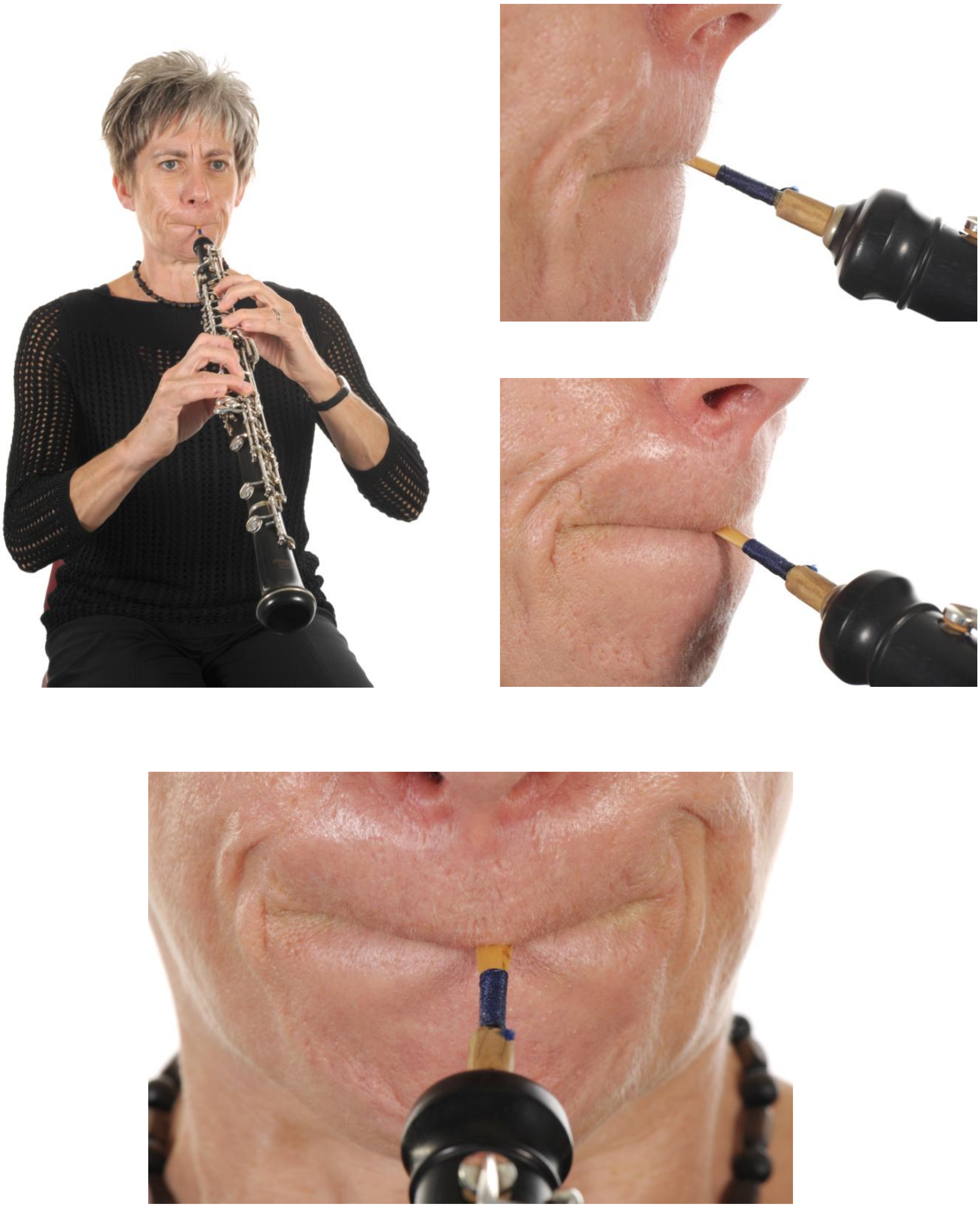

Figure 1.6 Professional bassoon player and embouchure with a double reed, oboe mouthpiece (Class C).

Figure 1.7 Professional flute player and embouchure with an aperture mouthpiece, flute mouthpiece (Class D).

1.6 The effects of playing a wind instrument on the occlusion

1.6.1 Expert opinion and anecdotal evidence on the effects of playing a wind instrument on the occlusion

Following the suggestions by Strayer, other authors have provided observations and opinion in this field.

Porter (1952) suggested that the orthodontist may advise parents on the choice of wind instruments and monitor the progress of an instrument serving as an orthodontic appliance, provided that the instrument is carefully chosen and practised under the guidance of a qualified teacher.

Parker (1957) suggested that there is a favourable influence on the position of the teeth when the correct embouchure is employed and that proper embouchure will assist in maintaining maxillary teeth in a favourable position. Mandibular incisors may be prone to becoming displaced lingually and rotating due to the pressure from the wind instrument's mouthpiece and suggested that a lingual appliance should be constructed for retention.

Herman (1974) suggested that choosing the correct wind instrument may be crucial during orthodontic treatment as it may assist or hinder the tooth movements that the orthodontic treatment is aiming to achieve. Furthermore, he suggested that certain malocclusions may be partly corrected through the use of a wind instrument. For example, it was suggested that an anterior open bite may be corrected though playing a double reed instrument, as the pressure from the upper and lower lips may “force” the upper and lower anterior teeth together.

Gualtieri (1979) suggested that all subjects should undergo thorough orthodontic assessment prior to starting playing a wind instrument. Wind instrument players who have previously undergone orthodontic treatment should be closely monitored in the post-retention phase, and the orthodontist should be paying particular attention to the potential of lingual collapse of the mandibular anterior teeth.

Hruby and Kessler (1959), Ma and Laracuente (1979) and Dunn (1982) supported the suggestions of Strayer (1939), who advocated that playing a wind instrument may be used as an aid to the orthodontic appliances and exert forces which may affect the position of the teeth.

1.6.2 Previous research on the effects of playing wind instrument on the occlusion

Since the early observational evidence, numerous authors have attempted to examine over the last three decades the effects of playing a wind instrument on the occlusion more rigorously. The majority of the published studies have been cross-sectional observational studies comparing the study casts and/or lateral cephalograms of wind instrument players with that of a control group.

Parker (1957), in the Alameda Instrumentalist Study, assessed the upper incisor to maxillary plane angle by means of lateral cephalometry. This study included 84 school children of both sexes, aged 9-17, who had at least 2 years of experience with a wind instrument. The study included 30 trumpet, 32 clarinet, 14 saxophone and 6 flute players. The upper incisor to maxillary plane angle was not significantly different amongst various groups.

Engelman (1965) used an intraoral pressure transducer to measure the magnitude of lingually directed forces exerted by the upper lip on the maxillary anterior teeth during various activities including thumb sucking, swallowing, whistling and playing brass (cup-shaped mouthpiece) instruments, reed instruments and the flute. 20 subjects were selected, aged 10-17, who had at least one year of experience with playing a wind instrument. Engelman concluded that the mean pressure exerted by the upper lip to the upper incisors was highest for the brass group, followed by the reed group and it was lowest for the flute group. Furthermore, it was of interest to find that playing a brass instrument for certain subjects exerted a higher force on the maxillary incisors than thumb sucking. Based on this, Engelman concluded that the forces exerted on the dentition whilst playing a wind instrument may be of sufficient magnitude to produce or help to correct a malocclusion. However, it is well documented that the effects of thumb sucking on the dentition are primarily due to the pressure of the thumb acting on the palatal surfaces of upper incisors and not due to the lingually directed forces exerted by the upper lip.

Pang (1976), in a prospective study, assessed the effects of playing various wind instruments on the overjet and overbite of schoolchildren over a six-month period. Using study casts, changes in the position of the teeth of wind instrument players were compared to the changes in the position of the teeth of a control group of children, who did not play a wind instrument. This study included 76 school children of both sexes who had not previously undergone orthodontic treatment.

Pang concluded that, on an individual basis, the effect of playing a wind instrument on the anterior teeth is unpredictable and conclusions can only be drawn depending on the class of the instrument. Class A instruments reduced the overjet, Class B instruments did not significantly increase the overjet, Class C instruments reduced the overjet but may cause an anterior open bite and Class D instruments increased the overjet.

Gualtieri (1979) examined the dentition and assessed the lateral cephalograms of 150 subjects aged between 18 and 61 years. The subjects included student wind instrument players and professional wind instrument players from Classes A, B, C and D, and a control group comprising percussion musicians, dental hygiene students and dental assistants. A significant number of the subjects had previously undergone orthodontic treatment.

The clinical examination included assessment of Angle’s classification, anterior crowding and spacing, overjet, overbite, crossbites, dental arch form, centreline discrepancy, anterior tooth mobility, tongue shape, size and scalloping, and temporo-mandibular joint symptoms.

Gualtieri concluded that playing a Class B instrument causes an increase in the overjet and all classes of instruments caused retroclination of lower anterior teeth.

Herman (1981) carried out a two-year prospective study, which included 91 wind instrument players from Classes A, B, C and D, aged 11-13, and compared them with a control group comprising 36 children, aged 11-13, who did not play a wind instrument. Study casts were made at the beginning of the study, after one year and after two years.

Herman concluded that playing a wind instrument of Classes A, C and D decreased the overjet, whereas playing a Class B instrument increased the overjet. After two years, although there was no improvement in the alignment of the teeth in the control group, there was an improvement in the alignment of the teeth of 17% of the wind instrument players.

Rindisbacher et al. (1989) assessed and compared the faces and dentition of 62 adult male and female professional wind instrument players with a control group. The wind instrument players included 31 brass players and 31 reed and flute players and the control group comprised 75 male dental students and other university students. The facial morphology and the dentition were assessed by examining lateral cephalograms and study casts. The measurements carried out included overjet, overbite, length and width of the dental arches, incisor irregularity, maxillary length, mandibular length and upper and lower incisor inclination. It was concluded that playing a wind instrument has none or only a minor influence on the facial morphology and the occlusion.

Brattström et al. (1989) retrospectively assessed and compared the lateral cephalograms and study models of 58 school children playing a class A or a class B instrument to a control group, comprising 40 schoolchildren, who did not play a wind instrument. Inclusion into the study required the subject to have at least three lateral cephalograms and study models out of the following four time periods; 6, 9, 12 and 15 years of age.

The authors concluded that playing a wind instrument resulted in a favourable anterior growth rotation of the mandible and lower anterior facial height compared to the control group. The dental arch width was wider in wind instrument players compared to the control group and Class A instruments retroclined uppers incisors, whereas class B instruments proclined upper incisors.

In summary, Parker (1957) and Rindisbacher (1989) concluded that playing a wind instrument has little, if any, effect on the occlusion. On the contrary, Pang (1976), Gualtieri (1979) and Brattström et al. (1989) concluded that playing a wind instrument may affect the inclination of the upper and lower incisors and therefore result in an increase or decrease in the overjet and the overbite.

1.6.3 Critical appraisal of previous evidence on the effects of playing a wind instrument on the occlusion

In the context of currently accepted optimum research practice, many of the previously reported studies, which are now significantly dated, might be considered to suffer from potential flaws, which could affect the validity of the conclusions drawn. Potential inaccuracies could arise due to the following:

- Small sample size
- Lack of a control group or a biased control group, such as one comprising dental students or student dental hygienists or assistants
- Inclusion of amateur players, children and adolescents
- Inclusion of subjects who had previously undergone orthodontic treatment
- Inclusion of subjects from various ethnic groups
- The wind instrument players were not separated into groups or classes according to the type of instrument or the shape of the mouthpiece
- Study casts were not taken
- The examiners were not blinded
- The dental status of the participants was not stated
- Data and results were not presented
- Statistical analyses were not performed
- In prospective studies, the subjects were followed for a very short duration of time and there was a significant drop-out rate

1.7 Aims and objectives

The aim of this study is to assess whether playing a wind instrument has an effect on the position of the teeth or cause a malocclusion. In particular, the objectives of this study are to:

1. Determine if playing a wind instrument affects the overjet, overbite or transverse molar relationship
2. Determine if playing a wind instrument causes crowding and irregularity, or alters the intermolar widths
3. Determine if there is a difference in the prevalence of British Standards Institute Incisor relationship and crossbites in brass and woodwind players when compared with musicians who do not play a wind instrument.

1.7.1 Null Hypothesis

There is no difference in the position of the teeth and the malocclusion between musicians who play a wind instrument and those who do not play a wind instrument.

Chapter 2

Subjects and method

2.1 Subjects

Various well-established and reputable professional orchestras, jazz bands and music colleges were contacted. The subjects comprised wind instrument players of classes A and B and the control group comprised string instrument and percussion players, recruited from the same organisations as the wind instrument players. Due to the variation in the size of the mouthpieces of Class A instruments, subjects who played a Class A instrument were subdivided into those who play a brass instrument with a large cup-shaped mouthpiece (A.L), such as the tuba and the trombone, and those who play a Class A instrument with a small cup-shaped mouthpiece (A.S), such as the French horn and the trumpet.

The subjects were therefore separated into 4 different groups:

- A.L ; Large mouthpiece Class A (brass) wind instrument players, such as the tuba and trombone
- A.S ; Small mouthpiece Class A (brass) wind instrument players, such as the French horn and trumpet
- B ; Class B wind instrument players, such as the clarinet and saxophone
- C ; Control group- string and percussion players

The effects of playing classes of instruments C and D were not investigated in this study.

2.2 Organisations

The subjects were selected from the following organisations:

- Royal Philharmonic Orchestra
- City of Birmingham Symphony Orchestra
- London Philharmonic Orchestra
- Lucerne Symphony Orchestra
- Oxford Philomusica
- Royal Liverpool Philharmonic Orchestra
- BBC Big Band
- Welsh National Opera Orchestra
- Halle
- BBC Philharmonic Orchestra
- Opera North
- National Saxophone Choir
- Clarinet and Saxophone Society
- Trinity College of Music
- BBC Scottish Orchestra
- Royal National Scottish Orchestra
- Royal Scottish Academy of Music and Drama
- BBC Concert Orchestra
- Royal Welsh College of Music and Drama

Furthermore, two organisations, the East London Clarinet Choir and Notebenders Jazz Club, were visited but none of the musicians satisfied the selection criteria.

2.3 Inclusion and exclusion criteria

Subjects were eligible for inclusion in the study if they satisfied the following criteria:

Wind instrument players

Inclusion criteria

1. Adult
2. Caucasian only
3. Men and women
4. Professional wind instrument players who have been practising on average for at least 3 hours daily and for at least the last 4 years

Exclusion criteria

This depended on:

A. Patterns of practising the wind instrument;

1. Practising for less than 3 hours daily on average during the last 4 years
2. Wind instrument players who play more than one class of wind instruments, either professionally or recreationally, with the exception of Class B players who also played the flute or the piccolo

B. Dental Health;

1. Previous orthodontic appliance treatment
2. Extraction of permanent teeth other than second and third molars
3. Retained deciduous teeth
4. Presence of supernumerary teeth
5. Crowns in permanent teeth other than first, second and third molars
6. Restorations on incisor and canine teeth which extend over two surfaces
7. Pathology, including periodontal disease, previous fractures of the maxilla or the mandible and dental cysts
8. Thumb or finger sucking habit which is present now or ceased after the age of 10 years old
9. Congenital craniofacial syndromes or defects
10. Pipe smokers

Control group

<u>Inclusion criteria</u>

1. Adult
2. Caucasian only
3. Men and women
4. Professional string instrument and percussion players

Exclusion criteria

This depended on:

A. Patterns of practising the wind instrument;

Those who played or used to play a wind instrument were excluded

B. Dental Health;

1. Previous orthodontic appliance treatment
2. Extraction of permanent teeth other than second and third molars
3. Retained deciduous teeth
4. Presence of supernumerary teeth
5. Crowns in permanent teeth other than first, second and third molars
6. Restorations on incisor and canine teeth which extended over two surfaces
7. Pathology, including periodontal disease, fractures of the maxilla or the mandible and dental cysts
8. Thumb or finger sucking habit which is present now or ceased after the age of 10 years old
9. Congenital craniofacial syndromes or defects
10. Pipe smokers

2.4 Sample size calculation

Independent groups t-test analysis estimated that 32 subjects per group are required in order to detect a difference of 2mm in the overjet amongst various groups. This was based on an alpha significance level of 0.05 with a 95 per cent power.

The standard deviation for the sample size calculation was calculated as 1.9mm based on data obtained from the National Health and Nutrition Examination Survey III (NHANES III, 1998), which included detailed data on overjet across a very large population of Caucasians.

2.5 Ethical approval

Ethical approval was obtained from the University of Birmingham Research and Ethics Committee (ERN_08-370). An additional ethical approval was obtained from the Royal Northern College of Music Research and Ethics Committee.

All subjects were treated according to the Declaration of Helsinki (1964) and in accordance to the British Psychological Society’s Code of Ethics and Conduct (2006).

2.6 The procedure

Those who satisfied the criteria on the basis of a questionnaire had a brief examination of their teeth. Those who were eligible to participate had impressions by Mr. Ektor Grammatopoulos, Specialist Registrar in Orthodontics. Study casts were made and coded to preserve anonymity and ensure there was no examiner bias during the assessment of the casts.

Recruitment of participants stopped as soon as 32 musicians had participated in each group, as dictated by the sample size calculation. Overall 170 musicians participated, having satisfied the inclusion and exclusion criteria. This included 32 subjects in group A.L, 42 subjects in group A.S, 37 subjects in group B and 59 subjects in group C.

2.7 Measurements

The following features were assessed on the study casts:

1. Overjet (mm)
2. Overbite (mm)
3. British Standards Institute Incisor relationship (BSI 4492)
4. Upper and lower arch intermolar widths (mm)
5. Crowding in the upper and lower labial segments (mm)
6. Little's Irregularity Index (mm), Little (1975)
7. Crossbites, with reference to the first molars

All measurements were carried out by one examiner, Mr. Ektor Grammatopoulos. Digital callipers (Figure 2.1) were used to measure the linear measurements of overbite, intermolar width, crowding and Little's Irregularity Index. The examiner found it easier to use an orthodontic stainless steel ruler to measure the overjet. In order to confirm the accuracy of the digital callipers, the calibration of the digital callipers was repeated following the assessment of every 12 successive study casts.

The mesiobuccal cusps of the upper and lower first permanent molar teeth were taken as reference points in order to define the upper and lower arch intermolar widths. Little's Irregularity Index, which is the sum of the contact point displacement in the 6 anterior teeth, was measured as described by Little (1975).

Crossbites were assessed in terms of type and severity:

- In terms of type, each cast was scored as follows;

    1. Absence of crossbites
    2. Presence of buccal crossbites or buccal crossbite tendencies
    3. Presence of lingual crossbite or lingual crossbite tendencies

- In terms of severity, each cast was scored as follows;

    1. Absence of crossbites or presence of crossbites of less than half a cusp’s width
    2. Presence of crossbites of more than half a cusp’s width.

The intermolar difference for each cast was calculated as the difference between the upper and lower arch intermolar widths, measured in millimeters.

The intermolar width ratio was calculated as the upper arch intermolar width divided by the lower arch intermolar width.

Figure 2.1 Digital callipers

2.8 Statistical analysis

Statistical analysis of the data was performed using the SPSS Statistics 17.0 statistical package under the guidance of the University of Birmingham's Statistical Advisory Service.

Prior to commencing the measurements, the reproducibility of the measurements was confirmed by re-measuring 20 randomly selected study casts 9 days later. A matched pairs t-test indicated that there was no significant difference between the initial and subsequent measurements.

One-way Analysis of Variance (ANOVA) was used to compare the mean of interval variables amongst the various groups including overjet, overbite, upper and lower labial segment crowding, Little's Irregularity Index and upper and lower intermolar widths.

Retrospective sample size calculation confirmed that there is more than 80% power for the analysis and comparison of all other occlusal features:

- The power to detect a 2mm statistically significant difference in the overbite between the two groups with the least subjects, group A.L and B, based on a standard deviation of 1.867, was 95%
- The power to detect a 3mm statistically significant difference in the upper arch intermolar width between the two groups with the least subjects, group A.L and B, based on a standard deviation of 3.302, was 87%

- The power to detect a 3mm statistically significant difference in the lower arch intermolar width between the two groups with the least subjects, group A.L and B, based on a standard deviation of 3.030, was 87%
- The power to detect a 2.5mm statistically significant difference in the upper labial segment crowding between the two groups with the least subjects, group A.L and B, based on a standard deviation of 2.108, was 98%
- The power to detect a 2.5mm statistically significant difference in the lower labial segment crowding between the two groups with the least subjects, group A.L and B, based on a standard deviation of 2.275, was 97%
- The power to detect a 2.5mm statistically significant difference in upper Little's Irregularity Index between the two groups with the least subjects, group A.L and B, based on a standard deviation of 3.498, was 88%
- The power to detect a 2.5mm statistically significant difference in the lower Little's Irregularity Index between the two groups with the least subjects, group A.L and B, based on a standard deviation of 3.956, was 83%

A Chi-square test was used to assess if there is a difference in categorical variables amongst various groups, including the proportion of subjects with various incisor classifications and prevalence of crossbites.

Finally, a logistic regression was used for the investigation of potential confounding factors, such as whether gender may have an effect on the severity or prevalence of crossbites.

Chapter 3

Results

Section A Table of results

Table 3.1 Mean age and gender distribution of subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and data on mean age and proportion of men and women	All instrument groups	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Average age (Years)	33.37	32.50	33.41	29.84	36.19
Minimum age (Years)	18	18	18	19	18
Maximum age (Years)	57	56	52	56	57
Range (Years)	39	38	34	37	39
Standard deviation	10.46	10.13	10.19	9.81	10.68
Percentage of men	71.8%	100%	78.6%	54.1%	62.7%
Percentage of women	28.2%	0%	21.4%	45.9%	37.3%

Table 3.2 Summary of results for mean overjet, overbite, upper and lower labial segment crowding, upper and lower Littles Irregularity Index for subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and variable	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)	Significance level (ANOVA)
Overjet (mm)	2.77	2.83	3.01	3.12	**P=0.75**
Overbite (mm)	2.48	2.74	2.72	3.06	**P=0.55**
Upper crowding (mm)	0.79	1.66	1.44	1.50	**P=0.31**
Lower crowding (mm)	1.33	2.34	1.65	2.32	**P=0.10**
Upper Little's (mm)	3.36	3.52	3.60	3.94	**P=0.99**
Lower Little's (mm)	3.33	4.50	3.90	4.37	**P=0.16**

Table 3.3 Summary of results for upper and lower intermolar widths and mean of the difference between the upper and lower intermolar width for subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and upper and lower arch intermolar width and intermolar difference	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)	Significance level (ANOVA)
Upper arch intermolar width(mm)	51.5	50.8	50.1	50.6	**P=0.35**
Lower arch intermolar width(mm)	47.6	44.9	44.7	44.6	**P=0.001**
Upper minus lower arch intermolar width(mm)	3.93	5.99	5.42	6.01	**P=0.009**

Table 3.4 Overjet of subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and overjet	All instrument groups	A.L - Large Cup brass (trombone	A.S - Small cup brass (trumpet	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Mean overjet (mm)	2.96	2.77	2.83	3.01	3.12
Minimum overjet(mm)	-7.0	-7.0	-3.0	-1.0	0
Maximum Overjet(mm)	11.0	11.0	7.0	6.0	6.5
Range (mm)	18.0	18.0	10	7.0	6.5
Standard deviation	1.70	2.62	1.47	1.22	1.49
95% confidence interval- lower bound (mm)	2.70	2.18	2.31	2.46	2.68
95% confidence interval- upper bound (mm)	3.21	3.37	3.35	3.57	3.56

Table 3.5 Overbite of subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and overbite	All instrument groups	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Mean overbite (mm)	2.96	2.48	2.74	3.01	3.12
Minimum Overbite (mm)	-1.5	-0.5	-0.7	-1.5	-1.2
Maximum Overbite(mm)	8.5	5.5	6.3	6.7	8.5
Range (mm)	10	6.0	7.0	8.2	9.7
Standard deviation	1.87	1.40	1.54	2.10	2.14
95% confidence interval- lower bound (mm)	2.5	1.98	2.25	2.03	2.50
95% confidence interval- upper bound (mm)	3.08	2.99	3.21	3.43	3.61

Table 3.6 Upper labial segment crowding of subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and upper labial segment crowding	All instrument groups	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Mean crowding (mm)	1.40	0.79	1.66	1.44	1.53
Minimum crowding (mm)	-6	-6	-5	-3	-4
Maximum crowding (mm)	10	4	6	6	10
Range (mm)	16	10	11	9	14
Standard deviation	2.11	2.03	2.06	1.69	2.39
95% confidence interval- lower	1.08	0.55	1.02	0.76	0.99
95% confidence interval- upper	1.72	1.52	2.3	2.12	2.07

Table 3.7 Lower labial segment crowding of subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and lower labial segment crowding	All instrument groups	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Mean crowding (mm)	1.99	1.33	2.34	1.65	2.32
Minimum crowding (mm)	-0.5	-4.0	-0.5	-4.5	-5.0
Maximum crowding (mm)	9.5	7.0	7.0	8.0	9.5
Range (mm)	10	11	7.5	12.5	14.5
Standard deviation	2.22	1.62	2.43	2.28	2.19
95% confidence interval- lower	1.65	1.11	0.45	1.71	1.66
95% confidence interval- upper	3.03	2.19	2.21	2.90	2.31

Table 3.8 Upper Little's Irregularity Index of subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and upper Little's Irregularity Index	All instrument groups	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Mean (mm)	3.50	3.36	3.52	3.60	3.49
Minimum (mm)	0.00	0.20	0.00	0.30	0.00
Maximum (mm)	14.76	8.54	9.21	10.22	14.76
Range (mm)	14.76	10.54	9.21	10.52	14.76
Standard deviation	2.68	2.21	2.55	2.56	3.10
95% confidence interval- lower bound (mm)	3.09	2.56	2.72	2.74	2.68
95% confidence interval- upper bound (mm)	3.90	4.15	4.32	4.45	4.30

Table 3.9 Lower Little's Irregularity Index of subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and lower Little's Irregularity Index	All instrument groups	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Mean (mm)	3.96	3.33	4.50	3.39	4.27
Minimum (mm)	0.00	0.00	0.30	0.00	0.00
Maximum (mm)	15.16	8.37	15.16	7.91	14.03
Range (mm)	16.16	8.37	14.84	7.91	14.03
Standard deviation	2.87	2.56	3.19	1.97	3.18
95% confidence interval- lower bound (mm)	3.52	2.33	3.63	2.46	3.53
95% confidence interval- upper bound (mm)	4.39	4.33	5.37	4.31	5.00

Table 3. 10 Upper arch intermolar width of subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and upper arch intermolar width	All instrument groups	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Mean (mm)	50.73	51.53	50.84	50.10	50.60
Minimum (mm)	39.07	44.46	41.00	43.36	39.07
Maximum (mm)	59.35	58.10	57.11	56.88	59.35
Range (mm)	20.28	13.64	16.11	13.52	20.28
Standard deviation	3.30	2.93	3.50	3.20	3.43
95% confidence interval- lower bound (mm)	50.22	50.47	49.77	49.04	49.70
95% confidence interval- upper bound (mm)	51.22	52.58	51.92	51.17	51.49

Table 3.11 Lower arch intermolar width of subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and lower arch intermolar width	All instrument groups	A.L - Large cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Mean (mm)	45.24	47.58	44.86	44.68	44.59
Minimum (mm)	38.30	41.38	39.77	39.98	38.30
Maximum (mm)	58.34	58.34	50.92	49.90	50.55
Range (mm)	20.04	16.97	11.15	9.92	12.55
Standard deviation	3.03	3.52	2.74	2.46	2.69
95% confidence interval- lower bound (mm)	44.79	46.32	44.00	43.86	43.89
95% confidence interval- upper bound (mm)	45.70	48.87	45.71	45.50	45.30

Table 3.12 Tukey Post Hoc Test for the comparison of lower arch intermolar width between the experimental groups A.L, A.S, B and the control group, C.

Group of instrument compared	Group of instrument compared	Significance level
A.L - Large cup brass	**A.S - Small cup brass**	0.000
A.L - Large cup brass	**B - Single reed**	0.000
A.L - Large cup brass	**C - Control**	0.000
A.S - Small cup brass	**A.L - Large cup brass**	0.000
A.S - Small cup brass	**B - Single reed**	0.993
A.S - Small cup brass	**C - Control**	0.967
B - Single reed	**A.L - Large cup brass**	0.000
B - Single reed	**A.S - Small cup brass**	0.993
B - Single reed	**C - Control**	0.999
C - Control	**A.L - Large cup brass**	0.000
C - Control	**A.S - Small cup brass**	0.967
C - Control	**B - Single reed**	0.999

Table 3.13 Upper minus lower arch intermolar width of subjects in experimental groups A.L, A.S, B and the control group, C.

Instrument and upper minus lower arch intermolar width	All instrument groups	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Mean (mm)	5.48	3.93	5.99	5.42	6.00
Minimum (mm)	-7.06	-7.06	-0.40	-2.96	-5.09
Maximum (mm)	14.88	9.77	9.20	14.88	9.46
Range (mm)	21.94	16.83	9.60	17.84	14.55
Standard deviation	3.03	4.06	2.33	2.96	2.63
95% confidence interval- lower bound (mm)	5.02	2.46	5.26	4.44	5.32
95% confidence interval- upper bound (mm)	5.94	5.39	6.71	6.41	6.69

Table 3.14 Ratio of upper arch intermolar width divided by lower arch intermolar width for experimental groups A.S, B and the control group, C.

Instrument and upper divided by lower arch intermolar width	All instrument groups	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Mean (mm)	1.12	0.87	1.13	1.23	1.14
Minimum (mm)	0.87	0.99	0.87	0.94	0.88
Maximum (mm)	1.35	1.22	1.22	1.35	1.24
Range (mm)	0.48	0.23	0.35	0.41	0.36
Standard deviation	0.68	0.54	0.85	0.68	0.61
95% confidence interval- lower bound (mm)	1.11	1.11	1.06	1.12	1.11
95% confidence interval- upper bound (mm)	1.13	1.15	1.12	1.15	1.15

Table 3.15 Prevalence of crossbite severity of more than half a cusp's width for experimental groups A.L, A.S, B and the control group, C.

Instrument and prevalence of crossbite severity	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Subjects demonstrating no crossbite or crossbite tendency	19	36	28	52
Percentage of subjects demonstrating no crossbite or crossbite tendency	59%	86%	76%	88%
Crossbite severity of more than half a cusp's width	13	6	9	7
Percentage of subjects demonstrating crossbite severity of more than half a cusp's width	41%	14%	24%	12%

Table 3.16 Prevalence of buccal and lingual crossbites and crossbite tendencies for experimental groups A.L, A.S, B and the control group, C.

Instrument and prevalence of crossbites	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
No Crossbites	15	32	25	45
Buccal crossbite or buccal crossbite tendency	17	9	12	8
Lingual crossbite or lingual crossbite tendency	0	1	0	6

Table 3.17 Prevalence of incisor relationship for experimental groups A.L, A.S, B and the control group, C.

Instrument and incisor classification	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)	Total
Class I	16 50.0%	25 59.5%	18 48.6%	33 55.9%	92 54.1%
Class II(1)	3 9.3%	5 11.9%	7 18.9%	13 22.0%	28 16.5%
Class II(2)	5 15.6%	9 21.4%	3 8.1%	3 5.1%	20 11.8%
Class III	8 25%	3 7.1%	9 24.3%	10 16.9%	30 17.6%
Total	32	42	37	59	170 100%

Table 3.18 Upper and lower arch intermolar width, upper minus lower arch intermolar width and ratio of upper to lower arch intermolar width of male subjects only in experimental groups A.L, A.S, B and the control group, C.

Instrument and intermolar width	All instrument groups	A.L - Large Cup brass (trombone and tuba)	A.S - Small cup brass (trumpet and French horn)	B - Single reed (clarinet and saxophone)	C - Control (string and percussion)
Mean upper arch intermolar width (mm)	51.21	51.53	51.29	50.71	51.15
Mean lower arch intermolar width (mm)	45.93	47.60	45.48	45.33	45.20
Mean upper minus lower arch intermolar width (mm)	5.29	3.92	5.81	5.38	5.95
Ratio of upper to lower arch intermolar width	1.12	1.09	1.13	1.12	1.13

Section B Statistical analysis

Statistical analysis using one-way analysis of variance (ANOVA) found no statistically significant differences in the overjet (p=0.75), overbite (p=0.55), crowding (upper labial segment p=0.31, lower labial segment p=0.10) and Little's Irregularity Index (upper arch p=0.99, lower arch p=0.16) amongst various groups (Tables 3.2 and 3.4-3.9).

Statistical analysis using Chi-square tests found no statistically significant difference in the prevalence of incisor classification (p=0.15) amongst various groups (Table 3.17).

One-way ANOVA found that there was no significant difference in upper arch intermolar width (p=0.35) amongst various groups. However, one-way ANOVA found a significant difference in the lower arch intermolar width (p<0.001) between various groups. In order to establish where the significant difference lies, a follow-up statistical analysis with a Tukey Post Hoc Test was carried out, which found that the lower arch intermolar width for group A.L was significantly higher (p=0.000) than groups A.S, B and the control group C. There was no significant difference in the lower arch intermolar width between groups A.S, B and the control group, C. Furthermore, group A.L had a significantly lower difference between the upper and lower arch intermolar width (p=0.009) and significantly lower ratio of upper arch intermolar width to lower arch intermolar width (p=0.006). Statistical analysis with Chi-square tests found that group A.L players had a significantly higher prevalence of buccal crossbites when compared with the other wind instrument player groups and the control group (p=0.008). This is shown in tables 3.10-16 and 3.18.

Further statistical analysis was carried out using one-way ANOVA on the data from the two genders separately. It was found that there was no significant difference in the upper arch (p=0.92) and lower arch (p=0.37) intermolar widths and no significant difference in the mean difference between the upper and lower arch intermolar widths (p=0.58) and mean ratio of upper intermolar width to lower intermolar width (p=0.54) for female musicians between groups A.S, B and the control group. As there were no female musicians in group A.L, this statistical analysis did not include this group.

However, statistical analysis using one-way ANOVA and follow-up analysis with Tukey Post Hoc Tests found that there was a significant difference in the lower arch intermolar width (p=0.031), difference between the upper and lower arch intermolar widths (p=0.003) and ratio of upper arch to lower arch intermolar width (p=0.026) for male musicians in group A.L compared with the other experimental groups, A.S and B, and the control group, C. There were no significant differences in the lower arch intermolar width, difference between the upper and lower arch intermolar widths, and ratio of upper arch intermolar width to lower arch intermolar width for male subjects between groups A.S, B and the control group, C. Statistical analysis with one-way ANOVA found that there was no significant difference in the upper arch intermolar width (p=0.84) for male musicians amongst various groups, including no significant difference in the upper arch intermolar width between group A.L and all the other groups.

Furthermore, a logistic regression taking instrument into account confirmed that gender has no effect on the severity or prevalence of crossbites.

Chapter 4

Discussion

Discussion

The subjects chosen for this study were either professional musicians or student musicians in higher education training to become professional musicians. The study was controlled through the application of strict inclusion and exclusion criteria. Mean age of subjects was similar amongst various groups. However, there was a difference in the proportion of men and women amongst various groups, and in particular all the subjects in group A.L were men (Table 3.1). Whilst not ideal, this was unavoidable as it is representative of this division of brass players in various orchestras, jazz bands and schools.

Sample size calculation had determined that a minimum of 32 subjects were required in each group. Therefore, it was decided to stop participant recruitment as soon as 32 subjects were included in each group. This resulted in more than 32 participants in some groups. Recruitment of more than 32 participants in some groups was beneficial as it resulted in an increase in the power of the statistical analysis.

The present study focused on the effects of playing wind instruments from Classes A and B (Strayer, 1939) only, as results from previous cross-sectional observational studies had shown that playing Classes A and B have the most profound effect on the position of the teeth. It is, indeed, a popular belief amongst musicians and teachers that instruments of Classes A and B exert the highest forces on the teeth and they have the most pronounced effect on the position of the teeth. This is in keeping with the suggestions by Engelman

(1965) who also suggested that brass, followed by reed instruments exert the highest forces on the dentition.

There is large variation in the size of the mouthpieces of Class A instruments (Table 4.1). Therefore, Class A wind players (brass players) were subdivided into those who play with a large cup-shaped mouthpiece and those who play with a small cup-shaped mouthpiece, as the force exerted over a small surface area, such as with the mouthpiece of a trumpet, may be more potent than a force of the same magnitude exerted over a larger surface area, such as with the mouthpiece of a trombone (Figure 4.1). The size and the shape of the clarinet and the saxophone's single reed mouthpiece and the embouchure whilst playing the saxophone and the clarinet are very similar (Figure 4.2). Furthermore, it is common for clarinet players to also play the saxophone and vice versa. Therefore, it was not deemed necessary to separate Class B instrument players into a group of subjects playing the clarinet and a group of subjects playing the saxophone. Furthermore, this would have resulted in lower power for the statistical analysis.

It was decided to exclude all those wind instrument players who play wind instruments from two different classes of wind instruments, as the forces exerted by the tensed facial musculature or the mouthpiece on the teeth from the different classes of instruments may be acting in opposite directions. Therefore, on a theoretical basis, the resultant of the forces from two different classes of wind instruments may be zero. However, it was decided not to exclude strictly only those Class B instrument players who also played a Class D instrument. Most Class B players whilst at Music College take as a secondary class the flute or the piccolo and professional jazz players during their performances typically play, as well as the saxophone, the flute or the piccolo too. In keeping with the conclusions of Engelman (1965), music teachers and professional wind instrument players confirm that playing a Class D instrument results in low forces applied to the teeth compared to instruments from other classes. Inclusion of Class B players who also played the clarinet enabled the research team to recruit an adequate sample of Class B players. Furthermore, exclusion of such players may have lead to results which are not representative of the majority of the saxophone and clarinet players who very often play or used to play a Class D instrument.

In many previous cross-sectional observational studies, probably for practical reasons, dental students and student dental nurses or hygienists comprised part or the whole of the control groups. In this study, an unbiased control group comprising string and percussion players was chosen which is socioeconomically similar to the experimental groups. To date, there is little evidence to suggest that playing the violin or the viola may affect the position of the teeth (Kovero et al. 1997) and therefore the inclusion of string players as the control group was deemed appropriate. The musicians of the control group were selected from the same organisations as the musicians from the experimental groups.

Based on the equilibrium theory and aetiology of malocclusion, it may be possible that professional wind instrument players who have reduced periodontal support might be more prone to exhibiting changes on their occlusions due to playing a wind instrument. For this reason an attempt was made in the present study to exclude subjects who were suffering from or had previously suffered from periodontal disease. However, it should be borne in mind that periodontal disease is difficult to accurately diagnose in the premises of a concert theatre or a school as radiographic examination is not available in this setting. In addition, it was decided not to carry out probing depths due to ethical and practical implications. The use of disposable probes is prone to inaccuracy and would have raised cross-infection control problems and potential safety issues in the premises of a non-clinical environment. Furthermore, it may have caused discomfort to musicians and hence interfered with their performance or with the recruitment of participants in this study. There is, however, strong correlation between poor oral hygiene, periodontal disease, large restorations, crowns and extractions and subjects who had one or more of these were excluded from the study. Therefore, it is likely that most subjects with significant periodontal disease have been excluded from the present study on the basis of a different exclusion criterion. In addition to the potential for periodontal disease to exacerbate the effects of forces exerted on the teeth, it has also been questioned whether wind instrument playing could generate pressures which, in the same way as occlusal forces, could aggravate an existing poor periodontal condition. Previous cross-sectional observational work by Stamatakis et al. (1999), however, has suggested that playing a wind instrument is not an aetiological factor in the development of periodontal bone loss. At any rate, the above exclusion criteria should have excluded any subjects who might potentially have had a compromised periodontal status.

Despite the interest that the orthodontic-wind instrument interface has generated historically, there has been a lack of evidence-based data to enable clinicians to provide accurate advice in this area. Previous anecdotal evidence, expert opinion and popular belief of wind instrument players and teachers have suggested that playing a wind instrument may affect the position of the teeth.

The present cross-sectional observational study, however, suggests that playing a wind instrument, even at professional level, has very little effect on the teeth. There were no differences between the various experimental groups and the control group in the overjet, overbite, upper and lower labial segment crowding, upper and lower Little's Irregularity Index, prevalence of British Standard's Institute Incisor classification and upper arch intermolar width (Tables 3.2 and 3.3).

Through observing the embouchure of brass players (Figures 1.1 and 1.2) one may assume that the pressure from the mouthpiece on the lips may result in retroclination of the upper and/or lower incisors. This could have resulted in a decrease in the overjet and/or decrease in overbite. Retroclination of the upper and lower incisors could have also resulted in the teeth in the upper and lower labial segments subsequently occupying a smaller space, which could have resulted in an increase in crowding and Little's Irregularity Index. However, the results and the statistical analysis of the present study does not support such assumptions. Similarly, through observing the embouchure of a single reed player (Figures 1.3 and 1.4), one may assume that the pressure from the mouthpiece on the upper and lower teeth could have resulted in proclination of the upper incisors and/or retroclination lower incisors. This could have resulted in an increased overjet and a decreased overbite. Such proclination of upper incisors could have resulted in reduced crowding, or even spacing, in the upper labial segment as the upper labial segment teeth occupy more space. Retroclination of the lower incisors could have resulted in the teeth of the lower labial segment subsequently occupying a smaller space, which could have resulted in an increase in crowding and Little's Irregularity Index. However, the results and the statistical analysis of the present study does not support such assumptions either.

The results of this study are therefore in variance with the observational suggestions of authors such as Strayer (1939), Porter (1952), Dunn (1982) and results and conclusions of the research of various authors such as Pang (1976), Gualtieri (1979), Herman (1981) and Brattström et al. (1989), who suggested that playing a wind instrument may affect the position of the teeth and occlusion. For example, Pang (1976) had concluded that playing brass instruments tends to cause an increased overjet and Gualtieri (1979) had concluded that playing single reed instruments results in an increased overjet, and that playing all types of wind instruments caused retroclination of lower incisors.

A statistically significant difference was found in the lower arch intermolar width for those wind instrument players who play with a large cup-shaped mouthpiece, A.L, compared with the other experimental groups, A.S and B, and the control group, C (Tables 3.11 and 3.12). However, there was no difference in the upper arch intermolar width between A.L group and the other experimental groups and the control group (Table 3.10). Furthermore, the difference between the upper and lower arch intermolar widths and the ratio of the upper divided by lower arch intermolar width (Tables 3.13 and 3.14) was significantly lower for group A.L. This relatively wider lower arch intermolar width also resulted in a higher prevalence of buccal crossbites in group A.L compared with the other experimental groups and the control group.

It may be possible that this difference in the lower arch intermolar width is due to the fact that group A.L players keep their mouths slightly more open during playing, as the large cup-shaped mouthpieces are much bigger than the small cup-shaped mouthpieces (Figure 4.1 and Table 4.1). Subsequently, this may result in the tongue adopting a more inferior position, which may lead to an increase in the width of the lower arch intermolar width, which in turn could explain the increased prevalence of buccal crossbites for group A.L. However, although these differences are statistically significant, it is highly unlikely that they would be of clinical significance or the presenting complaint of a patient.

As all subjects in groups A.L were men, in order to confirm that gender is not a confounding factor for this difference in the lower arch intermolar width and crossbites, further statistical analysis was performed with the exclusion of data from women in all the other groups. This confirmed that there was no statistically significant difference in the upper arch intermolar width, whilst there was a statistically significant difference in the lower arch intermolar width, difference between the upper and lower arch intermolar width and ratio of upper to lower arch intermolar width between group A.L and the other experimental groups, A.S and B, and the control group (Table 3.18). Furthermore, a logistic regression that controlled for gender showed that there was no correlation between gender and prevalence or severity of crossbites.

The present study has demonstrated that playing a wind instrument, even at a professional level, does not significantly affect the position of the teeth and is not an aetiological factor for the development of malocclusion. This may be due to one or more of the following reasons:

- The magnitude of the forces exerted whilst playing a wind instrument do not exceed the threshold for tooth movement.

- The duration of the force applied whilst playing a wind instrument may not exceed the threshold of force duration for tooth movement to occur. Even the most skilled wind instrument players, who play at the most renowned orchestras and bands, play and practise on average 3-4 hours daily. This may not be exceeding the threshold of force duration for tooth movement to occur.

- Unlike the forces applied by the orthodontic appliances and forces by thumb-sucking, forces applied during wind instrument playing are not continuous, as wind players typically take breaks during their practice and performance.

- Forces by the mouthpiece on the teeth are cushioned by the lips. It is common knowledge amongst brass players that playing a brass instrument often requires pressing the mouthpiece tightly against the lips. Due to this prolonged and sustained pressure from the mouthpiece, it is common for brass players to develop well demarcated semi-lunar red scars on the philtrum of their upper lip, which corresponds to the size and shape of the mouthpiece (Figure 4.3). This red scar is often more apparent after a period of practising. Other than scars, the pressure applied from the mouthpiece on the lips occasionally causes labial muscle injury in brass players. Numerous reports have been published in the medical literature on orbicularis oris muscle rupture, known as Satchmo's Syndrome. This presents as weakness of the lips, which may result in signs and symptoms such as loss of endurance, loss of range and control of tone, diminished accuracy, and fatigue in the embouchure (Papsin et al. 1996). Therefore, it may be possible that, although the force exerted by the mouthpiece on the lips may be exceeding the force required for tooth movement to occur, this force does not result in tooth movement because it may be "cushioned" by the lips.

- The resting force from the lips, cheeks and tongue, swallowing and occlusion whilst the wind instrument player is not playing or practising may be more important in determining the position of the teeth than the force exerted whilst playing a wind instrument.

- Forces exerted by the mouthpiece and the tensed facial musculature may be balanced. For example, the force exerted by the instrument's mouthpiece on the palatal surfaces of the upper incisors may be balanced by the force exerted by the tensed upper lip on the labial surfaces of the upper incisors (Figure 4.4)

Figure 4.1 Size and shape of brass mouthpieces

A- Brass mouthpieces in order of ascending diameter: French horn, trumpet, trombone and tuba mouthpieces

B- Same person (non-musician) with a French horn and a tuba mouthpiece

Table 4.1 Sizes of the cup shaped instruments in a typical orchestra with examples of the names of the mouthpieces

Class A mouthpieces and diameter	**French horn mouthpiece**	**Trumpet mouthpiece**	**Trombone mouthpiece**	**Tuba mouthpiece**
Minimum diameter (mm)	24.70 Medium cup	26.59 Traditional cup	37.92 Alto trombone	44.28 Deep cup
Maximum diameter (mm)	28.00 Deep cup	28.50 Extra large symphonic	40.46 Bass trombone	47.35 Extra deep cup

Figure 4.2 Lateral, oblique and frontal photographs of a professional single reed player playing the clarinet and saxophone

Figure 4.3 Scar in the philtrum of a professional trumpet player due to the prolonged and sustained pressure from a cup-shaped mouthpiece

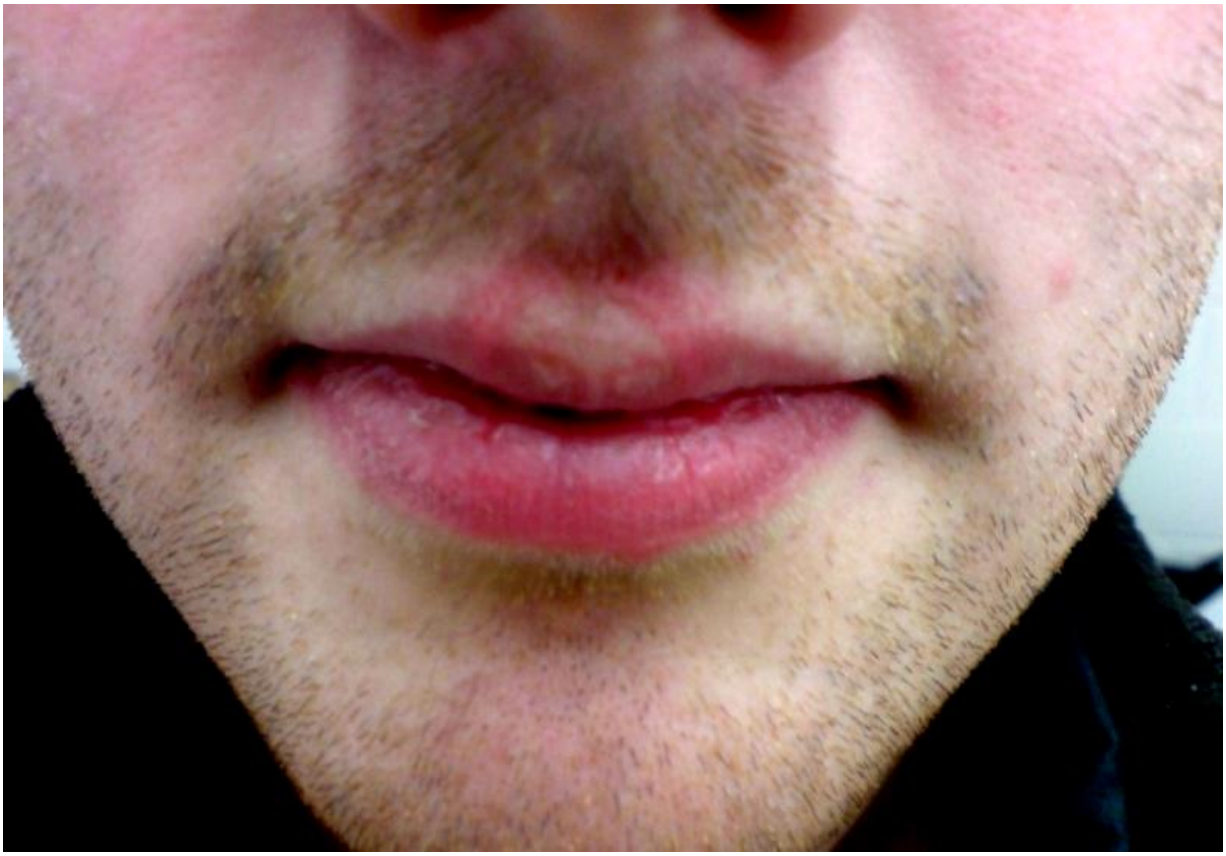

Figure 4.4 Professional clarinet player embouchure with labially and palatally directed forces exerted on the upper labial segment teeth, as indicated by the arrows

Perhaps the reason why a large proportion of musicians firmly believe that playing a wind instrument may affect the position of their teeth is because they or their colleagues have experienced late lower incisor crowding. With limited knowledge of the aetiology of such a common condition, a musician may attribute this to playing a wind instrument. The aetiology of lower incisor crowding is multifactorial and a variety of aetiological factors have been suggested and been investigated (Harradine et al. 1998). Increases in lower incisor irregularity occur throughout life in a large proportion of subjects who may have or may not have had orthodontic treatment (Richarson and Gormley 1998).

It has been suggested by previous authors, such as Porter (1952) and Herman (1974), that certain malocclusions are more compatible with playing certain instruments. For example, it has been suggested that it is easier to play a Class B instrument (clarinet and saxophone) if a subject has a class II division 1 malocclusion with a moderately increased overjet. The results of this research do not support this assumption, as it was concluded that subjects playing a Class B instrument had similar mean overjet, overbite and overall data on incisor classification with the other experimental groups and the control group (Tables 3.2-3.5 and 3.17). Most highly likely, mental characteristics such as the ability to study the music, determination for hard work and practice, staying in tune with the rest of the orchestra and physical characteristics such as manual dexterity, good lung capacity, strong diaphragm and stamina are more important for a musician to excel than a potentially favourable occlusion.

Impact of these findings on current advice

Following discussion with numerous music teachers and musicians in a variety of orchestras, jazz bands and music colleges, it became apparent that wind instrument teachers often dissuade young musicians to commence playing a brass instrument before the age of 8 years old in order to avoid “tooth damage or pushing in of the teeth”.

Upon eruption of the central and lateral incisors at the age of 6-8 years old, on average ¾ of their final root length is established (Gron 1962) and completion of root formation occurs at the age of 8.6-9.8 years old for central incisors and 9.6-10.8 years old for lateral incisors (Welbury 2001).

Before the age of 8 years old, the teeth may be more prone to tooth movement due to the force exerted by the mouthpiece as the teeth may have immature roots and the alveolar bone is very elastic. It is also uncertain whether this sustained pressure on a tooth with immature roots may also lead to dilacerations of the root. For these reasons, despite the conclusions of the present study that playing a wind instrument does not significantly affect the position of the teeth, the advice currently given by music teachers, in the authors’ opinion, should not change.

Chapter 5

Conclusions

Conclusions

1. Playing a wind instrument does not significantly affect anterior tooth position
2. Playing a wind instrument with a large cup-shaped brass instrument may result in the wind instrument player developing buccal crossbites

Therefore, the present research provides valuable evidence to reassure our patients and their parents that playing a wind instrument is highly unlikely to be an aetiological factor for the development of malocclusion or that their presenting malocclusion is the product of wind instrument playing.

Suggestions for further research

Jiggling forces, due to occlusal trauma or class II elastics (Linge and Linge, 1983), finger sucking habits (Linge and Linge, 1991) and severe nail biting (Odenrick and Brattström, 1985) have been suggested as aetiological factors for root resorption.

Therefore, research may be required to confirm that the jiggling forces on the dentition of wind instrument players, particularly in those who undergo fixed appliance treatment, are not an aetiological factor for root resorption.

Raney (2005), in a retrospective study by means of questionnaires completed by young wind instrument players who underwent orthodontic treatment, concluded that fixed appliances may interfere with the correct embouchure and therefore may have a negative impact upon the performance of young wind instrument players.

More well-controlled studies are required to ascertain whether undergoing orthodontic treatment may adversely affect the performance of wind instrument players and identify means of overcoming the problems that wind instrument players may encounter during their orthodontic treatment.

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Appendix

Appendix 1

UNIVERSITY OF BIRMINGHAM

Participant Invitation

Dear musician,

My name is Ektor Grammatopoulos and I am a specialist registrar in Orthodontics at Birmingham Dental Hospital. I am conducting a study as part of my postgraduate research degree aimed at investigating whether playing a wind instrument may affect the position of a musician's teeth. The title of the study is:

"A study of the effects of playing a wind instrument on the dentition".

Dentists are often asked by parents and their children whether playing a wind instrument may affect the position of their teeth. Unfortunately, we have no solid answers to give as there is no agreement amongst previous studies carried out on the effects of playing a wind instrument on the musician's teeth.

Benefits of the study

I would like to compare the position of the teeth of wind instrument players with that of string instrument and percussion players. The findings may have important implications.

If it is found that playing a wind instrument, even at a professional level, does not affect the position of the teeth, dentists can reassure wind instrument players regarding this matter.

However, if playing a wind instrument is found to affect the position of the teeth, dentists may inform wind instruments players of the likely effects.

Participation

If you are interested in participating in the study, I shall arrange a meeting with you at your practice venue, where you will be asked to complete a confidential questionnaire to find out whether or not you meet the criteria to take part in the study. Then, I will take a mould of your teeth. This is one of the simplest and safest procedures carried out regularly by dentists. The mould will be sent to a laboratory so that plaster models of your teeth are made. I will use these plaster models to study various features of your teeth. Any personal data, including your name and date of birth, will be stored on a NHS computer, which requires a swipe card and security code for access. If you wish, you may request a duplicate set of plaster models of your teeth.

Please do not hesitate to contact me if you would like to discuss the research project in more depth on Tel.[redacted] or [redacted]

Thank you very much for taking the time to read this. Your participation would be greatly appreciated.

Kind regards,

Mr. Ektor Grammatopoulos
Specialist Registrar in Orthodontics

Appendix 2

UNIVERSITY OF BIRMINGHAM

Participant Information Sheet

1. Invitation to participate in the study.

You are being invited to take part in a study that I am undertaking as part of a postgraduate research degree. Before you decide to take part, it is important that you understand why the research is being done and what it involves you to do as a participant. Please take time to read the following information carefully. Please do not hesitate to contact me if there is anything that is not clear or if you would like more information.

2. **Research Project Title:**

A study of the effects of playing a wind instrument on the dentition.

3. **What is the purpose of the project?**

This research project aims to find out the whether playing a wind instrument may affect the position of the teeth.

We are often asked by patients and parents whether playing a wind instrument may cause teeth to become crooked. We have no solid answers to give as there is no agreement amongst previous studies with regards to the effects of playing a wind instrument on the dentition. Furthermore, previous studies lacked strict methodology.

4. **Why have I been chosen?**

You have been chosen because I am looking to study the effects of playing a wind instrument may have had on your teeth. I will be comparing the teeth of wind instrument players to the teeth of an adult control group, which comprises string instrument and percussion players, to find out whether there is a difference.

5. **Do I have to take part?**

Participation in this study is entirely voluntary. If you decide to take part, you will be given an information sheet and you will be asked to sign a consent form. If you decide to take part, you will still be free to withdraw from the study at any time and without giving a reason. I may assure you that the findings of the examination of your teeth will be kept confidential. They will only be discussed with yourself and not with any of your colleagues or friends.

6. **What will happen to me if I take part?**

Participation is very simple and quick. If you are interested in taking part, I shall come and see you at your practice venue at an appropriate time. Following a short interview, during which I shall explain the study in further detail, I shall find out if you are eligible to participate in the study based on a set of inclusion and exclusion criteria. If you are eligible, I shall take an impression of your top and your bottom teeth. This is one of the simplest, easiest and safest procedures regularly carried out by dentists.

The interview will take approximately 10 minutes and taking the impressions will take a further 10 minutes.

I shall use these impressions to make plaster casts of your teeth. Various measurements will be taken from these study casts. Please do not hesitate to ask me for a duplicate set of these study casts.

7. **What do I have to do?**

If you decide to take part, you will just have to allow the research dentist to take moulds (impressions) of your teeth. This will take a few minutes. It will not affect your ability to play your instrument and there is no need to abstain from your practice. You may practise playing your musical instrument as normal just before and/or just after the impression is taken.

8. **What are the side effects or risks of having an impression taken?**

There are no reported side effects or risks. Impressions of children's and adults' teeth have been taken for many years by dentists.

9. **What are the possible benefits of taking part?**

Taking part in this study will allow information to be gathered on the effects of playing a wind instrument on the position of teeth.

This study has a variety of benefits to those who are interested in starting to play a wind instrument. If it is proven that playing a wind instrument has no effects on the teeth, children and their parents who were previously concerned about the effects of a wind instrument on the teeth may be reassured that playing a wind instrument does not affect the position of the teeth and it does not make them "crooked".

On the other hand, if it is proven that playing a wind instrument may change the position of the teeth, it is important for potential wind instrument musicians to be aware of this before starting to play a wind instrument.

10. **What if something goes wrong?**

If you feel something has gone wrong, please do not hesitate to discuss this with me. Alternatively, you may contact Professor P.J. Lumley, Director and Head of the School of Dentistry, University of Birmingham, [redacted], Tel. [redacted], who can provide you with independent advice.

11. **Will my taking part in this project be kept confidential?**

All information which is collected about you during the course of the study will be kept strictly confidential. The information I shall collect will include your name, surname, date of birth and contact telephone numbers. Furthermore, I shall ask you about the type of instrument that you play, for how many hours per day and for how many years you have been practising. I shall also ask you if you have had previous orthodontic treatment or adult teeth taken out at your dentist and if you used to suck your thumb when you were younger. The impression will be labelled with a number corresponding to yourself, so that only myself and the research team will know the identity of the study cast. All this information will be kept strictly confidential.

I am intending to do the interviews and the impressions at your practice venue in order to make it easier for you to take part in the study. Therefore, your colleagues may acknowledge the fact that you are participating in the study.

If you wish, the interview and the impressions may be carried out in the Orthodontic Department of Birmingham Dental Hospital or in the Oral and Facial Department of Warwick Hospital. Please do not hesitate to discuss with me this option.

12. **What will happen to the results of the research project?**

The results are likely to be published in autumn 2010 in dental and orthodontic journals and possibly music or other journals. Individual results of participants will be anonymous and kept on password secure NHS computers. Individual results will not be identifiable in any report or publication. The collective results of all the participants will be analysed and may be published.

13. **Who is organising and funding the research?**

The study is being paid for by the University of Birmingham. Your research orthodontist will not be paid for carrying out or for including you in this study.

14. **Who has reviewed the project?**

The project has been reviewed by the University of Birmingham Research and Ethics Committee.

15. Translation

For those musicians that English is not their first language, a translation of the information sheet and consent form will be provided by a qualified translator.

16. Contact for further information.

For further information about this study or for any concerns please do not hesitate to contact Mr. Ektor Grammatopoulos on Tel. [redacted] or [redacted]

Thank you very much for taking part in this study

Appendix 3

Posters displayed in music organisations for the education and recruitment of participants

Appendix 4

Questionnaire

WIND INSTRUMENT PLAYERS

PLEASE TELL ME ABOUT YOURSELF

Name

DOB Age Gender

Email address (optional)

Telephone number (optional) Orchestra/organisation

PLEASE TELL ME ABOUT YOUR MUSIC

What instrument do you play?

For how many years have you been playing this instrument?

How many hours a day on average do you play and practise? 1 2 3 4 5 6 7 8 9

Approximately, how many days on average a year do you abstain from practice?

Do you play any other wind instrument other than this?

Have you had any breaks in your career in the last 4 years?

Has the number of hours a day you have been practising been the same over the last 4 years? If no, please specify

Do you smoke a pipe?

PLEASE TELL ME ABOUT YOUR TEETH

Have you had orthodontic treatment (braces) in the past?

Have you ever had any teeth extracted?

Do you suck your thumb or have you ever sucked your thumb?
If so, when did you stop?

THANK YOU VERY MUCH FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE

Appendix 5

Questionnaire

STRING INSTRUMENT AND PERCUSSION PLAYERS

PLEASE TELL ME ABOUT YOURSELF

Name

DOB Age Gender

Email address (optional)

Telephone number (optional) Orchestra/organisation

PLEASE TELL ME ABOUT YOUR MUSIC

What instrument do you play?

For how many years have you been playing this instrument?

How many hours a day on average do you play and practise? 1 2 3 4 5 6 7 8 9

Approximately, how many days on average a year do you abstain from practice?

Have you had any breaks in your career in the last 4 years?

Has the number of hours a day you have been practising been the same over the last 4 years? If no, please specify

Do you play, or did you used to play a wind instrument?

Do you smoke a pipe?

PLEASE TELL ME ABOUT YOUR TEETH

Have you had orthodontic treatment (braces) in the past?

Have you ever had any teeth extracted?

Do you suck your thumb or have you ever sucked your thumb?
If so, when did you stop?

THANK YOU VERY MUCH FOR TAKING THE TIME TO COMPLETE THIS QUESTIONNAIRE

Appendix 6

UNIVERSITY OF BIRMINGHAM

Consent form

A study on the effects of playing a wind instrument on the dentition

I confirm that Mr. Ektor Grammatopoulos has explained the nature of the research project and what this involves me to do as a volunteer.

I have understood that participation in this study will involve a simple dental examination and impressions of my teeth taken. I have been explained and demonstrated the procedure of having an impression of my teeth taken. I understand that the research dentist will use these impressions to make study casts made of plaster.

I have had the opportunity to ask questions and having had enough time to consider my decision, I am happy to consent to participating in the study. I understand that I may withdraw at any time and I will receive no payment for participating in this study.

I also understand that the brief dental examination is not a substitute for the six-monthly dental check-up with my own dentist.

Signed………………………Date………..
NAME:……………………………………

Signed ……………………...Date………
NAME   EKTOR GRAMMATOPOULOS

Mr. Ektor Grammatopoulos
Specialist Registrar in Orthodontics
Birmingham Dental Hospital
[redacted]
Tel. [redacted]
[redacted]

Appendix 7

UNIVERSITY OF
BIRMINGHAM

Invitation to have photographs taken

My name is Mr. Ektor Grammatopoulos and I am a Specialist Registrar in Orthodontics at Birmingham Dental Hospital. I am conducting a study as part of my postgraduate research degree aimed at investigating whether playing a wind instrument may affect the position of a musician's teeth. The title of the study is:

"A study of the effects of playing a wind instrument on the dentition".

Please do not hesitate to request a separate Participant Information Sheet for this study.

You are being invited to have photographs of your face and teeth, including at rest and whilst playing a wind instrument. These photographs may be used for presentation in academic meetings and conferences and for publication purposes in dental, orthodontic and music journals. Your name will not appear alongside any photographs but your affiliation may be stated. Furthermore, your face and your teeth may be recognised.

Even if you consent to having photographs you may withdraw at any time without giving any reasons for doing so. In such case, you should email Mr. Ektor Grammatopoulos and inform him of your decision. If these photographs have already been published, it may be impossible for me to subsequently withdraw this consent.

If you are interested in participating, I shall arrange a meeting with you at your practice venue. Please do not hesitate to contact me if you would like to discuss the research project in more depth on Tel. [redacted] or [redacted]

Thank you very much for taking the time to read this. Your participation would be greatly appreciated.

Kind regards,

Mr. Ektor Grammatopoulos
Specialist Registrar in Orthodontics
Birmingham Dental Hospital
[redacted]

Appendix 8

UNIVERSITY OF BIRMINGHAM

Photography Consent form

A study of the effects of playing a wind instrument on the dentition

I consent to having photographs of my face and teeth, including whilst playing a wind instrument. These photographs may be used for presentations in academic meetings and conferences and for publication in dental, orthodontic and music journals. I understand that my face and my teeth may be recognised and my affiliation may appear alongside the photographs but my name will not be stated.

I understand that I may withdraw at any time without giving any reasons for doing so. In such case, I ought to email Mr. Ektor Grammatopoulos and inform him of my decision.
I understand that I shall receive no payment for having these photographs taken.

Please sign section A or B below. Please do not hesitate to ask if you do not fully understand.

A. I consent to the photographs being used for presentation purposes only.

Signed……………………….Date………..
NAME:……………………………………

B. I consent to the photographs being used for both presentation and publication purposes in a journal or textbook.

Signed……………………….Date………..
NAME:……………………………………

Signed ………………………Date………
NAME EKTOR GRAMMATOPOULOS

Specialist Registrar in Orthodontics
Birmingham Dental Hospital
[redacted]

Appendix 9

Poster - Summary of the aim, methodology and results of the research study,

presented at the British Orthodontic Conference, Edinburgh 2009

UNIVERSITY OF BIRMINGHAM

A study of the effects of playing a wind instrument on the occlusion

Mr Ektor Grammatopoulos, Dr Allan White, Dr Ashish Dhopatkar

Introduction

Strayer[1] classified wind instruments into four classes (A, B, C and D) according to the shape of the mouthpiece and the embouchure. Porter[2] described and illustrated the means by which the embouchure is formed and suggested that the forces exerted may result in tooth movement.

Class A instruments

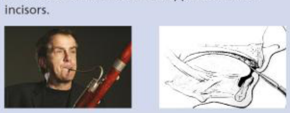
Class A instruments have a cup-shaped mouthpiece and include brass instruments such as the trumpet and tuba. The theoretical effects are retroclination of upper and lower incisors.

Class B instruments

Class B instruments have a single-reed mouthpiece and include woodwind instruments such as the saxophone and clarinet. The theoretical effects are proclination of upper incisors and retroclination of lower incisors.

Class C instruments

Class C instruments have a double reed mouthpiece and include woodwind instruments such as the oboe and bassoon. The theoretical effects are retroclination of upper and lower incisors.



Class D instruments

Class D instruments have an aperture at the head of the instrument and include instruments such as the flute and piccolo. The theoretical effects are retroclination of upper and lower incisors.

Several authors, including Pang[3] and Gualtieri[4], through using cross-sectional observational studies found that playing a wind instrument affects the position of the teeth. To date, there have been very few well-controlled studies. Hence, it has been impossible to provide evidence-based advice to our patients regarding whether playing a wind instrument may affect the position of the teeth or cause malocclusion.

Aim

To investigate whether playing a wind instrument has an effect on the position of the teeth.

Method

Ethical approval

University of Birmingham Research and Ethics Committee and Royal Northern College of Music Research and Ethics Committee.

Players

- Large cup-shaped players (A-L) e.g. tuba
- Small cup-shaped players (A-s) e.g. trumpet
- Single reed players (B) e.g. clarinet
- Control group (C) : String and percussion players

Inclusion criteria

- ✓ Caucasian
- ✓ Adult men and women
- ✓ Musicians from well-established organisations
- ✓ Wind instrumentalists playing for 3 hours a day for at least the last 4 years

Exclusion criteria

- × Previous orthodontic treatment
- × Missing or supernumerary teeth
- × Retained deciduous teeth
- × Extractions of permanent teeth other than second and third molars
- × Crowns in any teeth other than first molars
- × Congenital syndromes
- × Pathology e.g. periodontal disease
- × Digit-sucking habit after 10 years of age
- × Pipe smokers
- × Wind instrumentalists playing instruments from two different classes
- × String and percussion instrumentalists who play a wind instrument recreationally

Subject selection and recording

- Eligibility to participate was defined by means of a questionnaire and dental examination
- Eligible musicians had impressions taken
- Study casts were made and coded
- Measurements were made with digital callipers

Measurements

1. Overjet
2. Overbite
3. Upper and lower labial segment crowding
4. Little's Irregularity Index[5]
5. British Standards Institute Incisor Classification[6]
6. Upper and lower intermolar widths
7. Crossbites

Sample size calculation

- Independent groups t-test analysis
- 95% power to detect a 2mm statistically significant difference
- Sample size : 32 subjects in each group

Subjects and Organisations

- 170 subjects : 32 Class A-L
  42 Class A-s
  37 Class B
  59 Control
- Subjects were selected from 21 organisations

Results

Statistical analysis

- Matched pairs t-test confirmed reproducibility
- ANOVA for analysis of interval variables
- Chi square tests for categorical variables

Instrument and variables	A-Large Cup brass (trombone and tuba)	A-Small cup brass (trumpet and French horn)	B-Single reed (clarinet and saxophone)	C-Control (string and percussion)	P-value
Overjet (mm)	2.77	2.83	3.01	3.12	P=0.75
Overbite (mm)	2.48	2.74	2.73	3.06	P=0.55
Upper crowding (mm)	0.79	1.66	1.44	1.52	P=0.31
Lower crowding (mm)	1.33	2.34	1.65	2.32	P=0.10
Upper Little's (mm)	3.36	3.52	3.60	3.49	P=0.99
Lower Little's (mm)	3.33	4.50	3.90	4.27	P=0.16
Upper intermolar width (mm)	51.5	50.8	50.1	50.6	P=0.35
Lower intermolar width (mm)	47.6	44.9	44.7	44.6	P<0.001
Upper - Lower intermolar width (mm)	3.93	5.99	5.42	6.00	P=009

No statistically significant differences were found in overjet (p=0.75), overbite (p=0.55), crowding (upper arch p=0.31, lower arch p=0.10), Little's Irregularity Index (upper arch p=0.99, lower arch p=0.16) and prevalence of incisor classification (p=0.15) between the wind instrument players and the control group. However, group A-L had a significantly wider lower intermolar width (p<0.001), whilst there was no significant difference in upper intermolar width (p=0.35). This also resulted in a higher prevalence of buccal crossbites for A-L group when compared with other wind instrument player groups and the control group (p=0.008).

Conclusion

Playing a wind instrument does not significantly influence the position of the anterior teeth and is not a major aetiological factor in the development of malocclusion. However, playing a brass instrument with a large cup-shaped mouthpiece, such as the tuba and the trombone, may predispose to buccal crossbite development.

References

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Acknowledgements

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Royal Philharmonic Orchestra, City of Birmingham Symphony Orchestra, London Philharmonic Orchestra, Lucerne Symphony Orchestra, Oxford Philomusica, Halle, BBC Philharmonic Orchestra, Opera North, Royal Liverpool Philharmonic Orchestra, Welsh National Opera Orchestra, BBC Scottish Symphony Orchestra, Royal National Scottish Orchestra, BBC Concert Orchestra, BBC Big Band, Clarinet and Saxophone Society, National Saxophone Choir, Royal Scottish Academy of Music and Drama, Trinity College of Music, Royal Welsh College of Music and Drama, Notebenders, Jazz Club, East London Clarinet Choir.

Contact details: [redacted]

Appendix 10

Raw data

Key to abbreviations relating to the various parameters assessed and tabulated below

A. Musician's code- the code given to each musician in order to preserve anonymity and eliminate examiner bias. This code includes a serial number for the participant followed by the date and month of birth of the participant
B. Overjet- The horizontal overlap of upper and lower incisors measured in millimeters
C. BSI- British Standards Institute incisor relationship, as defined by the British Institute
D. Overbite- The vertical overlap of upper and lower central incisors, measured in millimeters
E. Intermolar upper- The distance between the upper left and right molar, taking the mesiobuccal cusps as reference points for measurement, measured in millimeters
F. Intermolar lower- The distance between the lower left and right molar, taking the mesiobuccal cusps as reference points for measurement, measured in millimeters
G. Upper Crowding- Crowding in upper labial segment, measured in millimeters
H. Lower Crowding- Crowding in lower labial segment, measured in millimeters
I. Upper Little's- Little's Irregularity Index in the upper arch, measured in millimeters
J. Lower Little's- Little's Irregularity Index in the lower arch, measured in millimeters
K. Buccal Xb/Lingual Xb- Absence of crossbite was given a score of 1. Presence of buccal crossbite or buccal crossbite tendency (Buccal Xb) was given a score of 2 and presence of lingual crossbite or lingual crossbite tendency (Lingual Xb) was given a score of 3.

L. X-Bite severity- Presence of crossbite or crossbite of less than half a cusp's width was given a score of 1, crossbite of more than half a cusp's width was given a score of 2.

M. Instrument code- Code 1; Small cup-shaped mouthpiece players
Code 2; Large cup-shaped mouthpiece players
Code 3; Single-reed mouthpiece players
Code 4; String and percussion players

N. Gender- Code M; Male participant
Code F; Female participant

O. DOB- Date of birth

P. IM ratio- Ratio of upper divided by lower arch intermolar width

Q. IM difference- Difference between upper and lower arch intermolar widths, measured in millimeters

Musician's code	Overjet	BSI Incisor relationship	Overbite	Intermolar upper	Intermolar lower
3.21.08	1.5	4	4.7	47.34	40.12
10-27.06	2	1	1.1	50.84	44.82
42-12/05	2	1	1.2	51.88	43.21
87-14/01	1.5	4	4.3	49.93	44.64
98-22/03	4	1	3.7	47.61	40.15
116-13/06	4	1	2.3	50.22	42.9
187-27/02	3	4	2.4	42.84	41.37
190-29/03	3	3	0.3	49.81	41.45
191-07/12	2	4	3.8	52.3	44.42
35-05/10	2	3	1.6	52.02	45.03
46-21/09	2.5	4	5.3	48.81	41.5
67-03/08	2	4	5	50.33	43.45
68-16/03	1	2	6.7	47.68	41.52
69-20/09	1	2	1.2	46.17	41.61
71-17/04	3	1	1.3	49.21	46.58
73-07/07	3	4	4.9	44.87	39.98
74-13/12	2.5	1	4	47.03	41.91
120-21/07	2.5	1	-1	48.01	43.66
132-22/10	5.5	2	0.5	49.81	47.35
133-18/07	2	3	2	49.3	46.9
134-26/03	4	1	2	54.37	47.3
135-06/12	2	4	2.6	47.11	45.68
141-17/12	2.5	1	1.6	54.68	46.48
147-05/12	2.5	4	3.8	44.31	40.9
152-04/12	4	1	-1	49.51	44.92
173-22/12	2.8	1	2.6	56.88	42.01
8.17.12	2	1	0.8	55.39	47.13
12-13.08	2.5	1	-1.2	51.48	44.75
12-17.04	5.5	2	-0.9	54.34	47.12
16-05.03	2	4	4.1	44.85	38.3
23-23.08	1	3	0	39.07	44.16
43-03/04	2	4	5.4	49.2	43.01
49-04/01	2	1	3.3	51.66	44.13
50-06/05	2	1	6.6	49.01	41.59
51-01/02	6	2	2	47.27	39.01
53-12/08	2.5	1	2.2	49.16	44.86
65-09/12	2.5	1	3.6	49.12	43.47
67-27/09	4	2	4.8	50.93	44.71
68-19/05	3	1	2.3	50.29	42.99
88-10/11	3	4	4	47.1	41.94
92-30/04	2	1	4.9	50.69	43.7
106-25/04	3	1	1.1	50.71	44.63

Musician's code	Overjet	BSI Incisor relationship	Overbite	Intermolar upper	Intermolar lower
124-25/04	4	1	-1.2	52.54	47.43
164/21/02	2	1	2.5	50.86	44.43
170-06/02	5	4	8.5	46.53	41.52
179-26/02	2.3	1	2.7	52.02	45.16
180-13/05	3	1	1.7	50.51	41.49
1-08.04	2.5	4	2.8	55.24	48.32
2.18.04	2	1	0.6	49.93	45.81
4-30.01	2.5	1	1.4	55.21	46.76
11-17.09	2.5	1	1.6	52.5	45.79
20-30.08	3.5	1	3.4	52.62	46.44
39-04.09	5.3	2	5.2	50.1	46.01
32-07/10	4	2	-0.7	48.51	48.88
36-22/04	2	1	3.8	51.78	43.61
40-23/01	-3	3	3.2	51.28	46.07
56-29/04	2	3	0.2	51.16	41.96
59-12/07	2.5	1	4.3	46.48	39.77
60-23/01	2	1	1.8	52.41	45.71
63-13/10	2.5	1	3.4	50.56	43.62
64-06/04	2	1	3.7	55	50.92
82-03/07	4	4	4.3	48.97	43.42
90-18/01	3	1	1.5	53.58	46.42
97-01/05	3.5	1	2.2	50.92	44.81
99-17/07	2	1	2.1	54.5	49.36
103-21/10	2	4	4	46.65	41.09
109-16/07	4.5	2	2.7	45.74	44.73
111-22/04	2.5	1	3	55.85	47.07
113-18/08	3	1	5.5	48.6	42.68
119-01/09	2.5	1	3.3	55.56	48.44
121-17/12	3	4	1.3	48.89	41.24
122-14/11	4	1	2.3	57.11	48.92
128-10/10	7	2	6.3	50.6	46.46
139-30/07	5.5	2	0	41.04	40.99
143-11/02	2	1	3.4	52.03	45.01
145-13/07	3	4	4.2	47.26	45.01
146-14/02	2.5	1	2.6	55.37	47.34
156-02/12	4	1	2.7	53.43	46.18
181-08/06	2.5	1	2	51.5	45.85
194-13/01	3	1	3.2	52.28	46.26
6-14.02	2.5	1	2.3	57.73	49.06
9-11.04	2.5	1	2.3	53.55	46.98
15-12.01	2	3	1.5	51.28	58.34
21-22.07	2.5	1	1.9	49.21	41.38
22-06.06	1	3	1	53.11	47.15
38-06/05	4.5	1	3.9	44.46	50.84
44-17/06	4	1	3	49.08	44.22

Musician's code	Overjet	BSI Incisor relationship	Overbite	Intermolar upper	Intermolar lower
54-30/12	2.5	1	3.3	52.13	53.39
57-20/09	3	1	1.7	50.73	50.34
61-17/09	3	1	3.1	58.1	48.76
62-30/12	4	1	2.8	50.68	45.19
83-01/12	3.5	1	2.5	52.91	49.77
96-25/01	1.3	4	3.9	51.85	43.31
100-21/10	3.5	4	3.1	52.67	53.78
114-22/11	3	4	5.5	53.84	50.57
126-30/08	2	1	4.4	52.09	43.9
130-17/08	2	3	3.2	48.08	44.52
131-15/01	2	1	2.2	50.8	44.61
137-12/03	4.5	2	0.4	49.75	48.64
153-10/01	3	1	-0.5	46.8	44.5
163-15/04	4	4	3.1	51.8	47.22
166-27/03	7	2	4.3	48.3	45.07
167-07/11	3.5	1	3.8	55.6	49.84
167-10/05	-7	3	2.4	53.86	46.59
168-16/07	0.5	3	0.3	50.37	50.23
169-16/05	3.3	1	1.8	54.05	44.28
177-27/03	1	3	0.4	53.85	48.8
178-14/05	3.5	1	1.4	49.41	46.03
186-01/12	11	2	4.5	48.16	44.83
193-03/10	2	4	3.6	52.22	46.49
195-29/04	1.8	3	1.3	52.89	46.53
5-20.08	1.8	1	3.1	44.96	41.72
41-03/06	1.5	3	6.7	53.88	46.99
45-21/07	3.5	2	0.8	49.99	47.01
66-22/09	4	1	1.5	45.82	48.78
70-04/07	3	1	4.5	50.64	44.17
72-11/05	3	1	1.2	51.53	44.14
84/31/05	4	4	2.7	43.36	41.56
112-07/02	3	4	5.8	51.56	45.92
136-23/12	2	4	5	50.02	43.34
148-02/07	6	2	4.1	53.1	46.5
149-23/09	2.8	1	4.3	53.07	46.67
151-15/06	5.5	2	-1	49.7	46.34
154-09/08	5.5	2	-1.5	52.05	49.9
157-22/09	4	1	3.5	53.45	45.8
159-28/05	4	1	3.1	51.6	45.38
160-29/03	3	1	2.5	53.98	48.02
172-11/06	2	1	3.2	49.61	43.25
175-16/07	2.8	1	3	51.47	42.4
189-02/08	3	1	1.4	52.88	43.79
192-31/08	2.5	4	4.3	51.54	44.86

Musician's code	Overjet	BSI Incisor relationship	Overbite	Intermolar upper	Intermolar lower
19-13.07	1	2	3.1	49.46	43.25
7-01.08	2	1	2.3	44.58	46.83
14-27.11	4	1	4.1	51.41	45.73
17-01.01	3	1	3.1	51.74	46.54
24-15.08	2	4	2.1	48.12	46.72
25-07.07	3	1	-0.5	51.52	43.92
26-13.04	2.5	1	1.9	47.95	46.24
27-20.06	4.5	4	5.2	52.85	48.8
28-05.12	0.8	4	7.9	51.74	46.05
29.09/07	2	1	4.3	49.3	40.1
31.12/52	4.5	2	0.6	48.52	43
33-25/12	2.5	1	2.8	53.86	47.67
34-06/03	4.5	2	3.5	51.7	44.4
37-29/01	6.5	2	4.8	50.5	43.22
39-09/12	6.5	2	3.8	52.5	48.67
47-28/05	3.8	1	1.8	54.3	47.3
48-13/02	2	1	1.8	48.33	39.13
52-02/11	3.5	1	2.3	56.99	49.16
66-21/07	6	2	4.6	46.23	40.71
89-21/02	6	2	5.8	43.71	44.47
94-02/01	2	1	4.9	55.88	50.55
95-06/07	1	4	3.8	52.06	45.1
104-12/06	3	4	5.5	47.55	43.11
105-02/04	3.5	1	6.7	49.25	42.8
107-29/09	3.5	1	1.8	52.49	45.67
118-14/06	4	1	3	52.02	46.48
125-01/06	3	1	2.5	54.3	45.2
129-24/12	4.5	2	6.6	53.23	46.06
127-07/05	0	3	0.5	47.88	42.59
158-23/10	4	2	2.9	52.23	47.04
171-10/06	5	4	3.9	45.81	39.97
182-20/01	3	1	3.9	55.1	46.48
183-16/10	2.5	1	1.5	51.83	44.51
184-25/05	3	1	4.3	59.35	49.89
185-30/03	5	2	0.9	51.61	44.41
161-04/11	2.5	1	1.1	52.14	43.42

Musician's code	Upper crowding	Lower crowding	Upper Little’s	Lower Little’s
3.21.08	5	4.5	9.21	6.72
10-27.06	1	0.5	2.53	1.84
42-12/05	1	3	1.45	4.45
87-14/01	2	2.5	0.92	5.16
98-22/03	1	1	2.45	3.53
116-13/06	2	5.5	4.24	9.39
187-27/02	3	4.5	8.29	5.78
190-29/03	1	1	1.81	0.7
191-07/12	1	1.3	1.45	2.37
35-05/10	1	1	0.9	0.39
46-21/09	2	0.5	2.2	0.32
67-03/08	3	2	4.66	2.32
68-16/03	1	1	0.31	4.52
69-20/09	2	0.3	2.09	0.91
71-17/04	1	0.5	4.27	0.4
73-07/07	3	7	5.44	6.59
74-13/12	1	0	10.22	1.51
120-21/07	1	2	1.32	4.64
132-22/10	0	1	0.59	2.45
133-18/07	0	-4	2.41	0.5
134-26/03	4	1.5	4.95	4.45
135-06/12	5	1.5	5.51	7.91
141-17/12	1	1.5	1.64	2.61
147-05/12	6	1	7.49	1.87
152-04/12	1	0.5	2.28	1.43
173-22/12	4	1.5	6.39	4.86
8.17.12	0	0.5	0	0.87
12-13.08	1	2.5	2.6	4.32
12-17.04	-2	1.5	0.95	1.19
16-05.03	2	4	6.76	5.51
23-23.08	8	3.5	9.39	5.32
43-03/04	1	0.5	1.3	0.88
49-04/01	2	1.5	3.74	2.61
50-06/05	-1	1	7.3	2.43
51-01/02	1	7.5	1.47	10.68
53-12/08	1	1	1.09	2.15
65-09/12	2	1.5	3.33	3.73
67-27/09	-1	0.5	2.3	2.21
68-19/05	-1	1.5	0.98	2.65
88-10/11	1	1.5	0.3	3.08
92-30/04	1	2.5	1.12	2.95
106-25/04	1	0.5	2.19	1.18
108-27/03	1	0.5	3.69	1.26
124-25/04	4	3.5	5.88	3.67

Musician's code	Upper crowding	Lower crowding	Upper Little’s	Lower Little’s
164/21/02	2	1.5	2.33	3.26
170-06/02	2	1.3	5.73	0.6
179-26/02	0	0.5	1.6	2.98
180-13/05	1	1	3.43	3.2
1-08.04	3	1.5	4.95	4.45
2.18.04	0	1.5	1.21	2.7
4-30.01	4	7	5.81	7.3
11-17.09	0	0	0	0.3
20-30.08	5	3	4.94	4.95
39-04.09	3	1	2.65	1.2
32-07/10	6	5	4.75	5.71
36-22/04	0	2.5	3.7	6.1
40-23/01	2	2	5.61	4.45
56-29/04	-1	0.5	3.44	3.99
59-12/07	0	5	0	13.38
60-23/01	0	0.5	0	1.62
63-13/10	3	0.8	7.93	3.91
64-06/04	1	0.5	1.2	1.13
82-03/07	3	3	1	4.62
90-18/01	2	2	6.38	5.5
97-01/05	2	1.5	1.78	2.58
99-17/07	1	1.5	2.71	1.12
103-21/10	5	0	9.14	1.55
109-16/07	6	3.5	6.93	4.8
111-22/04	1	0.5	3.48	3.49
113-18/08	0	3	0.8	5.66
119-01/09	1	0.5	0.77	2.49
121-17/12	1	7.5	5.75	11.39
122-14/11	-1	-0.5	2.59	2.79
128-10/10	5	3.5	5.45	5.76
139-30/07	4	9.5	4.51	15.16
143-11/02	2	3	2.4	3.78
145-13/07	1	0.5	1.07	2.68
146-14/02	-5	1	2.7	1.48
156-02/12	2	0.5	5.81	2.2
181-08/06	0	0.5	1.16	4.85
194-13/01	2	2.8	5.07	5.88
6-14.02	2	3	4.35	5.17
9-11.04	1	3	3	6.58
15-12.01	0	0	0.8	1.21
21-22.07	1	4.5	3.64	2.7
22-06.06	4	7	4.99	7.71
38-06/05	1	0.5	1.85	0.82
44-17/06	0	0	1.05	0.3
54-30/12	-6	-3.3	0.42	0
55-10/08	2	0	4.21	0

Musician's code	Upper crowding	Lower crowding	Upper Little’s	Lower Little’s
57-20/09	2	1	5.28	1.51
61-17/09	1	1.5	1.71	6.33
62-30/12	2	1	4.31	4.04
83-01/12	2	0.5	2.2	1.3
96-25/01	1	0.5	0.81	2.28
100-21/10	1	0	4.12	0.63
114-22/11	4	3.5	7.8	2.99
126-30/08	1	4.5	1.2	7.87
130-17/08	0	0.3	0.2	0.81
131-15/01	0	0	1.6	1.55
137-12/03	0	1	2.27	1.91
153-10/01	2	4	3.04	4.71
163-15/04	3	2	3.35	2.45
166-27/03	1	0.8	4.9	2.45
167-07/11	-1	1.3	2.04	2.23
167-10/05	-2	1.5	1.61	4.22
168-16/07	-2	-5	5.56	3.48
169-16/05	1	3.5	2.81	7.66
177-27/03	4	4	8.54	5.77
178-14/05	3	4	7.94	8.37
186-01/12	2	0.8	5.48	5.78
193-03/10	3	0.3	1.6	3.48
195-29/04	-4	-3	4.84	0.31
5-20.08	1	3	1.33	3.95
41-03/06	0	1	0.75	1.03
45-21/07	2	2.5	3.21	5.31
66-22/09	2	2	5.61	3.52
70-04/07	1	5	1.59	6.64
72-11/05	1	2	3.75	2.89
84/31/05	3	3	7.86	1.38
112-07/02	3	0.5	5.48	2.81
136-23/12	4	2.5	7.9	4.54
148-02/07	1	2	5.55	3.12
149-23/09	1	1.5	1.81	6.71
151-15/06	-3	2.5	0.31	3.86
154-09/08	2	2	3.36	4.76
157-22/09	1	2.3	2.9	2.76
159-28/05	2	2	2.51	3.85
160-29/03	1	1.3	2.3	5.25
172-11/06	0	2.8	1.78	3.02
175-16/07	-1	2.8	2.29	5.41
189-02/08	4	1	8.52	2.81
192-31/08	-1	0.8	1.67	4.23
7-01.08	0	1	0	1.2
14-27.11	2	1.5	3.06	4.7
17-01.01	4	3	4.64	6.75

Musician's code	Upper crowding	Lower crowding	Upper Little’s	Lower Little’s
18-12.06	2	2	3.35	2.03
19-13.07	-3	-2.5	1.95	0.03
24-15.08	3	4.5	4.6	6.41
25-07.07	1	3.5	1.6	3.35
26-13.04	-1	0.5	1.8	3.3
27-20.06	2	1	3.6	0.5
28-05.12	5	7	8.35	10.3
29.09/07	2	4	2.02	2.8
31.12/52	-1	0	0.29	0.3
33-25/12	-4	0	0.61	1.04
34-06/03	2	4.5	2.8	5.43
37-29/01	5	5.5	13.85	8.6
39-09/12	-1	0	0	1.04
47-28/05	1	5.5	1.48	7.27
48-13/02	2	7.5	6.61	14.03
52-02/11	2	3	2.29	6.85
66-21/07	1	1	0.41	2.65
89-21/02	7	8	8.91	14.03
94-02/01	1	-4.5	3.49	4.32
95-06/07	0	3.5	1.81	7.88
104-12/06	5	1.3	8.35	2.08
105-02/04	3	2	3.43	5.63
107-29/09	7	3.5	1.22	4.81
118-14/06	1	3.3	1.73	3.31
125-01/06	1	2.5	4.29	5.55
129-24/12	4	3.5	6.62	9.5
127-07/05	3	1.8	4.8	5.56
158-23/10	1	3	3.25	3.5
171-10/06	10	3.5	14.76	6.38
182-20/01	0	4	3.32	5.82
183-16/10	1	0.5	2.22	2.74
184-25/05	0	0.3	0.98	0.88
185-30/03	2	2.8	3.21	7.91
161-04/11	3	5	2.98	6.75

Musician's code	Buccal Xb/ Lingual Xb	X-bite severity	Instrument Code	Gender
3.21.08	1	1	1	F
10-27.06	1	1	1	F
42-12/05	1	1	1	F
87-14/01	1	1	1	F
98-22/03	1	1	1	F
116-13/06	1	1	1	F
187-27/02	2	1	1	F
190-29/03	3	1	1	F
191-07/12	1	1	1	F
35-05/10	1	1	3	F
46-21/09	1	1	3	F
67-03/08	1	1	3	F
68-16/03	1	1	3	F
69-20/09	1	1	3	F
71-17/04	2	2	3	F
73-07/07	1	1	3	F
74-13/12	1	1	3	F
120-21/07	2	2	3	F
132-22/10	2	2	3	F
133-18/07	2	2	3	F
134-26/03	1	1	3	F
135-06/12	2	1	3	F
141-17/12	1	1	3	F
147-05/12	1	1	3	F
152-04/12	2	2	3	F
173-22/12	1	1	3	F
8.17.12	1	1	4	F
12-13.08	1	1	4	F
12-17.04	1	1	4	F
16-05.03	1	1	4	F
23-23.08	2	3	4	F
43-03/04	3	1	4	F
49-04/01	1	1	4	F
50-06/05	1	1	4	F
51-01/02	1	1	4	F
53-12/08	1	1	4	F
65-09/12	1	1	4	F
67-27/09	1	1	4	F
68-19/05	1	1	4	F
88-10/11	1	1	4	F
92-30/04	1	1	4	F

Musician's code	Buccal Xb/ Lingual Xb	X-bite severity	Instrument Code	Gender
106-25/04	1	1	4	F
108-27/03	1	1	4	F
124-25/04	2	1	4	F
164/21/02	1	1	4	F
170-06/02	1	1	4	F
179-26/02	1	1	4	F
180-13/05	1	1	4	F
1-08.04	1	1	1	M
2.18.04	2	2	1	M
4-30.01	1	1	1	M
11-17.09	1	1	1	M
20-30.08	1	1	1	M
39-04.09	2	1	1	M
32-07/10	2	2	1	M
36-22/04	1	1	1	M
40-23/01	2	2	1	M
56-29/04	1	1	1	M
59-12/07	2	1	1	M
60-23/01	1	1	1	M
63-13/10	1	1	1	M
64-06/04	2	2	1	M
82-03/07	1	1	1	M
90-18/01	1	1	1	M
97-01/05	1	1	1	M
99-17/07	1	1	1	M
103-21/10	1	1	1	M
109-16/07	2	2	1	M
111-22/04	1	1	1	M
113-18/08	1	1	1	M
119-01/09	1	1	1	M
121-17/12	1	1	1	M
122-14/11	1	1	1	M
128-10/10	1	1	1	M
139-30/07	2	3	1	M
143-11/02	1	1	1	M
145-13/07	1	1	1	M
146-14/02	1	1	1	M
156-02/12	1	1	1	M
181-08/06	1	1	1	M
194-13/01	1	1	1	M
6-14.02	1	1	2	M
9-11.04	1	1	2	M
15-12.01	2	2	2	M
21-22.07	1	1	2	M
22-06.06	1	1	2	M

Musician's code	Buccal Xb/ Lingual Xb	X-bite severity	Instrument Code	Gender
44-17/06	2	1	2	M
38-06/05	1	1	2	M
54-30/12	2	3	2	M
55-10/08	2	2	2	M
57-20/09	2	3	2	M
61-17/09	1	1	2	M
62-30/12	1	1	2	M
83-01/12	2	2	2	M
96-25/01	1	1	2	M
100-21/10	2	2	2	M
114-22/11	2	2	2	M
126-30/08	1	1	2	M
130-17/08	2	2	2	M
131-15/01	1	1	2	M
137-12/03	2	2	2	M
153-10/01	2	2	2	M
163-15/04	2	2	2	M
166-27/03	2	1	2	M
167-07/11	1	1	2	M
167-10/05	2	1	2	M
168-16/07	2	2	2	M
169-16/05	1	1	2	M
177-27/03	1	1	2	M
178-14/05	2	2	2	M
186-01/12	2	1	2	M
193-03/10	1	1	2	M
195-29/04	1	1	2	M
5-20.08	2	2	3	M
41-03/06	1	1	3	M
45-21/07	2	2	3	M
66-22/09	2	1	3	M
70-04/07	1	1	3	M
72-11/05	1	1	3	M
84/31/05	1	1	3	M
112-07/02	1	1	3	M
136-23/12	1	1	3	M
148-02/07	1	1	3	M
149-23/09	1	1	3	M
151-15/06	2	2	3	M
154-09/08	2	2	3	M
157-22/09	1	1	3	M
159-28/05	1	1	3	M
160-29/03	2	1	3	M
172-11/06	1	1	3	M
175-16/07	1	1	3	M

Musician's code	Buccal Xb/ Lingual Xb	X-bite severity	Instrument Code	Gender
189-02/08	1	1	3	M
192-31/08	1	1	3	M
17-01.01	2	2	4	M
18-12.06	1	1	4	M
19-13.07	1	1	4	M
24-15.08	2	3	4	M
25-07.07	1	1	4	M
26-13.04	2	2	4	M
27-20.06	3	1	4	M
28-05.12	3	2	4	M
29.09/07	3	3	4	M
31.12/52	1	1	4	M
33-25/12	1	1	4	M
34-06/03	1	1	4	M
37-29/01	3	1	4	M
39-09/12	1	1	4	M
47-28/05	1	1	4	M
48-13/02	1	1	4	M
52-02/11	1	1	4	M
66-21/07	1	1	4	M
89-21/02	1	1	4	M
94-02/01	1	1	4	M
95-06/07	1	1	4	M
104-12/06	1	1	4	M
105-02/04	1	1	4	M
107-29/09	2	1	4	M
118-14/06	1	1	4	M
125-01/06	1	1	4	M
129-24/12	1	1	4	M
127-07/05	2	1	4	M
158-23/10	1	1	4	M
171-10/06	1	1	4	M
182-20/01	3	1	4	M
183-16/10	1	1	4	M
184-25/05	1	1	4	M
185-30/03	1	1	4	M
161-04/11	1	1	4	M

Musician's code	DOB	IM ratio	IM difference
3.21.08	21-Aug-77	1.18	7.22
10-27.06	27-Jun-90	1.13	6.02
42-12/05	12-May-87	1.2	8.67
87-14/01	14-Jan-64	1.12	5.29
98-22/03	22-Mar-83	1.19	7.46
116-13/06	13-Jun-73	1.17	7.32
187-27/02	27-Feb-90	1.04	1.47
190-29/03	29-Mar-89	1.2	8.36
191-07/12	07-Dec-86	1.18	7.88
35-05/10	05-Oct-76	1.16	7
46-21/09	21-Sep-86	1.18	7.31
67-03/08	03-Aug-77	1.16	6.88
68-16/03	16-Mar-78	1.15	6.16
69-20/09	20-Sep-08	1.11	4.56
71-17/04	17-Apr-86	1.06	2.62
73-07/07	07-Jul-81	1.12	4.89
74-13/12	13-Dec-82	1.12	5.13
120-21/07	21-Jul-78	1.1	4.35
132-22/10	22-Oct-68	1.05	2.45
133-18/07	18-Jul-84	1.04	2.1
134-26/03	26-Mar-86	1.15	7.07
135-06/12	06-Dec-79	1.03	1.42
141-17/12	17-Dec-86	1.18	8.2
147-05/12	05-Dec-89	1.08	3.4
152-04/12	04-Dec-87	1.1	4.59
173-22/12	22-Dec-72	1.35	14.88
8.17.12	17-Dec-76	1.18	8.26
12-13.08	13-Aug-86	1.15	6.73
12-17.04	07-Apr-86	1.15	7.22
16-05.03	05-Mar-87	1.17	6.55
23-23.08	23-Aug-67	0.88	-5.09
43-03/04	03-Apr-88	1.14	6.19
49-04/01	04-Jan-79	1.17	7.53
50-06/05	06-May-81	1.18	7.42
51-01/02	01-Feb-81	1.21	8.26
53-12/08	12-Aug-67	1.1	4.3
65-09/12	09-Dec-72	1.13	5.65
67-27/09	27-Sep-67	1.14	6.22
68-19/05	19-May-55	1.17	7.3
88-10/11	10-Nov-78	1.12	5.16
92-30/04	30-Apr-67	1.16	7
106-25/04	25-Apr-78	1.14	6.07
108-27/03	27-Mar-78	1.17	7.14
124-25/04	25-Apr-64	1.11	5.11
164/21/02	21-Feb-88	1.14	6.43

Musician's code	DOB	IM ratio	IM difference
170-06/02	06-Feb-91	1.12	5.01
179-26/02	26-Feb-68	1.15	6.86
180-13/05	13-May-63	1.22	9
1-08.04	08-Apr-64	1.14	6.92
2.18.04	18-Apr-78	1.09	4.12
4-30.01	30-Jan-81	1.18	8.45
11-17.09	17-Sep-89	1.15	6.7
20-30.08	30-Aug-84	1.13	6.18
39-04.09	04-Jul-63	1.09	4.1
32-07/10	07-Oct-59	0.99	-0.4
36-22/04	22-Apr-77	1.19	8.2
40-23/01	23-Jan-58	1.11	5.23
56-29/04	29-Apr-68	1.22	9.2
59-12/07	12-Jul-79	1.17	6.71
60-23/01	23-Jan-72	1.15	6.7
63-13/10	13-Oct-82	1.16	6.94
64-06/04	06-Apr-66	1.08	4.08
82-03/07	03-Jul-73	1.13	5.55
90-18/01	18-Jan-66	1.15	7.16
97-01/05	01-May-57	1.14	6.11
99-17/07	17-Jul-71	1.1	5.14
103-21/10	21-Oct-80	1.14	5.56
109-16/07	16-Jul-77	1.02	1.01
111-22/04	22-Apr-81	1.19	8.78
113-18/08	18-Aug-83	1.14	5.92
119-01/09	01-Sep-66	1.15	7.12
121-17/12	17-Dec-57	1.19	7.65
122-14/11	14-Nov-70	1.17	8.19
128-10/10	10-Oct-63	1.09	4.14
139-30/07	30-Jul-83	1	0
143-11/02	11-Feb-89	1.16	7.03
145-13/07	13-Jul-89	1.05	2.26
146-14/02	14-Feb-86	1.17	8.03
156-02/12	02-Dec-83	1.16	7.23
181-08/06	08-Jun-74	1.12	5.65
194-13/01	13-Jan-83	1.13	6.02
6-14.02	14-Feb-78	1.18	8.67
9-11.04	11-Apr-85	1.14	6.57
15-12.01	12-Jan-77	0.88	-7.06
21-22.07	22-Jul-82	1.19	7.82
22-06.06	06-Jun-68	1.13	5.96
38-06/05	06-May-73	0.87	-6.38
44-17/06	17-Jun-79	1.11	4.86
54-30/12	30-Dec-68	0.98	-1.26
55-10/08	10-Aug-69	1.03	1.55
57-20/09	20-Sep-75	1.01	0.39

Musician's code	DOB	IM ratio	IM difference
61-17/09	17-Sep-83	1.19	9.34
62-30/12	30-Dec-71	1.12	5.49
83-01/12	01-Dec-52	1.06	3.14
96-25/01	25-Jan-76	1.2	8.55
100-21/10	20-Jan-72	0.98	-1.11
114-22/11	27-Nov-61	1.06	3.27
126-30/08	30-Aug-61	1.19	8.19
130-17/08	17-Aug-76	1.08	3.48
131-15/01	15-Jan-70	1.14	6.2
137-12/03	12-Mar-71	1.02	1.11
153-10/01	10-Jan-89	1.05	2.3
163-15/04	15-Apr-87	1.1	4.58
166-27/03	27-Mar-83	1.07	3.23
167-07/11	07-Nov-85	1.12	5.76
167-10/05	10-May-90	1.16	7.27
168-16/07	16-Jul-90	1	0.14
169-16/05	16-May-58	1.22	9.77
177-27/03	27-Mar-60	1.1	5.05
178-14/05	14-May-86	1.07	3.37
186-01/12	01-Dec-67	1.07	3.33
193-03/10	03-Oct-89	1.12	5.73
195-29/04	29-Apr-72	1.14	6.36
5-20.08	20-Aug-71	1.08	3.24
41-03/06	03-Jun-89	1.15	6.89
45-21/07	21-Jul-68	1.06	2.98
66-22/09	22-Sep-68	0.94	-2.96
70-04/07	04-Jul-88	1.15	6.47
72-11/05	11-May-85	1.17	7.39
84/31/05	31-May-52	1.04	1.8
112-07/02	07-Feb-55	1.12	5.64
136-23/12	23-Dec-64	1.15	6.68
148-02/07	02-Jul-87	1.14	6.6
149-23/09	23-Sep-88	1.14	6.4
151-15/06	15-Jun-87	1.07	3.36
154-09/08	09-Aug-89	1.04	2.15
157-22/09	22-Sep-75	1.17	7.65
159-28/05	28-May-65	1.14	6.22
160-29/03	29-Mar-71	1.12	5.96
172-11/06	11-Jun-76	1.15	6.36
175-16/07	16-Jul-69	1.21	9.07
189-02/08	02-Aug-87	1.21	9.09
192-31/08	31-Aug-85	1.15	6.68
7-01.08	01-Aug-63	0.95	-2.25
14-27.11	27-Nov-87	1.12	5.68
17-01.01	01-Jan-86	1.11	5.2
18-12.06	12-Jun-86	1.15	7.03

Musician's code	DOB	IM ratio	IM difference
19-13.07	13-Jul-89	1.14	6.21
24-15.08	15-Aug-62	1.03	1.4
25-07.07	07-Jul-71	1.17	7.6
26-13.04	13-Apr-76	1.04	1.71
27-20.06	20-Jun-60	1.08	4.05
28-05.12	05-Dec-54	1.12	5.69
29.09/07	09-Jul-51	1.23	9.2
31.12/52	03-Dec-52	1.13	5.52
33-25/12	25-Dec-82	1.13	6.19
34-06/03	06-Mar-64	1.16	7.3
37-29/01	25-Jan-70	1.17	7.28
39-09/12	09-Dec-80	1.08	3.83
47-28/05	28-Apr-76	1.15	7
48-13/02	13-Feb-78	1.24	9.2
52-02/11	02-Nov-54	1.16	7.83
66-21/07	21-Jul-54	1.14	5.52
89-21/02	21-Feb-70	0.98	-0.77
94-02/01	02-Jan-70	1.11	5.35
95-06/07	06-Jul-74	1.15	6.96
104-12/06	12-Jun-69	1.1	4.44
105-02/04	02-Apr-71	1.15	6.45
107-29/09	29-Sep-77	1.15	6.83
118-14/06	14-Jun-83	1.12	5.54
125-01/06	01-Jun-61	1.2	9.1
129-24/12	24-Dec-75	1.16	7.17
127-07/05	06-May-64	1.12	5.3
158-23/10	23-Oct-67	1.11	5.26
171-10/06	10-Jun-88	1.15	5.84
182-20/01	20-Jan-63	1.19	8.62
183-16/10	16-Oct-67	1.16	7.32
184-25/05	25-May-68	1.19	9.46
185-30/03	20-Mar-58	1.16	7.21
161-04/11	04-Nov-77	1.2	8.72