

THE EFFECTS OF THUMB SUCKING ON DENTAL CHARACTERISTICS IN THE PRIMARY DENTITION

Anastasia Botha

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DECLARATION

I, Anastasia Botha, declare that this research report is my own work. It is being submitted for the degree of Master of Science in Dentistry to the University of Witwatersrand, Johannesburg. It has not been submitted before for any degree or examination at this or any other University.


.....

.....15th.....day of Nov 2011

Dedication

This report is dedicated to my husband Lior, and to my daughter Talya.

ABSTRACT

Two groups of underprivileged black South African children were compared for occlusal characteristics and dental arch dimensions, based on the presence or absence of the thumb-sucking habit. The study was cross-sectional in nature and comprised children between the ages of four and five years. Dental arch parameters including arch widths, arch lengths, arch depths, overjet, anterior open bite, posterior crossbite, Class II canine and molar relationships and palatal depth were measured from study models obtained from the children. Comparisons of the means of the data between thumb-sucking and non-habit children were made using the Student's t-test. The results suggest that children with a thumb-sucking habit have significantly decreased inter-canine and inter-molar maxillary arch widths ($p = 0.0107$; $p = 0.0163$ respectively), increased mandibular inter-canine arch width ($p = 0.0086$), increased maxillary canine arch depth ($p = 0.0003$), increased anterior mandibular arch length ($p = 0.0282$), highly significantly increased overjet and anterior open bite ($p < 0.0001$) compared with those without the habit. Education and recommendations for the discontinuation of this habit are therefore required.

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INTRODUCTION

Thumb sucking is a common childhood habit seen throughout the world. The resultant malocclusions produced by thumb sucking vary in presentation as described through the literature as well as the question as to whether they persist into the permanent dentition. Controversy exists regarding the aetiology, treatment and timing of intervention of these habits.

1.1 JUSTIFICATION OF STUDY

Opinions in the dental literature regarding the extent to which thumb sucking alters the occlusion are sometimes conflicting. Many researchers combine pacifier and thumb sucking into one “non-nutritive” habit group, which makes it difficult to determine which habit may be responsible for particular malocclusions. A higher proportion of children over the age of four years thumb suck compared with those that use a pacifier. This suggests that the thumb-sucking habit is more difficult to stop (Bishara, Warren, Broffitt *et al.*, 2006). As the deciduous dental arches are the precursors for harmonious development of the permanent dentition, it is important for oral health professionals to identify early clinical signs, such as malocclusions that are produced by thumb sucking.

This research aimed to determine the malocclusions that could develop due to thumb sucking exclusively. A meticulous comparison between children in whom a thumb-sucking habit was present and those from a control group of non-habit participants was conducted. This information clarified the unfavourable influences of this habit on a child’s dentition and skeletal growth, confirming the need for the

Government Health Departments and other oral health care institutes in South Africa to offer oral health educational programmes to parents and guardians in underprivileged areas. This would allow parents and guardians to be better equipped to seek treatment at the appropriate time to intercept and manage the habit appropriately. Ultimately, this would help in decreasing the risk of children developing malocclusions, which could persist into the permanent dentition, causing incorrect skeleto-dental development. Skeleto-dental malocclusions have been classified as a dental health problem by the World Health Organisation Global Oral Health Programme as they can affect the general health and confidence of a child (Peterson, 2003).

Mothers play a vital role in the development of good oral habits for their children. The children of mothers who received oral health education while pregnant have better oral health status than the children of mothers who did not receive any oral health education (Rothwell, Gregory & Sheller, 1987). The prevention of malocclusions also decreases the costs associated with their correction, which is in any event generally unavailable and unaffordable for this population group.

The thumb-sucking habit is more prevalent and widely documented in Westernised countries. Information regarding prevalence of thumb sucking in South Africa is sparse. Due to cultural and ethnic variations, it is not possible to extrapolate Western data to South Africa. Comparisons between developed, Westernised countries and South Africa, a developing country, are pertinent and relevant.

1.2 AIMS AND OBJECTIVES

The aim of this research was to identify malocclusions that resulted from long-term thumb sucking in black South African children from underprivileged communities. The occlusal and dental arch characteristics in the primary dentitions of thumb-sucking individuals were examined with regard to parameters such as arch width, arch length and arch depth. The arches were assessed for overjet, overbite, anterior open bite, posterior crossbite, Class II canine and molar relationships and palatal depth. The measurements obtained from study models from this group of children were statistically compared with those of a control group using the Student's t-test. These data may be applied in determining the frequency and intensity of the various clinical signs of thumb sucking that may present in the dental arch and the occlusion of the children who habitually suck their thumbs.

Finally, the project highlighted the need for recommendations to be made to the relevant health care authorities to develop oral health programmes to better educate parents on the role or impact that thumb sucking plays on the developing dentition and how to prevent, manage, and control it.

LITERATURE REVIEW

1.3 THE THUMB SUCKING HABIT

Thumb sucking is a common childhood habit which has been associated with boredom, a feeling of security and as a means to soothe the child, thus preventing anxiety (Jacobson, 1979; Polyakov, 2002). Thumb sucking in infants and toddlers is seen as a normal developmental process. Prolonged thumb sucking may develop as a consequence of unmet psychological needs or simply as a habit (Jacobson, 1979). Klackenberg (1949) estimated that approximately 50% of one year-old infants suck a thumb or digit. Between four and five years of age spontaneous cessation of the habit occurs, resulting in a decline in the number of children pursuing this habit to approximately 15% (Klackenberg, 1949; Traisman & Traisman, 1958; Bishara, 2007a). Traisman and Traisman (1958) reported that the average age for spontaneous cessation is approximately 3.8 years.

Thumb and finger sucking as well as pacifier/dummy sucking are habits associated with oral gratification. These are often grouped together (Katz, Rosenblatt & Gondim, 2004; Heimer, Katz & Rosenblatt, 2008). Other researchers have separated these non-nutritive sucking habits in order to determine their specific effects and severity of their respective malocclusions. (Warren & Bishara, 2002; Aznar, Galan, Marin *et al.*, 2006; Bowden, 1966a, 1966b; Kato, Watanabe, Kato *et al.*, 2009; Larsson, 1994; Ozawa, Hamada, Takekoshi *et al.*, 2005).

Thumb sucking is of concern as sustained repetition has been related to malocclusions (Bowden, 1966a; Larsson, 1971, 1972; Warren & Bishara, 2002;

Graber, 1958; Traisman & Traisman, 1958). Simões (1978) emphasised that malocclusions are a consequence of developmental disorders of the craniofacial complex that may affect the jaws, tongue and facial muscles. Corruccini and Potter (1980) noted that malocclusions are not only the result of genetic effects but also environmental factors, such as non-nutritive sucking habits. In fact, many authors have documented the effects of digit and thumb sucking on dental, soft tissue and skeletal structures as well as on the production of speech. The resulting malocclusion is usually unsightly and may cause other functional problems (Johnson & Larsson, 1993; Graber, 1959, 1962; Littlefield, 1952).

1.4 THE EFFECT OF THUMB SUCKING ON THE OCCLUSION

The deciduous dental arches form the template for the correct development of the permanent arches, predicated by their growth and the available existing space. If these usually favourable factors are hampered in the deciduous dentition by a thumb-sucking habit, correct alignment of the permanent dentition may not take place (Aznar *et al.*, 2006). These malocclusions have been reported to persist into adolescence and even to result in craniofacial disharmony (Warren & Bishara, 2002; Bishara *et al.*, 2006; Bowden, 1966a; Popovich & Thompson, 1973; Kurol and Berglund, 1992; Sonnesen, Bakke & Solow, 2001).

Johnson and Larsson (1993), in a review of several studies, noted that malocclusions produced by prolonged thumb sucking habits are characterised by the following: anterior open bites, labial inclination of the maxillary incisors, an increase in overjet and spacing of the maxillary incisors. Other maxillary changes include an increase in arch depth, anterior displacement of the maxilla, high

palatal vaults and narrowing of the inter-canine and inter-molar arch widths. Class II canine and molar relationships and posterior crossbites have been observed in thumb-sucking individuals. In the mandible increases in inter-canine arch widths have been detected and the incisors may be labially or lingually inclined.

Larsson and Bishara (2007) are of the opinion that malocclusions produced by thumb sucking are potentially more harmful than those produced by pacifiers. These authors focused on two main factors:

1. During thumb sucking, the thumb acts as a lever directing an anterior force on the maxilla displacing it anteriorly, producing greater increases in overjet, upper incisor proclination and elongation of the anterior maxillary base than does the pacifier.
2. The habit is more difficult to stop than that of a pacifier sucking habit. Higher incidences of thumb sucking habits exist in children over the age of four than recorded for pacifier habits. This has been noted by other authors. (Larsson, 1971; Bishara *et al.*, 2006)

1.4.1 *Vertical and horizontal effects*

The digit, which is usually placed ventrally against the palate and against the lingual surfaces of the upper incisors, is positioned at an angle and forms a fulcrum which consists of the digit, the wrist and the forearm. The force produced by this lever may be subdivided into horizontal and vertical vectors (Bishara & Larsson, 2007b; Graber, 1959, 1962; Larsson, 1994, Littlefield, 1952).

These vectors mechanically either inhibit or exacerbate unfavourable growth (Swineheart, 1938). The horizontal vector generates pressure on the palatal aspect of the alveolar process and the maxillary incisors. This results in lengthening and anterior displacement of the anterior maxillary base, proclination of the maxillary incisors and spacing and splaying of the upper incisors, all resulting in an increase in overjet (Ruttle, Quigley, Crouch *et al.*, 1953; Warren & Bishara, 2002; Fukata, Braham, Yokoi *et al.*, 1996; Littlefield, 1952; Duncan, McNamara, Ireland *et al.*, 2008; Al-Dawood, 2004). Overjet may be exacerbated by retroclined lingual incisors (Al-Dawood, 2004). The vertical vector delays the vertical growth of the anterior maxillary base, hindering the eruption of the anterior teeth while simultaneously allowing the posterior segments to over-erupt. The incisors cannot occlude and an open bite is created (Bishara & Larsson, 2007b; Larsson, 1994; Fukata *et al.*, 1996; Al-Dawood, 2004; Littlefield, 1952).

Both proclination and retroclination of the lower incisors have been observed (Graber, 1962; Subtelny and Subtelny, 1972; Al-Dawood, 2004; Moore & McDonald, 1997). Retroclination of the lower incisors observed in some studies is due to the lever action of the thumb and the action of the lower lip and mentalis muscle directing a lingual force on the incisors (Bishara & Larsson, 2007a; Graber, 1959, 1962; Larsson, 1994). Proclination may be due to an accompanying tongue thrust (Graber, 1959, 1962; Subtelny & Subtelny, 1973) or due to the position of the tongue which, in most instances of thumb sucking, is in contact with the dorsal surface of the thumb with the tongue tip placed on the lingual surfaces of the mandibular incisors directing a labial force on them (See Figure 1) (Subtelny & Subtelny, 1973). Several authors reported no significant difference in mandibular

incisor angulation relative to a control group but did note some outlying cases displaying retroclination and some proclination (Larsson, 1972; Subtelny and Subtelny, 1973; Moore and McDonald, 1997).

The open bite and excessive overjet may produce lip incompetence where difficulty is encountered forming a seal during deglutition or closure of the lips. In an effort to form a seal during swallowing a compensatory lip sucking or tongue thrusting habit may develop (Graber, 1959; Bishara & Larsson, 2007a; Subtelny & Subtelny, 1973). To enable a seal to be produced, the lower lip is placed lingual to the maxillary incisors, driving the maxillary incisors even further forward, increasing the severity of the overjet and anterior open bite. Clinically the lip-sucking habit may be identified by the wrinkling of the mentalis muscle during swallowing. The vermillion border may appear hypertrophic while the surrounding area is dry and flaky. The development of either one of these compensatory habits serves to sustain the malocclusion and prevents self-correction (Graber, 1959, 1962).

Anterior open bites are also observed in the tongue-thrusting habit. As open bites are common in children having either habit, it is difficult to determine which came first, the thumb or tongue habit. It has been recognized that a primary tongue thrust is relatively rare (Proffit, 2007). Subtelny and Subtelny (1973) observed that a majority of thumb suckers demonstrated tongue thrusting action. Tongue-tip protrusion over the lower incisors during swallowing was observed in 80% of the cases. Bowden (1966a) also noted an increase in the frequency of tongue thrusting activity and lip incompetence in thumb-sucking children.

Finger habit opens mouth beyond postural resting position, exerting a labial and depressing vector on maxillary incisors and a lingual and depressing vector on the mandibular incisors. Observe that the tongue is also displaced by the habit.

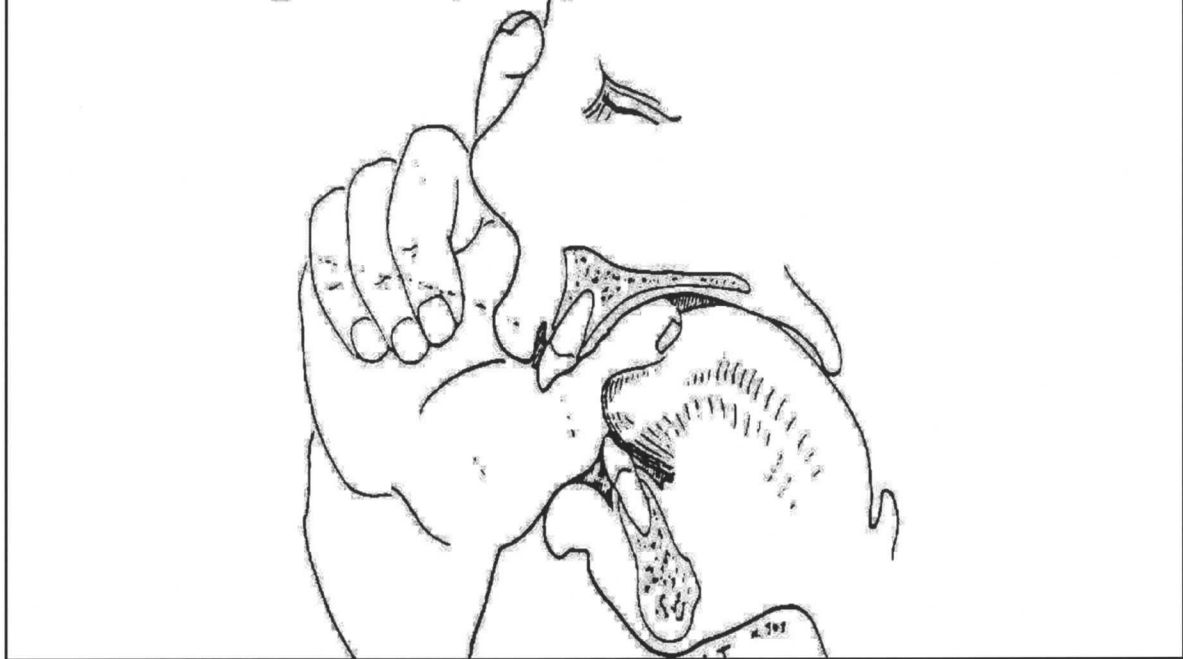


Figure 1: Vectors produced by the thumb during thumb sucking.

(Graber, 1962)

Anterior open bite, overjet and maxillary protrusion are the most commonly reported malocclusions related to thumb sucking (Traisman & Traisman, 1958; Bowden, 1966a, Warren & Bishara, 2002; Ozawa *et al.*, 2005; Al-Dawood, 2004; Duncan *et al.*, 2008; Fukata *et al.*, 1996). Al-Dawood (2004) reported that the prevalence of anterior open bites was ten times greater than in the non-habit group. Reports of incidence of anterior open bite in the thumb sucking groups vary from 15.1% (Fukata *et al.*, 1996) to 30.9% (Ozawa *et al.*, 2005). Reports of incidence of increased overjet have been reported to vary from 39.1% (Warren & Bishara, 2002 (> 4 mm) to 45% (> 6 mm) (Singh, Utreja & Chawla, 2008). Fukata *et al.* (1996) noted that these malocclusions of the anterior segment resulting from

thumb sucking occur before three years of age. Warren and Bishara (2002) confirmed these findings.

Several authors have reported that the increase in overjet is not due only to incisor proclination, but also to the elongation and anterior advancement of the anterior segment of the maxilla (Ruttle *et al.*, 1953; Al-Dawood, 2004; Warren & Bishara, 2002; Larsson, 1972, 1978; Kato *et al.*, 2009). Yokota, Mishihiro, Abe *et al.* (2007) recorded pressure on the anterior region of the palate from the thumb during thumb sucking and found that it was twice as much as the maximum pressure from the tongue. This provides a convincing rationalization as to why the anterior region of the maxilla is displaced forwards in digit suckers and vertical growth is greatly hindered.

Kato *et al.*, (2009) made use of a semiconductor laser which allowed three dimensional analysis of the configuration of the palate to measure and compare different surface areas and volumes of the palate in five-year old thumb-sucking subjects and non-habit subjects. These authors recorded significant increases in the length and volume of the anterior palate in thumb-sucking children compared with the non-habit participants. The length was measured from the mid-lingual point of the primary first molar forward. Similar findings have been reported by Kuyama, Kato and Daito (2008).

Ruttle *et al.* (1953) noted that in thumb-sucking children the maxillary arch altered significantly by narrowing and elongating anteriorly into a tapering arch form. Larsson (1972; 1978) also proved these effects to be the case by using analysis of

cephalometric records in a follow-up study of thumb-sucking children. Larsson (1972) reported a significant increase in proclination of the maxillary incisors with a significant increase in the SNA angle compared with a non-habit group. SNB was not affected. The maxillary apical base, represented by point A (subspinale), was more anteriorly placed and the antero-posterior maxillary length was significantly increased compared with the non-habit group.

In 1978, Larsson performed a follow-up study of the 1972 thumb-sucking sample, who were 16 years old at the time. The incisor angulation was found not to be significantly different from that of the control group, which may have been due to self correction. However, in the habit group the SNA angle and the antero-posterior maxillary length were still significantly greater compared with the non-habit group. This demonstrates that skeletal changes occurred and persisted in thumb-sucking individuals. Further cephalometric investigations by Moore and McDonald (1997) concur with Larsson's (1972) and (1978) report.

Cephalometric assessments of the influence of the habit may be confounded by the notorious difficulty experienced in accurately locating Point A. It is situated on the alveolar bone in the deepest part of the inner curve of the "premaxilla between the anterior nasal spine and the incisor tooth" and may change position with growth and tooth movement (Proffit, Sarver & Ackerman, 2007, p. 205). The use of point A to measure maxillary prognathism has been criticised, as this land mark may be altered by the degree of proclination of the maxillary incisors. An increase in the angulation of the maxillary incisors will cause point A to be more anteriorly positioned, increasing the SNA measurement and creating the illusion of maxillary

prognathism and a skeletal Class II malocclusion. Hence changes in the SNA angle in thumb suckers should be interpreted with caution.

1.4.2 *Class II canine and molar relationships*

Children with a history of thumb sucking have been reported to exhibit a significantly higher incidence of Class II primary canine and molar relationships when compared with children with no history of the habit (Fukata *et al.*, 1996; Popovich & Thompson, 1973; Bowden, 1966b). Class II canine relationships occur with a higher incidence in thumb-sucking children than Class II molar relationships. This is related to the increase in anterior arch length caused by the anterior displacement of the maxilla, as greater changes occur anteriorly than posteriorly (Fukata *et al.*, 1996; Subtelny & Subtelny, 1973). The Class II molar relationship that occurs in thumb-sucking children is due to the lever action of the thumb and arm which tends to disarticulate and rotate the mandible in a downward and posterior direction, thus retruding the mandible in its entirety into a Class II skeletal position (Ruttle *et al.*, 1953). Bowden (1966b) surmised that this could be due to mesial drifting of the maxillary deciduous molars following the already anteriorly placed incisors prior to eruption.

Fukata *et al.* (1996) linked thumb sucking and the tendency towards Class II molar relationships in children four years of age and older. They concluded that posterior alterations to the occlusion, unlike anterior malocclusions, occur at a later stage. These authors are in agreement with others such as Popovich and Thompson (1973) who suggested that the likelihood that a child would develop a Class II malocclusion increased with greater persistence and intensification of the habit.

Class II molar relationships in the primary dentition results in Class II molar relationships in the permanent dentition as the distal surfaces of the second primary molars guide the erupting first permanent molars into position (Fukata *et al.*, 1996). Thumb sucking therefore should ideally be eliminated prior to damage to the terminal plane which changes at four years of age (Nabeta, Sakuma & Kawata, 1982). Ruttle *et al.* (1953) were amongst the few authors that could not find a statistical association regarding thumb sucking and Class II canine and molar relationships.

1.4.3 *Maxillary and mandibular arch width changes*

A narrow contracted maxillary arch in children with a thumb-sucking habit has been described by several authors (Yemitan, Da Costa, Sanu *et al.*, 2010; Swineheart, 1938; Littlefield, 1952; Kato *et al.*, 2009, Kuyama *et al.*, 2008; Warren & Bishara, 2002). This is due to an alteration in the balance between the tongue, which is forced down into the mandibular arch by the thumb, and the oral musculature (Christensen, Fields & Adair, 1999). In some cases where the cheeks are vigorously sucked inwards, a hypertrophic buccinator muscle and negative intra-oral suction pressure is produced (Littlefield, 1952; Luffingham, 1969; Christensen *et al.*, 1999). The result of this suction pressure, abnormal force from the cheeks and the lack of palatal support from the tongue, is a contracted maxillary arch (Swineheart, 1938; Littlefield, 1952; Christensen *et al.*, 1999). High vaulted palates are often observed in thumb sucking individuals with narrowed maxillary arches (Graber, 1962; Cerny, 1981). The lowered tongue position allows air to enter through the mouth leading to habitual mouth breathing which also

encourages a reduction in the maxillary arch width (Trawitzki, Anselmo-Lima, Melchior *et al.*, 2005; Kurol & Berglund, 1992, Ogaard, Larsson & Lindsten, 1994).

Kato *et al.* (2009) established that in thumb-sucking children, the palate took on a V- shape configuration and was constricted in the molar area. These authors reported that the volume of the actual posterior palatal region decreased and was constricted medially, while the anterior palatal region became shallower as it elongated. Kuyama *et al.* (2008) found comparable results. It appears therefore that palatal depth should be measured anteriorly and posteriorly as the palatal depth differs at both these sites. However, Warren and Bishara (2002) reported that palatal depth became shallower and not deeper in thumb-sucking individuals of longer duration.

Prolonged thumb sucking promotes an increase in mandibular inter-canine arch width. This is due to the tongue taking up a lower position within the mandibular arch during sucking, which increases the lateral pressure on the mandibular canines and incisors (Subtelny & Subtelny, 1973; Al-Dawoody, 2004). Studies by Aznar *et al.* (2006), Ruttle *et al.* (1952) and Bowden (1966a) did not find a consistent decrease in maxillary arch width or an increase in mandibular arch width in thumb-sucking individuals. Ruttle *et al.* (1953) however did acknowledge that in some thumb sucking cases, there was a marked degree of narrowing of maxillary canine arch width.

This decrease in the maxillary arch width and increase in mandibular arch width leads to the development of posterior crossbites (Al-Dawoody, 2004). It has been noted that the crossbite in thumb suckers is more due to the decrease in maxillary arch width than due to the increase in the mandibular arch width i.e. the transverse discrepancy occurs in the maxilla (Larsson, 1978; 1994; Ogaard *et al.*, 1994; Christensen *et al.*, 1999). Modeer, Odenrick and Lindner (1982) reported that most crossbites due to thumb sucking were unilateral and were more prevalent in children who persisted with sucking habits beyond the age of two. The establishment of the posterior crossbite occurs concurrently with the eruption of the primary canines at approximately 18 months of age (Lindner & Modeer, 1989). At this time, "maxillary occlusal relationships develop and the mandible undergoes functional adaptation, deviating to either the left or the right" thus establishing the posterior crossbite at an early age (Macena *et al.*, 2009, p 357).

This malocclusion warrants concern as it may be transferred to the permanent dentition and lead to progressive mandibular dysfunction and possibly craniofacial asymmetry (Kurol & Berglund, 1992; Sonnesen *et al.*, 2001). Modeer *et al.* (1982) observed that buccolingual occlusal relationship deteriorated in cases where the habit persisted. Furthermore, a risk of deterioration of the temporomandibular joint was found (Sonnesen *et al.*, 2001; Kurol, 2006).

1.4.4 *Self-correction after cessation of habit*

Many authors agree that malocclusions exhibit a tendency to self-correct if the habit ceases before five years of age, but that thereafter the unfavourable effects persist (Warren & Bishara, 2002; Bishara *et al.*, 2006; Bowden, 1966a, 1966b;

Duncan *et al.*, 2008; Larsson, 1978). Popovich and Thompson (1973) reported that none of the children in their study who had ceased thumb-sucking after the age of six years had a normal occlusion.

Cessation of the habit is associated with a significant reduction in anterior open bite and overjet, especially between the ages of four and six years (Heimer *et al.*, 2008; Proffit & Fields, 1986; Littlefield, 1952; Bowden, 1966a). Self-correction of these malocclusions occurs as normal lip and cheek pressures restore the teeth to their original positions (Graber, 1959). Heimer *et al.* (2008) and Proffit and Fields (1986) reported that the greatest incidence of spontaneous correction of these malocclusions occurred in children with horizontally balanced growth patterns and that spontaneous self-correction of a posterior crossbite rarely occurs. The growth rate in the transverse plane slows down earlier than in the sagittal or vertical dimension, which decreases the chance of spontaneous correction (Modeer *et al.*, 1982).

Other researchers, such as Lindner (1989) and Kuroi and Berglund (1992) reported that a measurable percentage of self-correction of cross bites does occur. Their studies were conducted over longer periods of time (from five to ten years) allowing for longer observation of subjects, which in turn may have permitted spontaneous readjustment to occur.

Popovich and Thompson (1973) reported that the incidence of Class II malocclusion in those children who had stopped the habit after the age of six was higher than those who had ceased between the ages of three and six.

1.4.5 *Factors affecting the malocclusions produced by thumb sucking*

In the literature there is conflicting evidence regarding the actual malocclusions and severity of malocclusions produced by thumb sucking (Fukata *et al.*, 1996; Warren & Bishara, 2002; Ozawa *et al.*, 2005; Singh *et al.*, 2008; Larsson, 1994; Traisman & Traisman, 1958). These differences can be ascribed to several factors:

1.4.5.1 Duration, intensity and frequency

The severity of the malocclusions that present is linked to the duration, intensity and frequency of the habit (Christensen *et al.*, 1999; Graber, 1959). "Intensity is the amount of force that is applied to the teeth during sucking. Duration is defined as the amount of time spent sucking a digit. Frequency is the number of times the habit is practiced throughout the day" (Christensen *et al.*, 1999, pg. 393). Duration is the most critical factor in the causation of a malocclusion by a thumb-sucking habit. A child who sucks with a high intensity, but sporadically, will create less damage than one who sucks with less intensity but incessantly (Christensen *et al.*, 1999; Graber, 1959, 1962). According to Proffit (1986) the thumb must be sucked for a period of at least six hours per day to exert an effect on the dentition.

1.4.5.2 Variations in thumb and tongue position

The placement and angulation of the thumb during sucking affects the direction of displacement of the palate and the incisors (Christensen *et al.*, 1999; Larsson & Bishara, 2007; Littlefield, 1952; Graber, 1962). Bishara & Larsson (2007b) claimed that the position of the thumb utilised by the child is always consistent. Subtelny

and Subtelny (1973) utilised cineradiographs in order to develop a classification of thumb positions during thumb sucking in order of decreasing occurrence. Their findings were as follows:

- 1) In approximately half the subjects, comprising Group One, the thumb enters the mouth past the first joint or knuckle. The thumb presses against the rugae of the palatal mucosa and alveolar tissue occupying a large part of the vault of the hard palate. The lower incisor is in contact with or pressed into the thumb.
- 2) In 24% of the subjects (Group Two), the thumb does not go completely into the vault area of the hard palate, but enters the mouth approximately up to the first joint and also makes contact with the lower incisors.
- 3) In Group Three (comprising 18% of the subjects) the position of the thumb is the same as Group One, however the thumb is not in contact with the lower incisors for the duration of the thumb-sucking episode.
- 4) In the last group, the thumb hardly enters the mouth while the lower incisors contact the thumb at the level of the thumb nail.

Subtelny and Subtelny (1973) further noted that within the above subgroups two variations in tongue posture exist:

- 1) In the majority of thumb suckers (82 %), the dorsum of the tongue is used for sucking and is located under the thumb and in full contact with it. The tongue-tip is pressed against the lingual aspect of the lower incisors. The action of the tongue in these instances may cause proclination of the lower

incisors. It was thought that the thumb exerted a distal force on the lower incisors causing them to retrocline but this force may be opposed by the action of tongue.

- 2) In the remainder of cases the tongue-tip contacts or approximates the end of the thumb and the tongue is placed posteriorly.

These findings indicate that the tongue position is closely related to that of the thumb during thumb sucking.

Another observation noted by Subtelny and Subtelny (1973) was that amongst thumb suckers, the extent to which the mandible moves varies. Those subjects displaying marked mandibular movement during thumb sucking exhibited active buccal and perioral musculature which resulted in upright lower incisors. Conversely, children with very little or no mandibular movement in which muscular activity was passive, exhibited a greater propensity toward proclination and a more forward positioning of both upper and lower incisors.

These variations in thumb and tongue position and the degree of mandibular movement explain the diverse findings in malocclusions produced by thumb suckers regarding: maxillary and mandibular arch width variations, palatal depth, anterior arch depth and inclination of upper and lower incisors.

1.4.5.3 Negative intra-oral pressure and muscle activity

Bowden (1966a) postulated a theory to explain the varied effects of the maxillary arch width, suggesting it could be due to different thumb-sucking mechanisms. Constriction of the maxillary arches is due to the vacuum produced from local negative intra-oral pressures and contraction of the buccinator muscles, which produces the inward sucking of the cheeks. The negative intra-oral pressure is initiated by contraction of the diaphragm and is increased by the movement of the tongue during sucking. Bowden (1966) believes that, in the majority of thumb-sucking cases, complete closure of the anterior oral seal during all phases of thumb sucking is not always maintained thus releasing the negative intra-oral pressure, producing a partial vacuum. This automatically decreases activity in the buccinator muscles and increases activity of orbicularis oris and mentalis muscles. Buccal pressure is not maintained and the maxillary arch is less likely to narrow.

Luffingham (1969) is in agreement with this view. However, in those thumb-sucking cases where a negative intra oral pressure was produced, a significant increase in buccal pressure against the teeth was noted.

Baril and Moyers (1960) studied twenty-four thumb-sucking children by applying an electromyographic analysis of the facial muscles. They support the findings of Bowden (1966a) reporting weak contraction patterns from the buccal wall and stronger contraction patterns from orbicularis oris and mentalis muscles.

1.4.5.4 Concomitant tongue thrust and/or lip habit

These additional habits may exacerbate a pre-existing malocclusion produced by thumb-sucking.

1.5 AETIOLOGY

There is no unanimity as to the exact aetiology of the thumb sucking habit, although several hypotheses exist. All are based on the instinctive suckling reflex, inherent in all infants, and is a biological drive which satisfies both psychological and nutritional needs (Johnson & Larsson, 1993; Kaplan, 1950; Jacobson, 1979). Intrauterine thumb sucking has been observed in the foetus as early as 18 weeks, indicating that this reflex occurs early (Nilson, 1994).

Two schools of psychological thought are most widely accepted regarding the aetiology of thumb sucking, namely the psychoanalytical theory and the learning behaviour theory (Polyakov, 2002; Larsson & Bishara, 2007). More recent theories link thumb sucking to reduced breastfeeding times (Larsson & Dahlin, 1985; Traisman & Traisman, 1958; Uzaezuoike, Ilechukwe & Okafor, 2003).

1.5.1 *Psychoanalytical theory*

The psychoanalysts draw from Sigmund Freud's original theory that infants derive pleasure from thumb sucking (Polyakov, 2002). According to psychoanalytic theory, thumb sucking begins initially as an instinctive reflex, which then develops into a form of infantile sexuality which, if prolonged, is symptomatic of a mental disturbance (Larsson & Bishara, 2007). They argue that prolonged sucking habits

are a fixation, a symptom of an emotional disturbance or deterioration in the child's mental development, which causes a regression into the habit. However, these theorists also hold the belief that thumb sucking at the ages between birth and two years is a normal behaviour pattern (Jacobson, 1979).

1.5.2 *Learning behaviour theory*

According to this theory, the habit is a matter of prolonged practice, which simply has been learnt as a neuromuscular response (Polyakov, 2002; Jacobson, 1979). The habit reduces anxiety, provides the infant with satisfaction and is not related to any underlying psychopathology (Larsson & Bishara, 2007). Thumb sucking is thus said to be "empty" (Klein, 1971). It is not known exactly when normal sucking behaviour becomes a habit, which may last from minutes to hours. The behaviourists therefore believe that the habit can be suppressed without psychological disorders developing (Polyakov, 2002; Jacobson, 1979). If the child cannot abandon the habit, the habit in itself may cause psychological problems in later years due to negative peer reactions to the childhood behaviour (Friman, McPherson, Warzak *et al.*, 1993; Larsson & Bishara, 2007). The unaesthetic dentofacial appearance and abnormal speech, which usually accompanies a thumb-sucking habit, may contribute to the child's low self-esteem and lack of confidence. These factors may affect the child's ability to interact socially (Friman *et al.*, 1993).

To a large extent the research findings regarding these two aetiologies are conflicting:

Mahalski and Stanton (1992), in a longitudinal project of over ten years, concluded that a strong correlation did indeed exist between thumb sucking and behaviour problems, especially in older thumb-sucking children. These authors also reviewed several relevant studies, which had found no correlation between thumb sucking and behaviour problems. They identified the shortcomings as the "limited use of standardised behavioural evaluations, poorly defined target samples, failure to include clinically referred and non-referred children in the comparison samples and an absence of measures of thumb-sucking severity (Friman *et al.*, 1993, p 432).

Friman, Larzelere and Finney (1994), in response to the report by Mahalski and Stanton (1992), conducted research on thumb suckers taking into account the criticisms listed above. They could not support the theory that thumb sucking is a symptom of psychopathology. These authors reported that an increase in behavioural problems occurred in general in children as they got older. In the study conducted by Friman *et al.* (1994), there were only sixteen participants identified in the "older children" thumb-sucking category. The small sample may have negatively impacted on the study's ability to statistically determine whether behavioural problems differ between the younger and older children with a thumb-sucking habit. In comparison, the study by Mahalski and Stanton (1992) had a larger sample of older thumb-sucking individuals. Lindsten, Larsson and Ogaard (1996) support the theory that thumb sucking is a comforting activity or a simple association with rest and not due to a predisposed psychopathology. All their study

participants used a dummy when going to sleep, while watching television, or when they were tired.

1.5.3 *Breastfeeding linked to sucking habits*

Recently, much research has focused on the link between decreased breastfeeding and non-nutritive habits, such as thumb sucking (Moimaz, Zina, Saliba *et al.*, 2008; Peres, Barros, Peres *et al.*, 2007). In earlier societies and in some traditional cultures, children were breastfed on demand for two years or more (Larsson & Dahlin, 1985). With more women in the workplace now than in earlier decades, mothers often have to return to work four months after giving birth, which has led to a decrease in breast-feeding (Carrascoza, Possobon, Tomita *et al.*, 2006). Furthermore, today's trend is to breastfeed in 20 minute sessions every four hours as opposed to the on-demand feeding of previous times (Larsson & Bishara, 2007). Larsson and Dahlin (1985) have suggested that reducing breast feeding time, early weaning and an increase in bottle feeding, has resulted in the sucking urge not being satisfied and thus, the infant may substitute the thumb for the breast.

Moimaz *et al.* (2008), Uwaezuoke *et al.* (2003) and Traisman and Traisman (1958) investigated the link between breastfeeding and non-nutritive habits and have shown that breastfeeding delays the need for pacifier and thumb sucking and protects against the development of malocclusion. Other studies have found no connection between nursing behaviour and oral habits (Ozawa *et al.*, 2005; Viggiano, Fasano, Monaco *et al.*, 2004; Zadik, Stern & Litner, 1977).

Traisman and Traisman (1958), Sarkar, Chowdhury and Mukherjee (1992) and Uwaezuoke *et al.* (2003) deduced that reduced breast feeding times were strongly associated with an increase in thumb sucking. Traisman and Traisman (1958) reported that children who presented with the lowest thumb-sucking scores were breast-fed frequently, for more than sixty minutes a session. Fewer children (45%) who were fed for less than thirty minutes developed a thumb-sucking habit, perhaps indicating that the desire for oral gratification had not been strongly implanted. Overall this evidence supports the theory that satisfactory breast-feeding delays the need for alternative sources of sucking (pacifier/thumb), thereby decreasing the likelihood of malocclusions. Whether this is due to the actual mechanism of breast-feeding or the decreased use of pacifier/bottle/thumb requires further investigation.

1.5.4 *Socio-demographic characteristics of thumb sucking*

It has been reported that thumb sucking is more prevalent in Westernised countries amongst higher socio-economic groups and amongst girls whose mothers are married (Johnson & Larsson, 1993; Dos Santos, de Holanda, de Sena *et al.*, 2009; North Stone, Fleming & Golding, 2002; Larsson, 1971; Al-Dawoody, 2004; Al-Jobair, Al-Emran, Ayer *et al.*, 2004; Farsi & Salama, 1997). Uwaezuoke *et al.* (2003) in Nigeria, however, reported a slightly higher incidence in the male population, which concurred with researchers in Calcutta, India (Sarkar *et al.*, 1992). Zadik *et al.* (1977) reported that no gender differences were found in children from different kibbutz in Israel. Traisman and Traisman (1958) reported equal distribution of the habit amongst boys and girls in a study conducted on 1208 thumb-sucking infants and children. Further investigations in South Africa are

required regarding the possible influence of race, education, culture and socio-economic standing on thumb-sucking habits.

1.5.5 Prevalence

Much of the previous work has focused on the prevalence of the habit, which is varied the world over, with a historically higher occurrence in Western cultures. Increased use of pacifiers in these societies has resulted in a decrease in the indulgence in thumb sucking of up to 20% in the past four decades (Larsson, 2001; Zadik *et al.*, 1977; Johnson & Larsson, 1993).

In eastern cultures like Japan, prevalence figures as high as 27.2% have been recorded (Ozawa *et al.*, 2005). Similar figures were reported in Westernised countries 30 years ago according to Fukata *et al.*, 1996; Ozawa *et al.*, 2005 and Larsson, 2001. In Saudi Arabia the incidence is estimated to be at only 10.49% due to mothers discouraging the habit by non-invasive procedures such as the use of bitter tasting substances and positive reinforcement (Al-Jobair *et al.*, 2004). Notably, amongst Eskimo children, the prevalence is as low as 1% (Curzon, 1974).

Documented literature related to non-nutritive habits including thumb sucking amongst Africans is sparse. Uwaezuoke *et al.* (2003) recorded a prevalence rate of 23% amongst Nigerian children. Larsson and Dahlin (1985) reported that pacifier and digit habits were rare in African children, where they recorded a two percent incidence. This study was conducted two decades ago on rural

Zimbabwean children and the data is not readily extrapolated to modern-day South Africa.

These variations may be ascribed to differences in heterogeneity within a sample, the age range of participants, sample size, race and social environment and differing infant feeding practices in various cultures (Fukata *et al.*, 1996). Prevalence also varies from one culture/population to another within a country (Ozawa *et al.*, 2005).

1.5.6 Conclusion

The effects on the skeletal and dental complex are numerous and well documented in the literature. Malformations such as a narrow maxillary arch, anterior open bite, maxillary incisor protrusion, anterior elongation of the anterior maxilla, and increase in mandibular arch width have been reported to be the consequences of prolonged thumb sucking. However, there are considerable variations in the studies and few on black South African children. Studies on black South African children can aid in identifying malocclusal traits in this population group and deduce whether they differ from those of studies of the mainly White population groups in Europe and America.

As the deciduous dentition and arch form is a template for the permanent dento-skeletal arches, knowledge of the various clinical signs in this population group may aid healthcare workers to identify the problem and give assistance with regard to counselling, prevention and treatment, where necessary.

METHODS AND MATERIALS

1.6 STUDY DESIGN

The current study was cross-sectional in nature, comparing various occlusal characteristics of a group of black children who suck their thumbs with those of a group who do not. The latter category was referred to as the non thumb-sucking group

1.7 STUDY POPULATION AND SAMPLE SELECTION

The study population consisted of children from the Johannesburg area attending the University of the Witwatersrand Paediatric and Restorative Department at the Wits Dental Hospital for dental treatment, as well as children from crèches/day care centres in the areas surrounding Edenvale and Germiston. These centres were randomly identified via the internet and by advertisements in the area newspaper – (The Edenvale and Bedfordview News). The control (non-habit) group was randomly selected amongst volunteers. These children did not have a thumb-sucking habit and parents and teachers/caregivers testified to having no recall of any habit. Children who were identified as having a persistent thumb-sucking habit were included in the study group. Children with a finger sucking habit were excluded. The children attended their respective crèche/day care centres between 07h30 and 17h00 from Monday to Friday. As more waking time was spent with teachers at the crèche than at home, the crèche staff were in a position to give an accurate account of the frequency of the habit. Where feasible, a discussion was held with the child regarding the thumb sucking habit.

All the participants were from low-income socio-economic backgrounds and all were South African, from the black population. There have been few studies on this group and the results of this study may facilitate reliable comparisons with the numerous literature reports pertaining to the white population groups in Europe and America.

The children were between the ages of four and five years old. This age group was selected as the complete deciduous dentition had been present over a time period sufficient for the effects of the habit to have manifested. Furthermore, children of this age were old enough to comply for the alginate impression procedure to be done.

1.7.1 *Inclusion criteria*

All children accepted into the study groups met the following inclusion criteria:

1. Complete deciduous dentition with no erupted permanent teeth.
2. No major tooth destruction, significant carious lesions and restorations.
Small occlusal cavities were accepted, as any damage they may have caused to the teeth would not affect the measurements. Furthermore, occlusal caries do not facilitate drifting of teeth which may affect arch length.
3. No congenitally missing or supernumerary teeth.
4. No evidence of a skeletal open bite.

(In one child there was a suspicion that the open bite was of skeletal origin and thus the child was not included. This child also testified that he had never sucked his thumb.)

1.7.2 *Final study sample*

Careful application of the criteria for inclusion resulted in a final sample that comprised 27 participants in the thumb sucking group and 29 in the non-habit group.

1.7.3 *Age*

In the thumb-sucking group (TS) 48% of the children were four years old and 52% were five years old. In the non-habit (NH) 82.7% of the children were four years of age and 17.3% were five years of age, as seen in Table 2, below.

GROUP	FOUR YEAR OLDS	FIVE YEAR OLDS
Thumb-Sucking	48%	52%
Non-Habit	82.7%	17.3%

Table 1: A comparison of age in the thumb-sucking and non-habit groups.

1.7.4 Gender

In the thumb sucking sample 59 % of participants were female, whilst in the non-thumb sucking group 28 % were female and 72 % were male, as seen in Table 2.

GROUP	MALE	FEMALE
Thumb-Sucking	41%	59%
Non-Habit	28%	72%

Table 2: A comparison of gender in the thumb -sucking and non-habit groups.

1.8 ETHICAL APPROVAL

Application was made to the University of the Witwatersrand Committee for Research on Human Subjects (Medical), who approved the research protocol. (Clearance Number R14/49 Botha). A detailed Informed Consent Form was also accepted by the Committee and was distributed to parents and caregivers before any child was included in the sample. The Approval Document and the Informed Consent form are included in Appendix A and B respectively.

In several cases the caregiver/teacher assisted the parents by translating the document and also acted *in loco parentis*, as a direct response from the parents was limited (33% response rate). Three parents declined to give permission and their children were not included. In addition, every child was fully informed of the procedures that would take place. Children are vulnerable and in instances where a child was nervous or where their behaviour indicated fear of the procedure, no coercion was applied and these children were excluded from the study. All the

information obtained was treated with the strictest of confidence. The names of the participants did not appear on the models or data form. No adverse comment or criticism was received at any time.

Children attending the Wits Dental Hospital who presented with a malocclusion or other dental/oral problems were referred to the appropriate discipline for assessment and treatment. The parents of the children attending crèches/day care centres were informed of any dental/oral problem and were advised to seek treatment at their nearest clinic.

1.9 DATA COLLECTION

1.9.1 Questionnaire

A questionnaire was designed to determine when the habit commenced and whether there was concomitant use of a pacifier. The response rate was unfortunately poor (33%). The questionnaires that were returned were not fully completed. The literature has documented this phenomenon where people from lower socio-economic groups and different ethnic backgrounds have a poor response rate to questionnaires (Patel, Moles, O'Neil *et al.*, 2008). Parents or guardians attending the Wits Dental Hospital provided verbal responses to the questionnaire, with the aid of the dental nurses, who in many instances, translated the questions.

1.9.2 *Clinical examination*

The children were assessed by means of a clinical dental examination conducted by the researcher. Children attending crèches/day care centres were examined in the classroom under natural light, while those attending the university were assessed in a dental chair with a dental light. A dental mirror and probe were utilised. The mirrors were cold sterilized for five minutes before use (Steriwise, Steritech). Gloves and masks were used.

1.9.3 *Impression taking*

For each child participating in the study, alginate impressions of the maxillary and mandibular arches were obtained. Wax bite registrations were taken with the children guided into habitual occlusion. White stone models were immediately cast from the impressions to minimise dimensional deformities, and were subsequently trimmed.

1.10 APPLICATION OF THE DATA COLLECTION TOOL

Landmarks for the pertinent measurements relating to malocclusions associated with these habits were identified and marked on each model. Measurements of specific dental arch parameters were made in millimetres (mm) using an electronic calliper accurate to 0.05mm (TA) (Figure 2, below) and were performed under the same conditions i.e. at the same working bench, position, and lighting and at similar times to ensure standardization and repeatability. Measurements were repeated three times on different occasions at least 24 hours apart to enable

assessment of operator reliability. The method of evaluating and measuring the cast models was based on a design described by Warren and Bishara (2002).

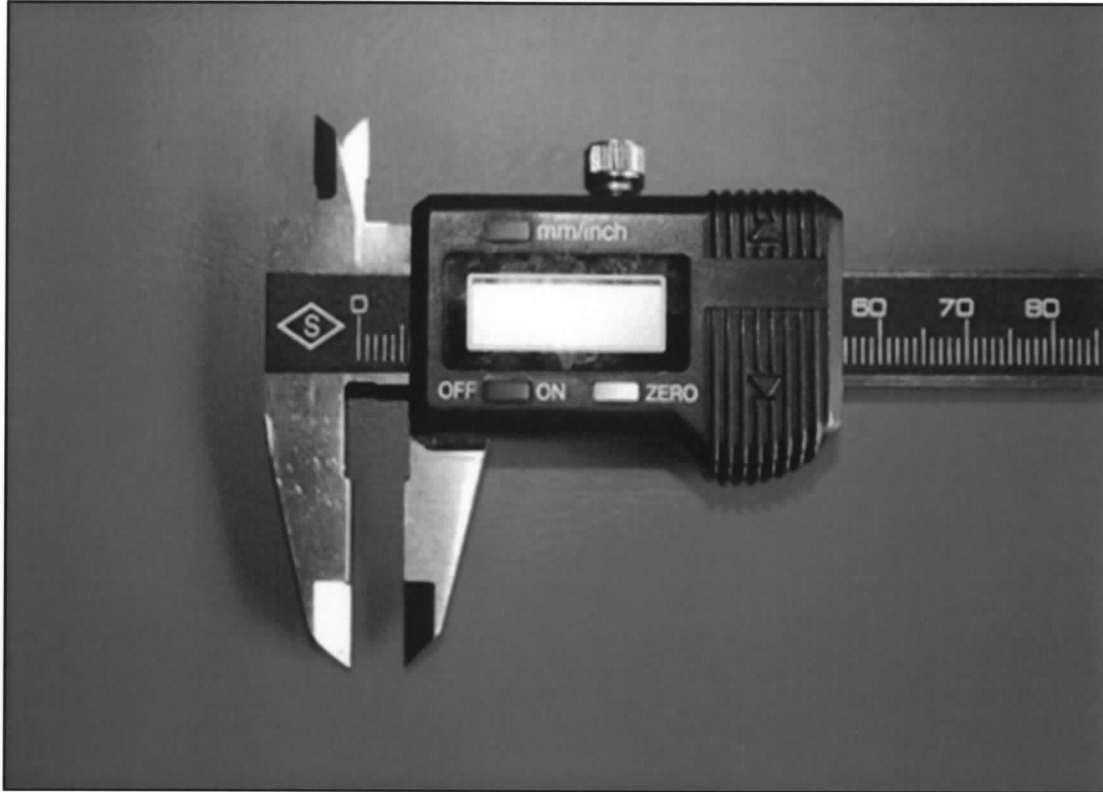


Figure 2: Electronic callipers, showing display panel*

1.11 OCCLUSAL RELATIONSHIPS

The assessment included the evaluation of the primary canine and molar relationships according to Angle's classification, and determined the presence or absence of anterior open bite, posterior crossbite and/or Class II relationships.

*MC Company, China, Item 02270108

1.12 REFERENCE POINTS AND MEASUREMENT TECHNIQUE FOR VARIOUS PARAMETERS

1.12.1 Arch width

- The inter-canine arch widths were measured between the deciduous canine cusp tips or the estimated location if wear facets had reduced the tip. (See Figure 3, below).
- Inter-molar arch widths were measured between the mesiobuccal cusp tips of the second primary molars (Figure 3, below).

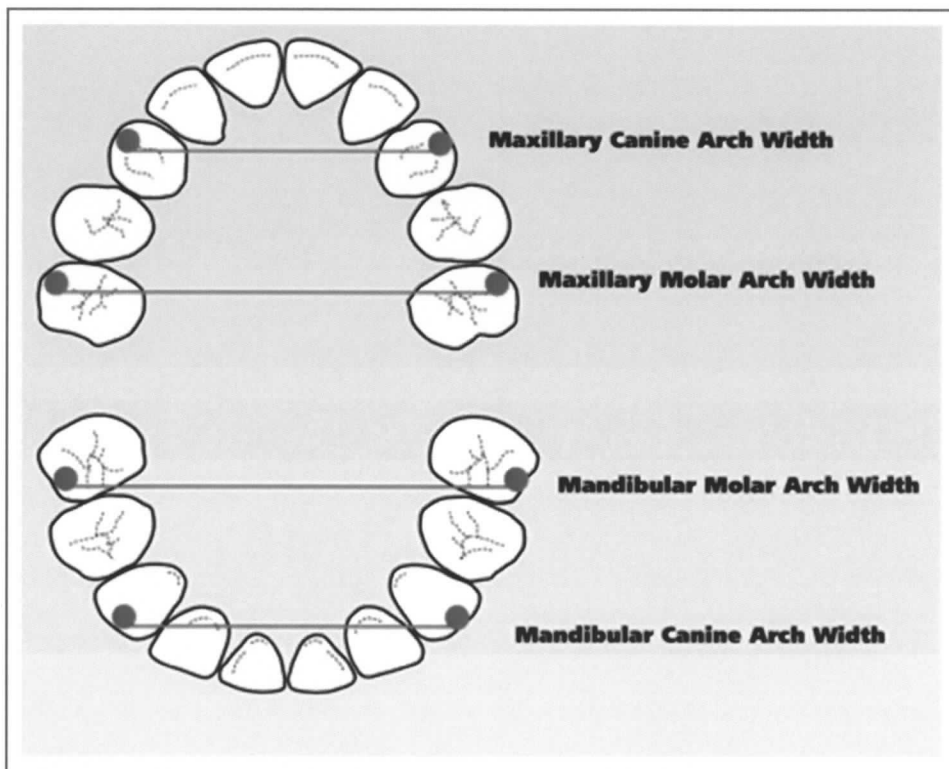


Figure 3: Maxillary and mandibular arch width measurements.

(Warren & Bishara, 2002)

1.12.2 Arch lengths

- Left and right anterior segments were measured as a straight line from the contact area between the primary central incisors to the contact area between the primary canine and first primary molar. (See Figure 4) (A and C).
- Left and right posterior segments were measured as a straight line from the contact between primary canine and first molar to the distal point of the second primary molar. (B and D). (Figure 4).

The segment lengths for right and left sides of each arch were summed to determine the total length of each arch.

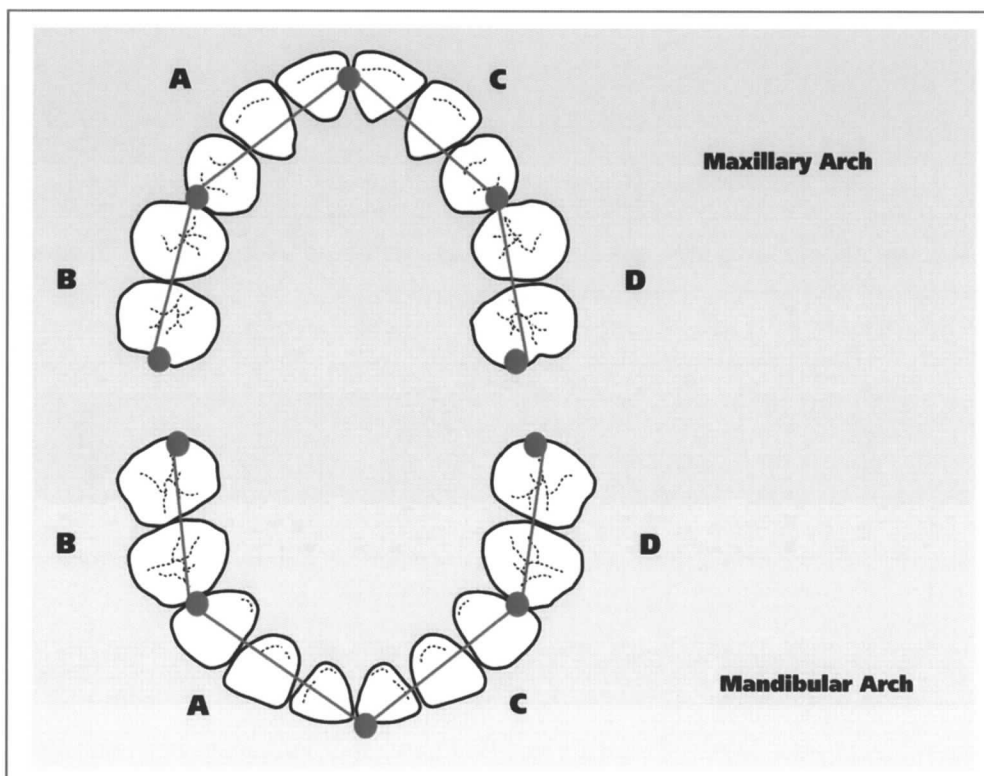


Figure 4: Diagram depicting the points used to define anterior and posterior segments.

(Warren & Bishara, 2002)

1.12.3 Arch depth

Two levels were measured:

- Anterior canine arch depth: the length of a perpendicular line raised from the midpoint between the central incisors to a small wooden dowel connecting the distal contact points of the contra-lateral deciduous canines in each arch. (Figure 5).
- Posterior molar arch depth: the length of a perpendicular line raised from the midpoint between the central incisors to a small wooden dowel connecting the distal curvatures of the contra-lateral deciduous second molars (Figure 5).

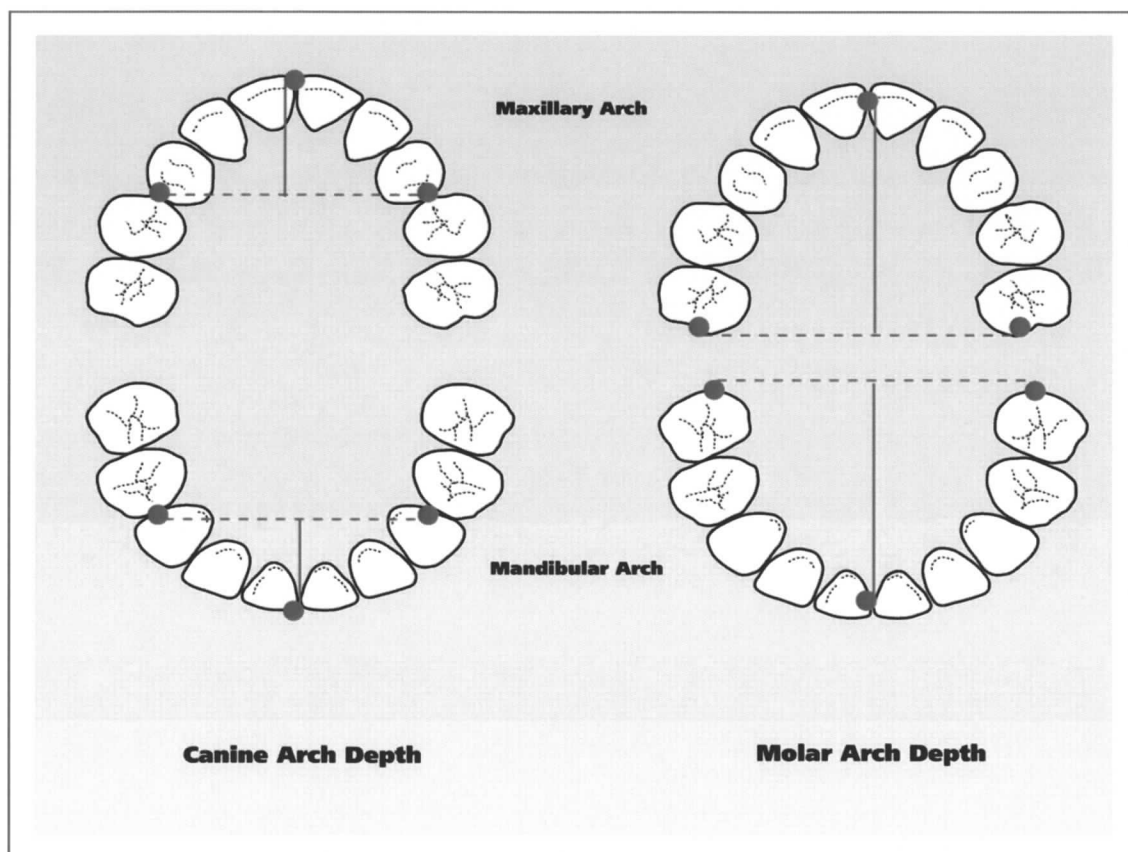


Figure 5: Canine and molar arch depth measurements.

(Warren & Bishara, 2002)

1.12.4 Palatal depth

The palatal depth was measured as the perpendicular distance from the deepest point in the palate to the occlusal plane at the first molars (Figure 6). This was measured by placing a Perspex sheet across the occlusal plane. A rod was then positioned at the deepest point in the palate and perpendicular to the Perspex sheet. The depth was marked on the rod with a light pencil scribe, the rod removed and the distance measured.

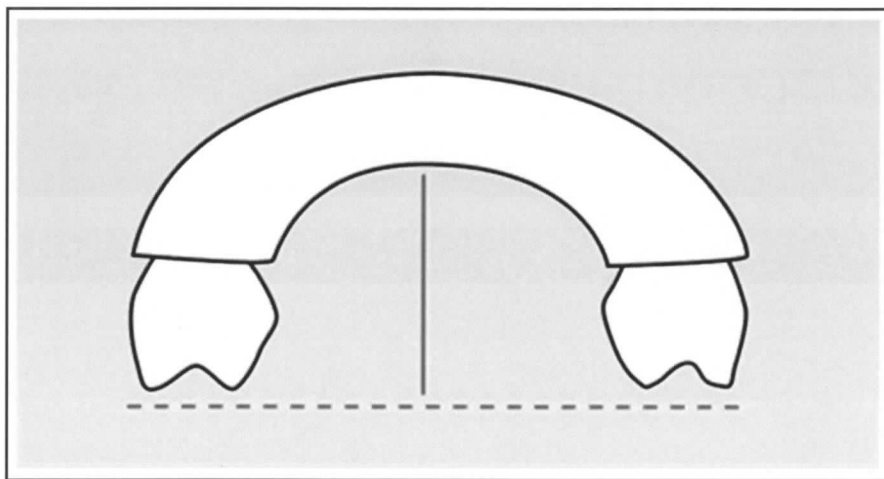


Figure 6: Palatal depth measurement.

(Warren & Bishara, 2002)

1.12.5 *Overjet*

Overjet is defined as the horizontal overlap of the incisors (Proffit, 2007). It is measured as the horizontal distance from the incisal edge of the labial surface of the maxillary central incisor to the incisal edge of the labial surface of the mandibular central incisor (Figure 7). Where vertical overlap occurs it is measured as the horizontal distance from the incisal edge of the labial surface of the maxillary central incisor to the labial surface of the mandibular central incisor. This was measured using the internal beaks of the callipers when the models were in habitual occlusion (Figure 2).

1.12.6 *Overbite*

Overbite is defined as the vertical overlap of the incisors (Proffit, 2007, p. 11). It is measured as the vertical distance between the incisal edge of the maxillary central incisor and the incisal edge of the mandibular central incisor. Where normal overbite occurs a light pencil line was scribed on the labial surface of the mandibular central incisor corresponding to the location of the incisal edge of the maxillary central incisor when the models were in habitual occlusion and was measured using the internal beaks of the callipers (Figure 7).

In the absence of vertical overlap/occlusion between the primary incisors i.e. an open bite case, the vertical distance between the incisal edges of the maxillary and mandibular central incisors was recorded with the reverse side of the callipers (Figure 2). A negative value was assigned to allow for differentiation between open bite and normal overbite.

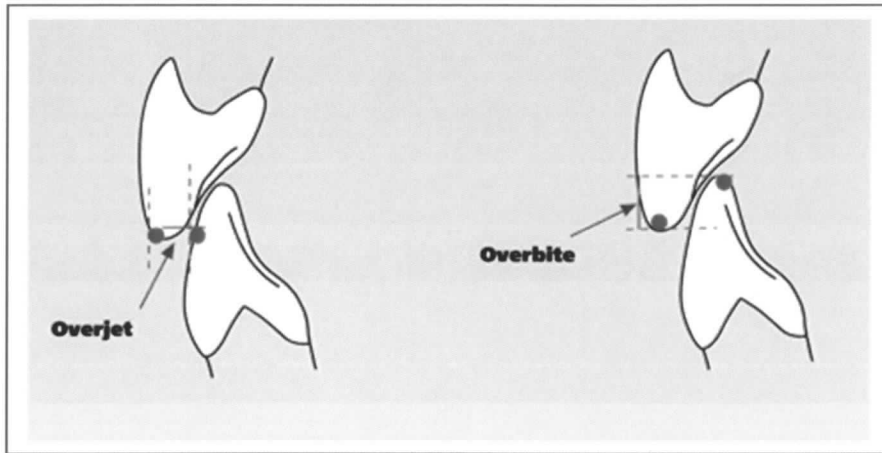


Figure 7: Overjet and overbite measurements.

(Warren & Bishara, 2002)

1.12.7 *Posterior crossbite*

Posterior crossbite was recorded when one or more maxillary primary molars buccal cusps occluded palatally to the buccal cusp of the opposing mandibular molars in habitual occlusion. No account of severity was recorded.

1.13 DATA ANALYSIS

The data was collected and entered onto an Excel® spreadsheet*. Data was statistically analysed to determine the descriptive statistics, which included averages, means and standard deviations, which enabled an assessment of the frequency and relative sizes of the recorded parameters. These data from the thumb-sucking and non-habit groups, were then compared using the Student's t-test. The statistical programme used was SAS version 9.1 and the level of significance was set at 0.05. The data under comparison included the parameters of: arch depths, lengths and width; open bite; overjet; crossbite and palatal depth. Messrs DMSA (Data Management and Statistical Analysis) advised on and interpreted the statistical analyses.

* Excel[®] is a product of Microsoft Office Home and Student 2007

RESULTS

1.14 INTRA-OPERATOR RELIABILITY

The three recorded measurements for each parameter for all the participants were assessed for intra-operator reliability utilizing the standard deviation function of Excel®. No statistically significant differences between the measurements were found. The standard deviations were below a 5% value and thus there was good concordance between the readings.

1.15 INTER-OPERATOR RELIABILITY

Ten of the stone models were randomly selected (five from the thumb-sucking group and five from the non-habit group) and all measurements repeated by a second examiner who was experienced in dental recording. The data from the second set of measurements was statistically compared with that of the original recordings, using the Students t-test. The measurements were found to be accurate within a 0.05mm range, with no statistically significant differences between the means. (Values varied from 0.08 – 0.9 see Appendix D)

1.16 DESCRIPTIVE STATISTICS

In both groups the data of each parameter were pooled, and the mean standard deviation and range were calculated, and are presented in the first six columns of the following tables (Table 3,4,5 and 6).

1.17 COMPARATIVE STATISTICS

Of the 17 parameters/variables included in the assessment, seven recorded statistically significant differences ($p < 0.05$) between the mean measurements of the two groups. These data are elaborated upon below. The column reflecting the mean values indicates the direction of significance.

1.17.1 *Inter-canine and inter-molar arch widths*

The results in Table 3 demonstrate that for maxillary inter-canine arch width there is a statistically significant difference between the means for the thumb-sucking and non-habit groups ($p = 0.0107$). The mean width is greater for the non-habit group (30.32 mm) than for the thumb-sucking group (28.89 mm). The narrowest maxillary inter-canine arch width measured in the habit group was 23.36 mm.

Variables	Group	N	Mean (mm)	SD	Min (mm)	Max (mm)	t-value	p-value
Inter-canine arch width: maxillary	TS	27	28.89	2.32	23.36	32.79	-2.64	0.0107
	Non-Habit	29	30.32	1.71	26.60	33.60	-2.64	
Inter-molar arch width: maxillary	TS	27	43.72	3.36	35.32	50.63	-2.50	0.0163
	Non-Habit	29	45.61	2.12	42.08	49.07	-2.50	
Inter-canine arch width: mandibular	TS	27	24.41	2.53	20.05	31.80	2.73	0.0086
	Non-Habit	29	22.67	2.25	16.82	27.81	2.73	
Inter-molar arch width: mandibular	TS	27	38.62	3.50	34.66	49.57	0.31	0.7579
	Non-Habit	29	38.38	2.10	34.17	42.15	0.31	

Table 1: Data reflecting inter-canine and inter-molar arch widths in thumb-sucking and non-habit children.

(p - values which are highlighted are statistically significant).

Similarly, there is a significant difference between the thumb-sucking and non-habit groups for the mean maxillary inter-molar arch widths ($p = 0.0163$). The mean width is, again, greater for non-habit group (45.61mm) as compared with thumb-sucking group (43.72mm).

In contrast with the maxillary parameters, it was the thumb-sucking group that recorded the greater mean inter-canine arch width in the mandible of 24.41mm compared with 22.67mm in the non-habit group. There is a statistically significant difference between the means of these measurements ($p = 0.0086$). The widest mandibular inter-canine arch width recorded was 31.80mm in the habit group.

The mandibular inter-molar arch widths between the two groups were almost identical with mean values of 38,62mm and 38,38mm for the thumb-sucking and non-habit group, respectively. The result was therefore not significant ($p=0,7579$).

1.17.2 Arch depth parameters

Data pertaining to arch depth parameter differences between the two groups are found in Table 4, below:

Variables	Group	N	Mean (mm)	SD	Min (mm)	Max (mm)	t-value	p-value
Arch depth: canine maxillary	TS	27	13.40	2.14	9.80	17.83	3.89	0.0003
	Non-Habit	29	11.26	1.98	6.94	14.56	3.89	
Arch depth: molar maxillary	TS	27	29.74	2.99	19.66	33.07	0.94	0.3506
	Non -Habit	29	29.01	2.76	25.26	35.60	0.94	
Arch depth:-canine mandibular	TS	27	9.00	1.53	4.56	12.09	-1.05	0.2967
	Non-Habit	29	9.55	2.32	3.41	13.92	-1.05	
Arch depth: molar	TS	27	26.06	3.67	17.83	35.93	0.16	0.8760
	Non-Habit	29	25.92	2.95	19.26	31.25	0.16	

Table 2: A comparison of arch depth parameters in the thumb-sucking and non-habit groups.

(p - values which are highlighted are statistically significant).

Highly statistically significant differences between the two groups for maxillary canine arch depths were recorded ($p= 0.0003$). The mean was greater for the thumb-sucking group (13.40mm) than for the non-habit group (11.26mm).

The greatest maxillary arch depth recorded was 17.83mm in the thumb-sucking group and the least was 6.94mm in the non-habit group.

Non-significant results ($p=0,3506$) were found for the mean maxillary molar arch depths for the thumb-sucking and non-habit group. There were also similar results for the mean mandibular canine arch depths ($p=0,2967$), indicating that there were not significant differences between the thumb-sucking and non-habit group (9,00 and 9,55, respectively). The mean mandibular molar arch depths varied very slightly between the groups and were also not statistically significant ($p=0,8760$).

1.17.3 *Arch length*

Mandibular anterior arch length in the thumb-sucking group showed a statistically significant difference compared with the non-habit group ($p=0.0282$). The mean mandibular anterior arch length was greater in the thumb-sucking group (31.48 mm) compared with the mean length of 30.02mm for the non-habit group.

Other non-significant findings were the mean maxillary and mandibular arch lengths which provided p-values of 0,7169 and 0,1706, respectively.

Table 5, below, provides data relating to these measurements:

Variables	Group	N	Mean (mm)	SD	Min (mm)	Max (mm)	t-value	p-value
Arch length maxillary	TS	27	76.67	4.03	69.01	85.41	0.36	0.7169
	Non-Habit	29	76.25	4.47	69.96	88.96	0.36	
Arch length maxillary anterior	TS	27	40.64	2.84	34.64	46.38	1.73	0.0898
	Non-Habit	29	39.41	2.51	34.42	44.66	1.73	
Arch length maxillary - posterior	TS	27	35.57	1.90	31.37	39.04	-0.74	0.4613
	Non-Habit	29	36.15	3.74	30.46	50.95	-0.74	
Arch length mandibular	TS	27	68.90	4.06	61.94	79.28	1.39	0.1706
	Non-Habit	29	66.67	7.51	31.75	75.75	1.39	
Arch length mandibular - anterior	TS	27	31.48	2.28	26.17	37.57	2.25	0.0282
	Non-Habit	29	30.02	2.55	25.75	35.63	2.25	
Arch length – mandibular - posterior	TS	27	37.12	2.58	31.88	43.42	0.98	0.3343
	Non –Habit	29	36.03	5.37	10.86	40.66	0.98	

Table 3: Arch length in thumb-sucking and non-habit children.

(p - values which are highlighted are statistically significant).

1.17.4 Overjet, overbite and palatal depth

Table Six, below, demonstrates how children who suck their thumbs differ from those that do not with regard to overjet, overbite and palatal depth.

Variables	Group	N	Mean	SD	Min	Max	t-value	p-value
Overjet	TS	27	4.27	1.69	0.81	7.46	7.22	<.0001
	Non-Habit	29	1.72	0.75	0.10	2.70	7.22	
Overbite	TS	27	-2.58	1.86	-6.77	1.85	-10.54	<.0001
	Non-Habit	29	1.35	0.56	0.00	2.77	-10.54	
Palatal depth	TS	27	14.60	2.02	10.58	20.89	1.78	0.0800
	Non-Habit	29	13.74	1.61	10.74	17.60	1.78	

Table 4: Overjet, overbite and palatal depth in children who suck their thumbs (TS) and those who do not (non-habit).
(p - values which are highlighted are statistically significant).

There was a highly statistically significant difference ($p < 0.0001$) between the thumb sucking and non-habit group with regard to the mean measurements of overjet. The thumb-sucking group recorded significantly greater overjet scores with a mean of 4.27mm compared with the non-habit group which had a mean value of 1.72mm. In the thumb-sucking group the greatest measurement recorded for overjet was 7.46mm. The smallest overjet recorded was 2.7 mm in the non-habit group.

Mean overbite values recorded remarkable statistically significant differences ($p < 0.0001$) with the thumb-sucking group reporting a mean value of -2.58mm and the non-habit group reporting a mean of 1.35mm . The negative value indicates the presence of an anterior open bite. The greatest measurement recorded for anterior open bite was -6.77mm . Ninety two percent of children in the thumb-sucking group displayed this malocclusion.

However, mean palatal depth values varied only slightly between the groups ($p = 0.08$). The mean values for the thumb sucking and the non-habit groups were 14.60mm and 13.74mm , respectively. The highest recorded value was 20.89mm in the thumb-sucking group.

1.17.5 Occlusal relationships

1.17.5.1 Canine and molar relationships

There was a greater incidence of Class II Canine and Molar relationships in the thumb-sucking group as demonstrated by Figure 8 and Figure 9, respectively.

Canine and Molar Class II relationships occurred in 22.2% and 14.81% of the thumb-sucking groups respectively, whereas in the non-habit groups the incidences of Class II canine and molar relationships were 3.45% and 6.9% , respectively. In the thumb-sucking group, Class II canine relationships occur 6.5 times more frequently than in the non-habit group and Class II molar relationships are doubled in the thumb-sucking group compared with the non-habit group. The incidence of Class III molar relationships was almost identical for the thumb sucking and non-habit group at 3.7% and 3.45% , respectively.

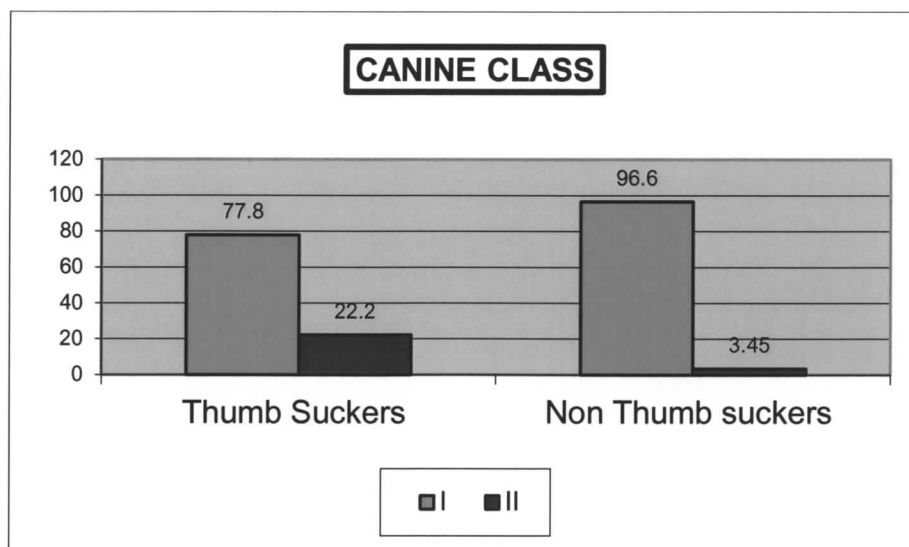


Figure 8: Canine class parameters.

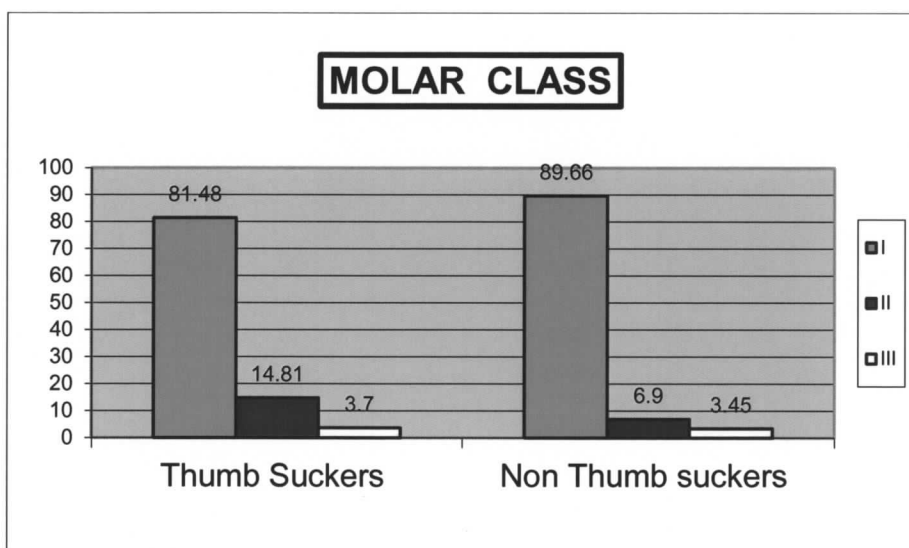


Figure 9: Molar class relationships.

1.17.5.2 Crossbite

The incidence of posterior crossbite was higher in the thumb-sucking group as demonstrated by Figure 10, which recorded that 14.81% of the sample presented with a unilateral posterior crossbite. All incidences of crossbite were unilateral. There was no recorded incidence of posterior crossbite in the non-habit group.

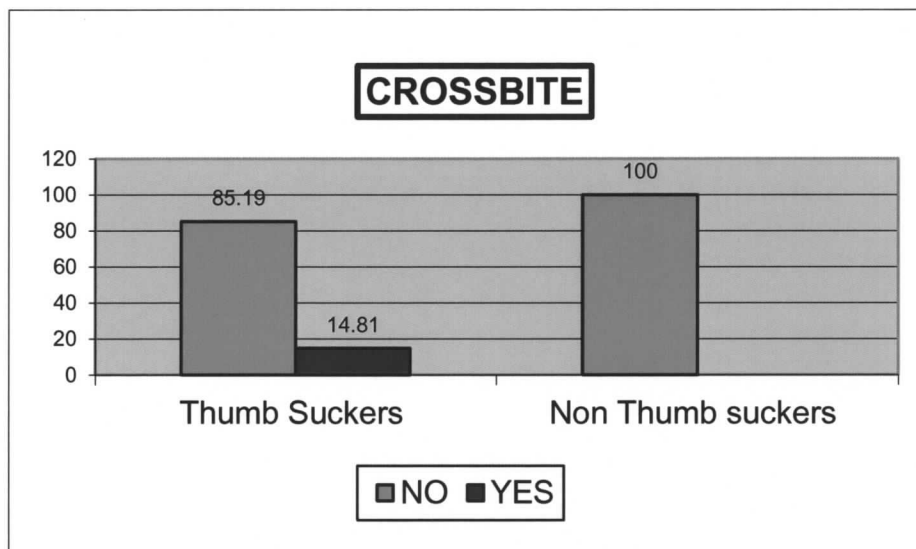


Figure 10: Incidence of posterior crossbite in thumb-sucking and non-habit participants.

1.17.5.3 Open bite

The most striking difference between the groups, as noted in Figure 11, below, was the incidence of anterior open bite which was significantly more prevalent in the thumb-sucking group (92.59 % incidence) as opposed to the non-thumb sucking group where none of the children demonstrated an open bite ($p < 0.0001$).

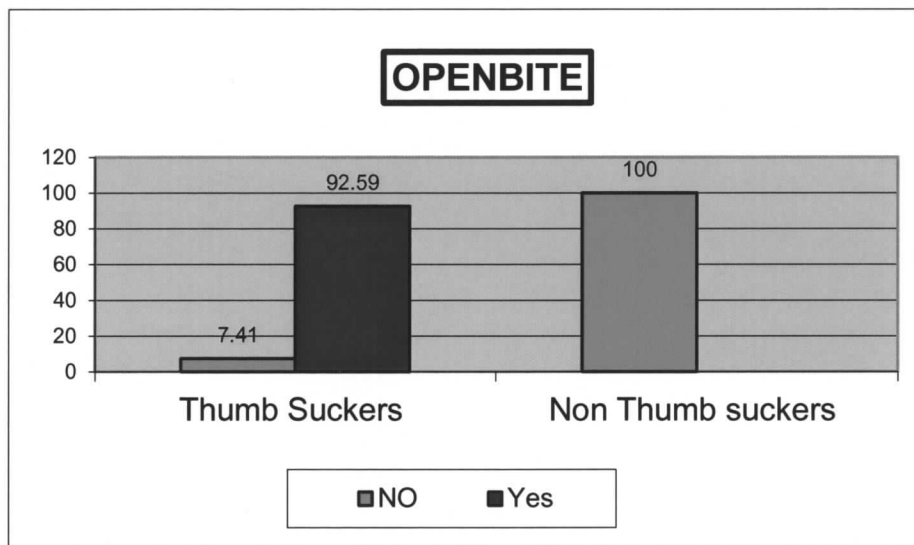


Figure 11: Incidence of anterior open bite in thumb-sucking and non-habit participants.

DISCUSSION

1.18 INTRODUCTION

This study has demonstrated that statistically significant differences exist between the oral and dental development of a group of thumb suckers compared with a non-habit group. The groups were age-matched and were drawn from the same racial and socio-economic population. The groups were not gender matched due to the difficulty encountered in finding a large enough sample of participants that thumb suck.

The method of evaluating the cast models, with the exception of the measurement of the palatal depth, was based on a design described by Warren and Bishara (2002). This method was demonstrated by these researchers to be extremely accurate and, furthermore, is able to take into account many dental arch parameters.

The data obtained from the study by Warren and Bishara (2002) probably provides the most relevant basis for comparative analysis with the data of the present study. Their sample was comprehensive, including 372 participants, thereby strengthening the statistical conclusions. The subjects in their study were from varied socio-economic strata, but limited to a small geographic area. Warren and Bishara (2002) noted that one of the limitations of their study was the disparate racial distribution, with the majority of the participants being white. However, that difference in sampling enabled a comparison to be made with this study, which comprised a sample of low-income, black South African children of the same ages.

1.19 GENERAL CHARACTERISTICS OF THE RESULTANT MALOCCLUSION

The study demonstrated that thumb sucking is associated with smaller maxillary inter-canine and inter-molar arch widths, greater anterior arch depth, wider mandibular inter-canine arch dimensions and longer mandibular anterior arch lengths. The most striking difference between the groups was the incidence of anterior open bite ($p < 0.0001$) and the relative increase in overjet ($p < 0.0001$), which were significantly more prevalent in the thumb-sucking group. Indeed, none of the children in the non-habit group demonstrated an open bite. The thumb sucking group also displayed an increased incidence of Class II canine and molar relationships which were respectively six and two times greater than seen in their non-habit counterparts.

The results indicate that:

- A higher incidence of anterior open bite exists in the habit group (92.59 %) due to exaggerated proclination of the maxillary incisors and anterior displacement of the maxillary base resulting from the horizontal vector produced by the thumb; this is also responsible for the concomitant significant increase in overjet. The anterior open bite is due to the vertical vector produced by the thumb, which retards growth of the maxillary anterior base. It also delays the eruption of the maxillary incisors while allowing over-eruption of the posterior dentition (Bishara & Larsson, 2007b; Proffit, 2007; Kato *et al.*, 2009). Overjet and anterior open bite may also be associated with tongue thrusting, seen in the majority of thumb suckers

during deglutition (Littlefield, 1952; Graber, 1959, 1962; Subtelny & Subtelny, 1973). A lip-sucking habit may also exacerbate these malocclusions (Graber 1959, 1962; Bishara & Larsson, 2007a).

- The increase in Class II canine relationships is due to the anterior displacement of the anterior maxillary base, indicated by an increase in canine arch depth (Warren & Bishara, 2002; Bowden 1966b). The increase in molar Class II relationships is possibly due to the downward and posterior displacement of the mandible, resulting in an opening rotation caused by the lever action of the thumb and arm. The effect also increases lower facial height and allows further eruption of the posterior segments (Graber, 1959; Ruttle *et al.*, 1953; Proffit 2007).
- The significantly smaller maxillary inter-canine and inter-molar arch widths are possibly due to the intense sucking in of the cheeks, which constricts the arch. The pressure on the buccal surfaces of the teeth forces them lingually. The tongue occupies a lower position within the mandibular arch and cannot support the palate; this therefore enables the narrowing of the maxillary arch and subsequent linguoversion of the maxillary dentition (Christensen *et al.*, 1994). The pressure from the tongue laterally on the mandibular canines and incisors and their alveolar processes causes the mandibular inter-canine arch width to increase (Christensen *et al.*, 1999; Littlefield, 1952; Subtelny & Subtelny, 1973).

- The narrowed maxillary arch, wider mandibular arch and anterior protrusion of maxillary incisors and base is indicative of children who place their thumbs in the mouth, palmar surface upwards, past the first joint or knuckle. This position of the thumb falls into categories one and three according to Subtelny and Subtelny's (1973) classification (*vide infra* p18).

1.20 CONSIDERATION OF SPECIFIC PARAMETERS

1.20.1 *Maxillary arch width*

The results of this study indicate that thumb sucking significantly contributes overall to a narrower maxillary arch. The constriction of the maxillary arch is due to the buccal force produced from contraction of the buccinator muscles during thumb sucking and the creation of negative intra-oral pressure (Littlefield, 1952; Bowden, 1966a). The lack of support from the tongue, which is displaced into the anterior mandibular arch, presents no hindrance to the contraction of the upper arch (Christensen *et al.*, 1999; Bowden, 1966a ; Proffit, 2007).

In the thumb-sucking group, the maxillary arch widths were significantly narrower than those of their non-habit counterparts. The mean differences between the groups were 1.43mm and 1.89mm for maxillary inter-canine and inter-molar arch widths, respectively. These results concur with the reports by Warren and Bishara (2002), Kato *et al.* (2009) as well as with Yemitan *et al.* (2010). Results of some relevant studies are depicted in Table 7.

Author	Relative decrease in inter-canine width (mm)	Relative decrease in inter-molar width (mm)	Significance $p < 0.05$
Warren <i>et al.</i> (2002)	1.00	1.00	$p = 0.009$ $p = 0.037$
Ruttle <i>et al.</i> (1952)	1.14	not significant	$p = 0.01$
Yemitan <i>et al.</i> (2010)	1.32	not significant	$p = 0.004$
Present Study (2011)	1.43	1.89	$p = 0.0107$ $p = 0.0163$

Table 5: Decrease in maxillary arch widths in thumb-suckers, compared with non-habit groups.

However, Bowden (1966a) and more recently Aznar *et al.* (2006) reported no significant differences in either maxillary or mandibular arch widths in their thumb sucking and non-habit groups. Bowden's (1966a) study was of a longitudinal nature, while the report by Aznar *et al.* (2006) was cross-sectional and recorded measurements of arch widths only. Another discrepancy was found in work performed by Subtelny and Subtelny (1973), who reported that maxillary inter-cuspid width was greater in the thumb -sucking group compared with normative data.

These contrasting results may possibly be explained by invoking Bowden's (1966a) theory on different sucking mechanisms in children related to negative intra-oral pressures. Further discrepancies are possibly due to the intensity with which the child sucks the cheeks in (Littlefield, 1952; Luffingham, 1969), the duration and frequency of sucking and genetic tendency (Graber, 1959, 1962). Another reason according to Littlefield (1952), for such inconsistencies between

different studies are osteoclastic and osteoblastic activity, which varies between individuals and may be genetically controlled. Greater activity results in a greater degree of bone remodelling which allows a skeletal response to the habit to develop at a quicker rate than in an individual with less active cells

Finally, the findings might express those of a "loaded" sample, i.e. the sample may just by chance have included more cases of children who either did or did not demonstrate a particular malocclusion.

1.20.2 *Mandibular arch widths*

The study confirms that prolonged digit-sucking habits are associated with an increase in mandibular inter-canine arch width (mean increase 1.74mm; $p = 0.0086$), but not significant differences between mean inter-molar widths. It is acknowledged that the measurements at the tip of the cuspids may have been influenced by the typical wear seen in deciduous canines. It is unlikely that this would have had any pronounced effect.

The increase in mandibular inter-canine arch width may be due to the pressure placed on the canines and their alveolar processes by the tongue, which in the majority of cases, is in close approximation to the thumb and is displaced into the anterior section of mandibular arch. No change is seen in the inter-molar arch widths where the influence of the tongue is reduced (Subtelny & Subtelny, 1973).

The significance of the results is consistent with other research that reports similar increases in the mandibular inter-canine arch widths (Ruttle *et al.*, 1953; Subtelny

& Subtelny, 1973). Warren and Bishara (2002) demonstrated a slight increase in the mean mandibular inter-canine arch width of 0.7mm, which approached but did not reach statistical significance. Ruttle *et al.* (1953) noted that the increases were due to a significant labial inclination of the mandibular canines.

Bowden (1966a) and Aznar *et al.* (2006) reported no significant changes in mandibular arch widths between children with or without digit-sucking habits, while Yemitan *et al.* (2010) noted an actual decrease in both inter-canine and inter-molar arch widths which were significant. This significant decrease may be attributed to the powerful contraction of the buccinators affecting both the maxillary and the mandible arch.

1.20.3 Arch depth

The statistically significant greater maxillary anterior arch depth amongst thumb suckers ($p = 0.0003$) indicates that the maxillary base has been anteriorly displaced by the habit. This is probably due to the lever action of the digit being placed up against the palate, which produces both a horizontal and a vertical force on the anterior maxillary base. The horizontal force produces an elongation and anterior displacement of the anterior maxillary base (Bishara & Larsson, 2007b).

Kato *et al.* (2009) reported that anterior arch depth area was 2 mm^2 greater in thumb-sucking subjects than in those without a habit whilst the volume was increased by 92 mm^3 . This report is in agreement with studies on habitual thumb suckers by Warren and Bishara (2002) and Yemitan *et al.* (2010) who reported a

statistically significant increase in maxillary canine and molar arch depth, the latter not as statistically significant as that of the canine arch depth.

The current investigation reported canine and maxillary molar arch depths which were 2.2mm and 2.7mm greater than those recorded by Warren and Bishara (2002). It suggests that the thumb suckers in the present study were persistent. However, the participants in the study by Warren and Bishara (2002) had ceased the habit and some self-correction may have occurred.

The mean mandibular canine and molar arch depths were not significantly different between the groups in the current study. This finding is supported by studies which indicate that the mandibular arch depth is not affected by thumb-sucking (Ruttle *et al.*, 1952; Larsson, 1972; Warren & Bishara, 2002). Ruttle *et al.* (1952) is of the opinion that the habit retrudes the entire mandible without changing its form, which probably contributes to the increased incidence of Class II relationships.

Yemitan *et al.* (2010), in contrast, reported a significant *decrease* in mandibular canine arch depth in the thumb-sucking group ($p=0.004$). No significant difference was reported for mandibular molar arch depths nor was any explanatory theory postulated. There may possibly have been more cases with retroclined mandibular incisors which may have decreased the anterior arch depth in the thumb sucking group.

1.20.4 *Arch length*

In this study only the anterior mandibular arch length was significantly increased. This is possibly due to increased angulation of the canines and proclination of the lower incisors from tongue pressure, as it is forced into the mandibular anterior arch by the thumb during sucking (Subtelny & Subtelny, 1973).

Ruttle *et al.* (1953) noted that the maxillary arch form transformed into a more elongated tapering arch and that the anterior mandibular arch transformed into a trapezoidal shape, indicating that arch form, but not the arch length was altered. A contrasting finding by Subtelny and Subtelny (1973) found that both maxillary and mandibular arch lengths were significantly longer in the thumb-sucking groups. However, the study by Warren and Bishara (2002) corroborated the results by Ruttle *et al.* (1953) in which arch lengths were not increased. The samples were, however, not well matched.

1.20.5 *Posterior crossbite*

In the present study, unilateral posterior crossbites were recorded in the thumb-sucking group, but none were seen in the control group. It appears therefore that some association between thumb sucking and posterior crossbites exists. It seems that the narrowed maxillary arch and wider mandibular arch both contribute to the development of the posterior crossbite seen in this relatively low percentage of thumb-sucking children. The narrowed maxillary arch imposes a functional mandibular shift to enable the teeth to occlude, a further contribution to posterior crossbite (Proffit, 2007).

Similar frequencies of posterior crossbites in thumb-sucking children have been reported by Warren and Bishara (2002), Duncan *et al.* (2008) and Modeer *et al.* (1982), all of which were statistically significant (Table 8).

Author	Percentage (%)	Age
Warren <i>et al.</i> (2002)	15.20	>48 months
Duncan <i>et al.</i> (2008)	19.00	61 months
Modeer <i>et al.</i> (1982).	11.00	48 months
Present study (2011)	14.81	48-60 months

Table 6: Research pertaining to the prevalence of posterior crossbite in persistent thumb suckers.

Despite these observations, Singh, Utreja and Chawla (2008)⁷¹ and Farsi and Salama (1997) found no statistical correlation between thumb sucking and posterior crossbite. Their studies disregarded for possible recovery after early cessation of the habit. Studies which demonstrated no statistically significant differences between maxillary and mandibular mean arch widths recorded poor correlation of posterior crossbites in thumb suckers (Bowden, 1966a; Aznar *et al.*, 2006).

Posterior crossbite is more frequently observed amongst pacifier users than thumb suckers (Warren & Bishara, 2002; Bowden, 1966a; Larsson, 1994; Duncan *et al.*, 2008, Aznar *et al.*, 2006). Warren and Bishara (2002) and Duncan *et al.* (2008) reported frequencies as high as 41.7% and 23% amongst pacifier users in the age group of four to five year olds, respectively. These authors propose that the

pacifier habits produce much greater increases in mandibular inter-canine arch widths than do thumb-sucking habits of the same duration, which corresponds with studies of thumb suckers which did not find increases in mandibular arch widths.

1.20.6 *Anterior open bite*

The most dramatic evidence of the influence of the habit was the overwhelming incidence of anterior open bite (92.59%; $p < 0.0001$) amongst the thumb-sucking group. None of the respondents in the non-habit group exhibited this discrepancy. This significant finding concurs with several reports in the literature, emphasising that it is one of the most frequently observed and documented occlusal characteristics of thumb-sucking habits, even though none of the papers reviewed recorded incidences above 40% (Table 9) (Ozawa *et al.*, 2005; Warren & Bishara, 2002; Fukata *et al.*, 1966; Duncan *et al.*, 2008; Singh *et al.*, 2008). This may possibly be explained by ethnicity. Black population groups have a five times greater incidence of anterior open bites that are greater than 2mm than whites (Proffit, 2007).

Authors such as Traisman and Traisman (1958), Duncan *et al.* (2008) and Fukata *et al.* (2008), have reported anterior open bite cases amongst the non-habit group, but with a much lower incidence than that of the habit group. Fukata *et al.* (2008) recorded an incidence of anterior open bite of 2.0% to 3.0% in the non-habit group with a large sample size of 1206 non-habit subjects. Duncan *et al.* (2008) reported that 7.6% of non-habit participants displayed an anterior open bite. The present report together with these previous studies confirms that this malocclusion is uncommon in children with no oral habits.

Author	Incidence (%)	Age of cessation	Significance p<0.05
Warren <i>et al.</i> (2002)	37.00	48 + months	p<0.001
Ozawa <i>et al.</i> (2005)	30.90	42 months	p<0.001
Duncan <i>et al.</i> (2008)	23.00	61months	p<0.001
Singh <i>et al.</i> (2008)	21.00	>18 MONTHS	p<0.01
Fukata <i>et al</i> (2008)	15.10	48 months	p<0.01
Botha (2011)	92.00	48 – 60 months	p <0.0001

Table 7: Incidence of anterior open bite.

The inconsistencies reported of the incidence of anterior open bite by the various studies may be explained by considering that in several cases the children had ceased digit-sucking at the time of the investigation. The open bite could thus possibly have begun to close, a resolution in accord with current opinion that this malocclusion tends to self-correct if the habit has ceased before five years of age (Bowden, 1966a; Littlefield, 1952; Duncan *et al.*, 2008; Heimer *et al.*, 2008).

1.20.7 Overjet

The present study recorded a mean overjet amongst the thumb-sucking group of 4.27mm, which is statistically significantly greater than in the non thumb-sucking group where a mean value of 1.72mm was recorded (p <0.0001). The statistically significant difference between the two groups is highly suggestive that thumb sucking plays a crucial role in increasing overjet. The incidence of overjet greater

than three and four millimetres recorded in the persistent thumb-sucking group was 76% and 44%, respectively. These results concur with literature that widely reports a higher incidence of overjet in association with a thumb-sucking habit (Table 10) (Fukata *et al.*, 1996; Warren & Bishara, 2002; Singh *et al.*, 2008; Bowden, 1966a; Larsson, 1994; Ruttle *et al.*, 1953).

Author	Benchmark	Percentage	Significance P<0.05
Warren and Bishara (2002)	≥4mm	39.1	p < 0.001
Fukata <i>et al.</i> (2008)	>5mm	24.2	p < 0.01
Singh <i>et al.</i> (2008)	Between 3-5mm	19.0	p< 0.05
Singh <i>et al.</i> (2008)	>6mm	45.0	p < 0.05
Ozawa <i>et al.</i> (2005)	Not specified	38.2	p<0.001
Present study (2011)	≥4mm	44.0	p < 0.0001

Table 8: Incidence of overjet.

Warren and Bishara (2002) recorded a significantly increased mean overjet of 3.7mm in a digit-sucking group of the same age as the present study, although both Warren and Bishara (2002) and Singh *et al.* (2008) observed children in whom the habit had ceased and spontaneous correction could have occurred explaining the relatively higher incidence and greater mean in the present study.

The initial position of the incisors with regard to overjet must also be taken into consideration. If the incisors are already protruding the thumb will exaggerate this malocclusion. If the incisors are linguallly tipped, the force exerted on the incisors

will improve their angulation and will not tend to cause an increase in overjet. It may therefore be relevant to note that other factors such as a skeletal Class II may contribute to an exacerbated overjet (Graber 1962).

As in cases of an open bite, increased overjet may also be exacerbated by a concomitant tongue thrust and lip biting habit which either developed in response to the anterior open bite or pre-existed (Graber, 1959; Subtelny & Subtelny, 1973). These associated habits were not evaluated in the present study.

1.20.8 *Class II canine and molar relationships*

It is possible that thumb sucking affects dental arch relationships due to the elongation of the maxillary anterior base, as 22.2% of participants in this study presented with a maxillary cuspid more anteriorly placed on one or both sides. As the alveolar process and maxillary incisors move forward, the maxillary anterior base elongates and a greater discrepancy is produced between the anterior maxillary and mandibular arches which produce a Class II canine relationship. This appears to be significant when compared with the non-habit group in which only 3.45% of the participants exhibited a Class II canine relationship. Consistent with the present research Subtelny and Subtelny (1973) also noted a higher incidence of Class II canine relationships (62%) than Class II molar relationships (54 %) in the thumb-sucking group compared with the non-habit group. They noted that this could be due to a "loaded" sample, as all the participants in the thumb-sucking group presented in any event with a malocclusion.

A higher incidence of Class II canine relationships existed than Class II molar relationships in the thumb-sucking group. The percentage of children in the thumb-sucking group who presented with a Class II molar relationship was 14.81%, which was slightly greater than the non-habit group (6.9%). Thumb sucking may not alter the posterior occlusion as extensively as it does the anterior occlusion. But as observed previously, the habit may result in a relative opening rotation of the mandible bringing it into a Class II relationship (Swinehart, 1938; Ruttle *et al.*, 1953; Singh *et al.*, 2008) Pre-existing Class II canine and molar relationship cannot, of course, be discounted. The thumb-sucking habit would then exacerbate this existing malocclusion.

Several studies have demonstrated similar results with a significantly higher incidence of Class II molar relationships in children with a thumb sucking habit compared with those without as depicted in Table 11 (Fukata *et al.*, 1996; Singh *et al.*, 2008; Popovich & Thompson, 1973; Bowden, 1966b). The differences may also be ascribed to ethnicity. Class II malocclusions are not as common in African and Asian population groups as they are in whites (Proffit, 2007). This is reflected in the studies of Bowden (1966b) and Popovich & Thompson (1973) whose samples were mainly white, Fukata *et al.* (1996) whose study sample was Asian, and this study which had a sample consisting only of black South African subjects.

Author	Thumb-Sucking	Non-Habit Group
Bowden (1966b)	40.00	29.00
Popovich & Thompson (1973)	31.80	17.85
Fukata <i>et al.</i> (1996)	12.10	1.40
Present study (2011)	14.81	6.90

Table 9: Previous research examining the incidence of Class II molar relationships between thumb-sucking and non-habit groups.

Ruttle *et al.* (1952) in contrast, found no association between thumb sucking and a Class II molar occlusion. Warren and Bishara (2002) reported that 47.8% of the thumb-sucking group recorded a Class II canine relationship, but the finding was not statistically significant.

1.20.9 Palatal depth

There was no significant difference recorded for palatal depth between the thumb-sucking and non thumb-sucking group. The mean measurement for palatal depth was 14.60mm and 13.74mm for the thumb-sucking and non-habit groups, respectively. The greatest depth recorded in the thumb-sucking group was 20.89mm.

Few studies have measured palatal depth. Most authors simply make observations that the palate appears to be deep and vaulted, claiming that intensive inward pressure from the buccinator causes a constriction of the

maxillary arch and lingual tipping of the maxillary molars resulting in a high arched palate (Cerny, 1981).

Warren and Bishara (2002) in contrast, found a significant decrease in the palatal depth in children with habits of a longer duration compared to those children who had only been sucking for a short period of time. These authors measured the palatal depth from the deepest point in the palate to the line connecting the buccal cusp tips of the primary second molar. The present study measured a line from the deepest point in the palate perpendicular to the occlusal plane, which allows a more relevant depth measurement. As significant narrowing of the maxillary arch was recorded, the presumption could be made that the palatal vault should have deepened. This was indeed the case in some individuals but not demonstrated by the sample as a whole.

1.21 DISCREPANCY IN ARCH SIZE

This study reported greater mean measurements for maxillary and mandibular arch lengths, arch widths and arch depths than those in the study by Warren and Bishara (2002) (Table 12).

The participants for this study were black South African children, while those investigated by Warren and Bishara (2002) were mainly white. As the measurement parameters were identical an assumption might be made that black South African children have larger jaws and teeth than their white counterparts. Burris and Harris (2000) reported an 8% increase in arch form and size in black Americans compared with white Americans.

Parameter mean	Warren & Bishara (2002) mm	Present study (2011) mm	Differences mm
Inter-canine maxillary arch width	27.8	28.80	1.09
Inter-molar maxillary arch width	40.5	43.72	3.22
Inter-canine mandibular arch widths	23.3	24.41	1.11
Inter-molar mandibular arch widths	35.6	38.62	3.02
Maxillary canine arch depth	11.2	13.40	2.20
Maxillary molar arch depth	27.0	29.74	2.74
Mandibular molar arch depth	23.2	25.94	2.74
Maxillary arch length	71.0	76.67	5.67
Mandibular arch length	64.0	68.90	4.90

Table 10: Arch discrepancies.

1.22 LIMITATIONS OF THE STUDY

The present study was affected by the following limitations:

(a) Selection bias: The relatively small sample could render the statistics weak.

The sample was well defined and therefore reasonably standard although the stringent selection factors rendered a restriction in the final sample.

(b) Information availability: Information such as duration, intensity and pacifier use could not be ascertained and could affect the results.

(c) The study was cross-sectional in nature. A longitudinal study following the children over a period of years is required to determine whether the existing malocclusions persist into the permanent dentition.

Intensity of the habit was not established as the author was unable to observe the children over long time periods, for practical reasons. Duration of the habit amongst all the participants could also not be established due to the poor return rate of the questionnaire. Several researchers have established that the majority of children in whom a thumb-sucking habit was present at four years of age had established the habit within three months post-partum (Modeer *et al.*, 1982; Laws, 1950; Traisman & Traisman, 1958; Patel *et al.*, 2008; Bishara *et al.*, 2006). Klackenberg (1949) reported that only 10% of thumb suckers initiated the habit after nine months of life. The use of pacifiers was not established. However there

is general agreement that the majority of thumb suckers (up to 89%) have never used a pacifier.

CONCLUSIONS

6.1.1 The results of the study indicate that amongst this group of black South African children, thumb sucking is associated significantly with the following alterations to the deciduous dental occlusion, arch form and arch relationships, compared with the dentition of a non-habit group:

- Narrower maxillary inter-canine and inter-molar arch widths
- Wider mandibular inter-canine arch widths
- Greater maxillary canine arch depths
- Greater mandibular anterior arch length
- Increased prevalence of anterior open bite
- Greater overjet
- Increased prevalence of Class II canine and molar relationships
- Increased prevalence of posterior crossbite

6.1.2 Comparison of these data with other studies of the effects of the habit suggest that there may be a wide variation amongst this black South African sample in the incidence and expression of changes in the deciduous dentition.

6.1.3 Further studies should include assessments of the character of the habit such as intensity, frequency and duration.

1.23 RECOMMENDATIONS

Oral health care programmes need to be developed to alert parents to the harmful effects of this habit on the developing dentition and how to prevent, manage and to seek treatment at the appropriate time. Considerable advantage would accrue were this proposal to be adopted in South Africa, as this will ease the already overburdened health system.

The current study did not investigate prevalence of thumb sucking in the general population, but socio-economic factors may be a pre-disposing factor in this increase in the black South African population. Therefore further exploration into the incidence of thumb and pacifiers sucking in this population group are required. This study focused on the dental characteristics of thumb sucking in black South African children. Further investigation is required to determine the prevalence of malocclusion traits related to thumb and pacifier sucking in this population group as reports are sparse. Furthermore thumb and pacifier sucking produce malocclusion traits of different significance which will need to be determined. As few studies have clarified whether these malocclusions are transferred to the permanent dentition, it would be advisable to compose a longitudinal study where participants with and without sucking habits are followed from the early primary dentition through to the permanent dentition.

These data may be relevant to any initiative on the part of governmental agencies seeking to reduce the impact of malocclusions.

APPENDIX A: ETHICS APPROVAL

UNIVERSITY OF THE WITWATERSRAND, JOHANNESBURG

Division of the Deputy Registrar (Research)

HUMAN RESEARCH ETHICS COMMITTEE (MEDICAL)

R14/49 Botha

CLEARANCE CERTIFICATE

PROTOCOL NUMBER M080722

PROJECT

The Effects of Thumb Sucking on
Dental Arch Characteristics in the
Primary Dentition

INVESTIGATORS

Dr A Botha

DEPARTMENT

Paedodontics Restorative Dent.

DATE CONSIDERED

08.07.25

DECISION OF THE COMMITTEE*

Approved unconditionally

Unless otherwise specified this ethical clearance is valid for 5 years and may be renewed upon application.

DATE 08.09.17

CHAIRPERSON



(Professor P E Cleaton Jones)

*Guidelines for written 'informed consent' attached where applicable

cc: Supervisor : Prof S Setzer

DECLARATION OF INVESTIGATOR(S)

To be completed in duplicate and ONE COPY returned to the Secretary at Room 10004, 10th Floor, Senate House, University.

I/We fully understand the conditions under which I am/we are authorized to carry out the abovementioned research and I/we guarantee to ensure compliance with these conditions. Should any departure to be contemplated from the research procedure as approved I/we undertake to resubmit the protocol to the Committee. I agree to a completion of a yearly progress report.

PLEASE QUOTE THE PROTOCOL NUMBER IN ALL ENQUIRIES

APPENDIX B: INFORMED CONSENT FORM

1.24 INFORMED CONSENT FOR PARENTS/LEGAL GUARDIANS:

(On behalf of minors under 18years old)

- Dr A Botha has provided me with a copy of the Participant Information Leaflet and Consent regarding clinical study (Protocol no 1): The effects of thumb sucking on dental arch characteristics in the primary dentition, and has fully explained to me the nature, risks, benefits and purpose of the study
- The study doctor has given me the opportunity to ask any questions concerning the study
- It has been explained to me that I will be free to withdraw my child from the study at any time, without any disadvantage to future care
- I have understood everything that has been explained to me and I consent for my child to participate in this clinical study.
- I am aware that the results of the study, including personal details regarding my child's sex, age, date of birth, initials and diagnosis will be anonymously processed into a study report.
- In view of the requirements of research, I agree that Dr A Botha can process the data collected during this study in a computerised system.
- I have had sufficient opportunity to ask questions and (of my own free will) declare that I consent for my child to participate in the study.

PARENT/LEGAL GUARDIAN:

_____ Printed Name	_____ Signature/Mark or Thumbprint	_____ Date and Time
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STUDY DOCTOR:

_____ Printed Name	_____ Signature/Mark or Thumbprint	_____ Date and Time
-----------------------	---------------------------------------	------------------------

TRANSLATOR/OTHER PERSON EXPLAINING INFORMED CONSENT:

_____ (DESIGNATION):

_____ Printed Name	_____ Signature/Mark or Thumbprint	_____ Date and Time
-----------------------	---------------------------------------	------------------------

WITNESS (If applicable):

_____ Printed Name	_____ Signature/Mark or Thumbprint	_____ Date and Time
-----------------------	---------------------------------------	------------------------

APPENDIX C: QUESTIONNAIRE

1. Participant no:
2. Age:
3. Sex:
4. Date of birth:
5. Did the child use a dummy?
6. For how long?
7. Did the child suck his or her finger?
8. Which finger?
9. For how long?
10. How many hours a day does the child suck his finger/thumb?
11. Did the child suck his/her lip?
12. For how long?
13. Any other observations?

APPENDIX D:

INTER-OPERATOR RELIABILITY

Variables	P - values
Inter-canine arch width: maxillary	0.290873
Inter-molar arch width: mandibular	0.613033
Inter-canine arch width: mandibular	0.387856
Inter-molar arch width - mandibular	0.086307
Arch depth canine – maxillary	0.788997
Arch depth molar – Maxillary	0.376141
Arch depth canine – mandibular	0.788997
Arch depth molar - mandibular	0.130405
Arch length –maxillary	0.453525
Arch length mandibular anterior	0.376141
Overjet	0.313498
Overbite	0.368081
Palatal depth	0.934576

Table 13: Inter-operator reliability p – values. Level of significance $p=0.05$.

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