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# A Clinical Study to Evaluate Changes in Maximum Intercuspation Position Following Placement of a Stainless Steel Crown in Children

A Thesis submitted in partial fulfilment of D.Ch.Dent

2010

Paediatric Dentistry

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**Summary**

An increase in occlusal vertical dimension (OVD) following restorative treatment in adults may result in discomfort. In contrast, an increase in OVD in children following placement of a stainless steel crown (SSC) or an orthodontic appliance has not lead to such reports in the literature.

**Study Aims**

In part I of this study we sought to prospectively determine

- The reproducibility of the T-Scan® III in a laboratory and clinical setting

In part II we sought to prospectively determine

- Whether local anaesthesia (LA) alters the child's ability to produce maximum intercuspation position (MIP)
- Whether placement of a SSC changes MIP
- Whether occlusion returns to normal following any change in MIP

**Material and Methods**

**Part I - T-Scan® III reproducibility**

Reproducibility of the T-Scan® III was initially assessed by analysing 3 repeated readings from a consecutive sample of children who were not receiving dental restorations. A laboratory study assessed repeatability of the T-Scan® III within a sensor and between sensors.

**Part II – clinical study**

Following ethical approval, informed consent was obtained from a consecutive sample of children, aged 6 to 12 years old, scheduled for placement of a SSC in the Dublin Dental School and Hospital. The SSCs were placed by 3 experienced operators in a standardized manner.

Examination of occlusion using the T-Scan® III was carried out by a single operator. Readings were obtained preoperatively, post administration of LA and at 3 time points following SSC placement, immediately postoperatively, and at 2 and

4 weeks postoperatively. No further treatment was provided during the study period. The outcome measured by the T-Scan® III was the percentage of total force on the selected tooth. Statistics was performed using the Wilcoxon test for paired non parametric data and significance was chosen to be $p<0.05$.

**Results**

**Part I - T-Scan® III reproducibility**

- Clinical and laboratory study show that repeatability of T-Scan® III was most reliable when the same sensor was used for each patient and the sensor placed in a standard fashion.

**Part II – clinical study**

Sixteen children were recruited who received 20 SSCs with the following results.

- There was no significant difference in MIP preoperatively and post administration of LA ($p=0.435$) for the entire population.
- MIP was disturbed by the placement of a SSC in 7 out of 20 SSC placed in this study.
- A significant difference was evident between the preoperative reading and post crown placement values on the day of treatment ($p=0.0013$) for the entire population. In the patients where MIP was altered, no symptoms were recorded and the MIP had returned to baseline levels at 4 weeks in all but 3 out of 20 crowns
- There was no statistically significant difference in MIP preoperatively and 2 weeks ($p=0.19$) and at 4 weeks postoperatively ($p=0.38$).

**Conclusions**

This study verifies that administration of LA did not affect the ability of a child to attain MIP. When MIP was disturbed by restorative treatment in a child, it returned to preoperative status within 4 weeks of crown placement.

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# 1 INTRODUCTION

"Proper dental care" should restore functional contact relationships following restorative treatments resulting in maximum function, minimum trauma and even load distribution throughout the dentition (Rosenstiel 1995). The requirement for a functional occlusion in paediatric patients is seldom discussed in the paediatric restorative literature.

Stainless steel crowns (SSC) were first introduced in 1950 by Engel. Throughout the latter part of the 20th century, there was extensive literature published comparing them to other restorative materials (Dawson 1981, Einwag 1996, Papanathanasiou 1994, Roberts and Sherriff 1990, Roberts *et al* 2005, Sharaf and Farsai 2004) several guidelines (Kindelan 2008, AAPD 2004) and several reviews including 2 Cochrane reviews (Seale 2002, Randall 2000, 2002, Attari and Roberts 2006, Innes and Ricketts 2005, Yengopal *et al* 2009) have been published with little or no mention of occlusal disturbances. SSC are considered the standard of care for extensive decay in primary molars. The current British Society of Paediatric Dentistry (BSPD) guidelines on SSC suggest avoidance of interferences greater that 1.5mm and report that an occlusal interference of up to 1.0 mm is well tolerated in children, with adaption to interferences occurring within a few weeks. This statement appears to be expert opinion since no reference or evidence is provided (Kindelan 2008).

Recently, the use of the Hall Technique has been reported in the literature (Evans 2000, Innes 2006, Innes 2007, Innes 2009, Innes 2010). This technique involves placing SSC on primary molars without local anesthesia (LA), caries removal or tooth preparation (Innes 2007). A prospective study reporting outcomes for 129 crowns at 23 months stated that the inevitable increase in OVD and premature contact was resolved fully at 1 year with operators postulating that equilibration occurs within 2 weeks (Innes 2007). Despite the introduction of premature contacts and creating an increase in the occlusal vertical dimension (OVD) there

were no reports of signs or symptoms of occlusal disorders or temporomandibular disorders (TMD) (Innes 2007). The authors quote orthodontic research where the increase in OVD resulting from the use of bite planes did not increase the risk of TMD (McDowell 1991) This lack of symptoms is attributed to children's considerable capacity for dento-alveolar compensation (Kindelan 2008)

Little research exists outside the area of orthodontics regarding occlusion. Furthermore, there is no research reporting on occlusal interferences (OI) resulting from restorative treatment in children. Since no data exist on the prevalence of OIs following placement of SSC, there is little evidence for the presence or resolution of signs and symptoms of increasing OVD in children. There is also no established method to monitor occlusal changes in children.

TMD in children and adults is multifactorial (Thilander 2002). The role of morphological and functional occlusion as contributing factors in the development of TMD has been discussed during the last decades yet there are still different opinions about the relative importance of occlusion and other factors (Thilander 2002). Much controversy has been reported regarding the role of occlusion in TMD, there is however no doubt that occlusal variables influence natural masticatory muscle function (Bakke and Møller 1980). Placement of the intercuspal position relative to the musculoskeletal system is determined by the formative craniofacial development. During puberty, with intensive skeletal development and increasing muscle strength, discrepancies in the mutual timing of these two elements as well as tooth eruption may influence the intermaxillary relationship, which may have an effect on occlusal stability (Thialander 2002). Consequently we postulate that any changes in MIP or the introduction of a premature contact in children receiving SSC will resolve quickly without increasing risk of TMD.

Our research was designed to address these gaps in the current literature. The T-Scan® III was chosen to assess the occlusion. Our aim was to assess its

repeatability in both a laboratory and clinical setting in children. Assessment of a child's ability to reproduce MIP after administration of LA as well as assessment of the occlusion pre and post placement of a SSC was investigated. Reassessment of occlusion 2 and 4 weeks after SSC placement was used to provide a measure of the predicted time course for normalisation of occlusion.

# 2 LITERATURE REVIEW

There are a large number of terms in occlusion which have multiple definitions and interpretations (Clarke and Evans 2001). Occlusion or malocclusion is divided into morphological and functional malocclusions, the terms of which were defined by Ahlgren and Posselt (1963). Morphological malocclusion describes a static, anatomical relationship of the teeth such as Angles classification, overbite, overjet or crossbite. Functional malocclusion refers to "occlusal disharmony which is described as an occlusal form and /or intermaxillary relationship out of harmony with the individual pattern of movement" (Ahlgren and Posselt 1963). In addition cuspal interferences and other occlusal disharmonies may cause functional disturbances of the masticatory system (Ahlgren and Posselt 1963). In children therefore, functional occlusion is most relevant following restorative treatment.

## 2.1 Occlusal interferences (OIs)

An occlusal contact is defined as the touching of opposing teeth and an occlusal interference (OI) is any tooth contact that inhibits the remaining occluding surface from achieving stable and harmonious contacts (Glossary of Prosthodontic Terms, Eighth Edition 2005). Carlsson has explained the controversy with regards to occlusal interferences by stating that an individual may have marked deviations from a normal occlusion with excellent function while another may have an optimal occlusion yet have mandibular dysfunction (Carlsson 1978).

A review of the early literature described several features which were likely to interfere with function. These included occlusal contact on the non-working side, unilateral contacts in the retruded contact position, slides (> 1mm) between the retruded contact position (RCP) and the intercuspal position (IP) as well as asymmetry in the slide between the RCP and the IP (Clarke and Evans 2001).

Clinical and electromyographical studies suggested that OI often, but not in all cases, lead to increased tone in the jaw muscles and pain associated with the TMJ in adults. Ramfjord also found that in some cases OI could in some cases trigger bruxism and removal of the OIs reduced these effects (Ramfjord 1961). Geering (1974) examined 251 patients and reported that OI were seen more often in patients with pain and dysfunction. Many patients had OIs without pain, suggesting adaptability of the masticatory system to occlusal abnormalities (Geering 1974).

### 2.1.1 Prevalence of occlusal interferences in children

Agerberg and Sandstrom (1988) studied the prevalence of OIs in healthy teenagers and young adults with no symptoms of mandibular dysfunction. They have reported unilateral tooth contacts in the retruded position in 75% of both 12 and 15 year old age groups, having defined an OI as occurring when the distance between retruded contact position (RCP) and intercuspal position (IP) exceeded 1mm and simultaneous lateral displacement of the lower jaw occurred (Aberberg and Sandstrom 1988).

Gazit *et al* (1984) investigated the prevalence of signs and symptoms of mandibular dysfunction in 369 10-18 year old children. Overall 56.4% indicated the presence of one or more symptoms of TMD with the prevalence increasing significantly from 51% in the 10-13 year old group to 67.8% in the 16-18 year old group. They reported that the older group exhibited a higher prevalence of OIs compared to the mixed dentition group. The frequency of malocclusions remained high in the older group despite the fact that 31% of the group had undergone orthodontics. In agreement with Sadowsko and BeGole (1980) the authors stated that no relationship was found between an increase in TMD symptoms and having undergone orthodontic treatment.

Two studies on the prevalence of functional disturbances in 2 different age groups have been carried out by Nilner (1981). In the first study, 440 randomly selected

children were recruited in the 7-14 year old age group. 36% reported symptoms which included recurrent headaches and TMJ sounds with 79% having OI in RCP. The second study involved 309 children in the 15-18 years old age group. 41% reported a history of symptoms of TMD which consisted of recurrent headaches and TMJ sounds as was found in the younger group. Clinically OI were found in 83% of the older age group (Nilner 1981). These epidemiological studies confirm that OIs occur regularly in all populations, including children from the age of 7 years.

### 2.1.2 Experimental occlusal interferences (EOI)

The role of OIs in the masticatory system has been a controversial one throughout history. The pattern by which interferences affect the functioning dentition is sometimes studied by the placement of EOIs. In the 1970s, Posselt assumed that OI or loss of posterior support caused masticatory muscle hyperactivity which lead to the patient attempting to grind the interference. He did state however, that even when the interferences were severe, they did not automatically lead to TMD (Posselt 1971). Ash and Ramfjord (1996) agreed with this theory postulating jaw muscle pain, joint overload and dysfunction resulted when OIs occurred in sensitive patients. Gerber (1971) expanded Costen's theory of overclosure and postulated that OI and loss of posterior support lead to eccentric positioning of the mandibular condyles leading to pain. This has since been rejected by Blaschke and Blaschke (1981) and Pullinger *et al* (1985) as they showed eccentric condyles in normally functioning patients with no symptoms.

#### 2.1.2.1 Local effects caused by EOI

Occlusal interferences in the form of high restorations have been studied as far back as 1931 (Gottleib and Orban 1931). High crowns were placed in young and old dog models with the dogs being sacrificed at various time points from 12 hours to 13 months following crown placement. Bone resorption was seen as early as 24 hours post crown placement, however when many months had elapsed a normal level of bone had been established suggesting movement of the tooth to relieve the traumatic occlusion had occurred. This was a demonstration of high crowns

causing a local but transient effect on the supporting bone (Gottleib and Orban 1931).

In 1935, Box used a sheep model to examine occlusal trauma and periodontal disease progression. He wrongly interpreted the increased gingival pocketing and tooth mobility found in periodontal disease to be accelerated by occlusal trauma (Box 1935). Svanberg (1974) and Polson *et al* (1976) both undertook animal studies demonstrating that plaque induced tissue inflammation, and not occlusal trauma, caused progression of periodontal disease.

The effect of occlusal trauma on the pulp was examined using the placement of inlays in humans and carrying out electric pulp tests over a period of 2 to 29 days. It was demonstrated that when a high inlay was place, the pulpal pain threshold decreased. The pulpal pain threshold returned to a normal level when the interference was removed or if the tooth was intruded over time (Ikeda 1998).

## 2.2 Temporomandibular disorders (TMD)

### 2.2.1 Prevalence of signs and symptoms of TMD in children

TMD are defined as conditions producing abnormal, incomplete, or impaired function of the temporomandibular joints (TMJs) or a collection of symptoms frequently observed in various combinations first described by Costen (Glossary of Prosthodontic Terms, Eighth Edition 2005). The association between occlusal factors and TMD is controversial thus a larger amount of literature exists regarding OIs or malocclusions and their possible consequences such as bruxism, tooth wear and TMD.

It is widely accepted that the signs and symptoms of TMD are seen regularly in all age groups and several studies have reported on the prevalence of these signs and symptoms in children and adolescents (Table 2.2-1). The variation in prevalence may be due to the widely divergent study design including variation in sample

size, age range, methodologies and questionnaires. In addition a number of different criteria were used to define TMD within the various studies (Thilander *et al* 2002). The signs and symptoms of TMD appear to increase with age as reported in several longitudinal studies such as Mohlin *et al* (1991) and Egermark-Eriksson *et al* (1981).

**Table 2.2-1** Prevalence of signs and symptoms of TMD in children

| AUTHORS | AGE (yrs) | NO OF PXS | SIGNS | SYMPTOMS |
|---|---|---|---|---|
| Geering-Gaerny '71 | 8-14 | 232 | 41% | - |
| Grosfeld & Czarnecka | 6-8 | 250 | 6% | 56% |
| '77 | 13-15 | 250 | 10% | 68% |
| Erkisson, Carlsson & | 7 | - | 30% | - |
| Ingervall '81 | 15 | - | 60% | - |
| Nilner & Lassinig '81 | 7-14 | 440 | 72% | - |
| | 15-18 | 309 | 71% | - |
| Egermark-Erkisson | 7 | 136 | 33% | 39% |
| '82 | 11 | 131 | 46% | 67% |
| | 15 | 135 | 61% | 74% |
| Niler '83 | 7-14 | 440 | 64% | 36% |
| | 15-18 | 309 | 55% | 41% |
| Gazit '84 | 10-18 | 369 | 56.4% | - |
| | 10-13 | | 51% | - |
| | 16-18 | | 67.8% | - |
| Magnusson '85 | 11 | - | 66% | - |
| | 15 | - | 66% | - |
| Jamasa et al '88 | 5 | 127 | 12% | - |
| | 10 | 109 | 41% | - |
| | 15 | 147 | 42% | - |
| Heikinheimo et al '89 | 12-15 | 167 | - | 65% |
| Pahkala and Laine '91 | 5-15 | 1008 | 39% both combined | |
| Mohlin et al '91 | 12 | 1000 | 46% | 16% |

## 2.3 Occlusal interferences (OIs) and TMD

### 2.3.1 EOI and TMD – animal studies

There are numerous studies that aim to investigate OIs as a possible aetiology in TMD in adults and children. There appears to be no agreement in the literature as to whether there is a link between OI and TMD. The initial research on the link between OI and the TMJ in the masticatory system was carried out on animal models.

Ruben and Malfa (1971) increased the OVD in the region of the first molar by 4mm in a rhesus monkey model using a bilateral splint. Two monkeys acted as controls wearing flat plane occlusal splints. The animals were sacrificed after 15 or 55 days and the histological findings have exhibited destructive bony changes in the TMJs. These changes occurred in the monkeys with both the pivoted and flat plane splint both after 15 and 55 days. More recently, a rat model was used by Kivnnsanld *et al* (1993) to examine the blood flow in the TMJ as a method of assessing altered joint loading. Thirty animals had 1mm high composite additions placed on the right maxillary molar and were sacrificed from 1 to 20 days post placement. This study has interpreted the increased blood flow on the ipsilateral side as a demonstration of altered joint loading. Richardin *et al* (1995) measured EMG activity in several masticatory muscles in 12 rats with occlusal splints. This study has observed increased muscle activity in the study group only, during the late phase of opening where no increase had been noted in the control group (Richardin *et al* 1995). It was observed that the TMJ of a rat has the ability to adapt to an experimentally induced OI by increasing the thickness of the intermediate zone within the disc (Sun *et al* 2009).

### 2.3.2 EOI and TMD – adult studies

Clarke *et al* (1999) reviewed the literature on EOI in adults from the 1950s to the late 1990s. It is stated that there is clear evidence of short term local effects of OI (Clarke *et al* 1999). Due to the short time frame (less than 4 weeks) and variation

of the studies the chance that long term effects do occur can not be ruled out. Based on the literature with OI of varying magnitudes, Clarke has suggested that the chance of TMJ or muscle pain developing from an OI is moderately low (Clarke *et al* 1999).

Anderson and Picton (1958) placed 0.5mm high onlays or normal inlays with inbuilt load sensors in 4 adult patients. It was found that the load on the tooth with a high inlay had twice the force measured as that on the tooth with the normal inlay. Randow *et al* (1976) carried out a slightly larger study where 0.25 mm high gold inlays were placed on mandibular molars in 8 healthy human participants. Functional disturbances or pain was recorded in all 8 subjects. One week after removal of the occlusal interference, 6 patients still complained of TMJ and muscle tenderness, 3 developed TMJ clicking on opening and 1 patient developed severe irregularity of movement in both joints.

Rise and Sheikholeslam (1982, 1983) created intercuspal interferences (0.5mm) in the maxillary molars of 11 healthy subjects using amalgam fillings and measured changes with surface EMG responses of the elevator muscles during rest, sub maximal and at maximal clenching. The pattern of postural activity was influenced by the EOI as early as 1 hour post placement. After 48 hours there was a significant increase in activity in anterior temporal muscles which persisted for the 1 week of the experiment even when the EOI was removed. As with previous studies, it has been noted that removal of the interference resulted in activity returning to pre study levels. Unlike previous studies, all subjects were observed over a longer time period of one month. Seven of the subjects suffered pain tenderness and fatigue in the masticatory muscles within 3 hours of the interference being placed and a further 8 subjects developed dysfunctional symptoms in the masticatory muscles or TMJ within 12 hours of placement. They reported that in 4 of these subjects the symptoms subsided gradually over the one month period however in the remaining 4, the symptoms only resolved on removal of the interference.

Christensen and Rassouli (1995a,b) showed that OIs cause short term clinical symptoms such as jaw muscle fatigue and discomfort, headaches as well as TMJ pain and clicking but the long term effects were not established fully. The second paper studied the effects of a unilateral OI on maximum intercuspation by measuring surface EMG activity and the tipping of the mandible. A rigid acrylic inlay was placed in 12 healthy patients creating a minimum interference of 0.24 mm in the second premolar/ first molar region. They concluded that EOIs and short term signs and symptoms were associated but failed to determine if serious long term effects occur with EOIs. They also stated that contradictions occur in the literature where some investigators have found EMG changes with EOI placement and other investigators have found none (Christensen and Rassouli 1995).

Magnusson and Enbom (1984) used a double blinded study to place bilateral balancing side interferences in the intervention group but simulated the presence of interferences in the control group. Interestingly, signs and symptoms of dysfunction developed in both groups proving that the relationships between OIs and signs and symptoms of TMD are not straight forward.

A long term, double blind, cross over study looked at muscle activity following placement of an interference in a natural environment (Michelotti *et al* 2005). The study group consisted of 11 healthy females with either active or dummy interferences placed for 8 days. They reported a significant reduction in the activity periods per hour in the OI group compared to the study group. No patients developed signs of TMJ disorders throughout the study and all appeared to adapt well to the placement of an OI. The shortcomings of this study included a selection bias regards recruiting a very small sample of healthy patients where the exclusion criteria excludes the part of the population who are most likely to develop TMD – those with a history of symptoms (Mitchelotti *et al* 2005). The selection bias was due to recruitment of patients who have adapted well to naturally occurring interferences thus will adapt well to any artificial interferences placed (Le Bell

2002). Other shortcomings of these EOI studies include the short, 1-2 week duration and small sample sizes (De Boever *et al* 2000, Le Bell *et al* 2002).

In order to remove this bias a double blinded randomised controlled trial (RCT) was undertaken to assess the effect of EOIs on patients with and without a history of TMD symptoms. It has been found that the participants with no history of previous TMD adapted well to the EOI as was seen in previous studies (Le Bell *et al* 2002). However when comparing patients with no history of TMD with those with a TMD history, the TMD history group has shown significantly more clinical signs of TMD. Le Bell *et al* (2006) concludes by questioning the validity of previous studies which found that OI was not etiological factor in TMD.

### 2.3.3 Naturally occurring OI's and TMD – adult studies

Ingervall *et al* (1980) reported a positive correlation between symptoms of dysfunction and non-working side interferences and single tooth contact on the working side. TMJ locking and sounds were also correlated with single tooth contact on the working side, TMJ sounds and muscle tenderness were associated with interferences in the retruded position of the mandible (Ingervall *et al* 1980). Agerberg and Sandstrom (1988) described unilateral tooth contacts in the retruded position in 75% of healthy teenagers and adolescents therefore, a large portion of healthy well functioning masticatory systems appear to have interferences, both in intercuspal position and mediotrusive movements. It is thus concluded that there is no support for OIs playing a major role in the etiology of TMD.

A systematic review of the literature regarding the link between malocclusions, functional malocclusions and TMD in adults was carried out by Gesch *et al* (2004). This review included studies by Mohlin (1982) and Jenni *et al* (1987). Mohlin (1982) studied the association of OIs and malocclusions with TMD symptoms in 205 women between the ages of 20 and 45 years of age. No association between functional occlusion and severity of clinical signs was found. Jenni *et al* (1987) recruited 210 males and females from the ages of 20-69 years

old. Both a clinical exam and a patient history of TMJ function were recorded. No statistically significant differences were found between the OIs and clinical signs of dysfunction and no differences exixted between OIs and the patient's history of TMJ dysfunction. Gesch *et al* (2004) summarises by stating that although a few associations have been found, the number of suitable randomised studies was very small and further well designed studies would be needed to clarify any association.

### 2.3.4 Naturally occurring OIs and TMD – children studies

Egermark-Eriksson *et al* (1983) carried out regression analyses on several factors related to TMD. A weak correlation was found between malocclusion factors, especially functional malocclusion, and signs of mandibular dysfunction. They also concluded, similar to adults, that the etiology of mandibular dysfunction was multifactorial. Egermark-Eriksson *et al* (1987) carried out a longitudinal study over 4 to 5 years to attempt to elucidate the role of occlusal factors in mandibular dysfunction. 240 children were recruited aged 7, 11 or 15 years old at the first examination. A weak correlation was found between TMJ sounds and lateral deviation of the mandible between retruded contact and intercuspation in all age groups. The study did not find any significant correlation between occlusal interferences and sign and symptoms of mandibular dysfunction and concluded that the aetiology of functional disturbances of the mandible was multifactorial.

Heikinheimo *et al* (1990) carried out a longitudinal study on 12 and 15 year old Finnish adolescents on occlusal interferences and signs of TMD. As with previous studies (Ingervall *et al* 1980, Egermark-Eriksson *et al* 1981, Magnusson 1985, Wanman and Agerberg 1986) a correlation was found between the patients who reported symptoms and the signs found clinically. The authors have stated that the aetiology was multifactorial as stated in several studies (Mohlin and Thilander 1984, Carlson and Droukas 1984, Solberg 1985, Magnusson 1986, Ash 1986, Egermark Eriksson *et al* 1987). They reported that the role of occlusal factors in TMD was controversial with some reporting no association (Carlsson and Droukas

1984, Agerberg and Sandstrom 1988) and others suggesting an association (Ingervall *et al* 1980, Egermark-Eriksson 1983 *et al*). As mentioned previously, functional malocclusions are considered to play a larger role in aetiology of TMD than that of morphological malocclusions (Ingervall 1976, Egermark-Erkissosn 1983 *et al*).

Egermark-Eriksson (1990) continued his study regarding malocclusions of children aged 7, 11 and 15 in relation to signs and symptoms of TMD for 5 years. His conclusion was that functional malocclusions/OIs had a greater influence on the development of TMD than morphological malocclusions/orthodontic issues. As with the Egermark-Eriksson (1982) study, crossbite, anterior open bite post and pre normal occlusion had the greatest impact on occurrence of TMD.

Vanderas (2002) carried out a cross-sectional multifactorial analysis of several factors thought to be involved TMD in children. It was stated that TMD is more likely to exist when more than one aetiological factor is found. He suggested that parafunctional and some psychological factors may increase the probability of the child developing signs and symptoms of TMD. However he noted that morphological malocclusions such as posterior crossbite appeared to be more significant than functional malocclusions such as non-working side interferences.

### 2.3.5 Occlusal interferences play little or no role in TMD

In contrast to De Boever *et al* (2000) other reviews on the aetiological role of occlusal factors in TMD have reported no strong evidence for support of an occlusal etiology (McNamara *et al* 1995, Okeson and Kanter 1996). Correlations found were weak thus suggesting they only play a small role in a multifactorial aetiology (Schiff 1992).

Droukas *et al* (1984) examined 48 dental students and questioned the students regarding symptoms of mandibular and oral dysfunction. The subjective symptoms reported included TMJ clicking, found in 19%, as well as headache, TMJ pain and

locking. In a clinical examination 40% had muscles tender to palpation and 35% had an impaired TMJ function, such as clicking. The occlusal conditions were extremely varied. This together with the small sample group may be the explanation that no statistically significant relationships occurred between occlusal variables and symptoms of functional problems in the masticatory system. He finally concluded that mandibular dysfunction has a multifactorial aetiology and that occlusion plays a minor role.

In 1985 Droukas *et al* repeated the 1984 study on a population of 50 patients referred for treatment of TMD and found various occlusal conditions. No occlusal conditions correlated with signs and symptoms of mandibuar dysfunction. These results suggest that occlusal variables do not correlate with severity of mandibular dysfunction signs and symptoms. The small numbers in the study and the even smaller number of each occlusal disturbance mean that few firm conclusions can be drawn from either study (Droukas *et al* 1984, 1985).

### 2.3.6 Occlusal adjustment to remove OIs

Some authors have advocated removal of interferences to prevent TMD development (Dawson 1974, Kirveskari *et al* 1998). Others have studied the effects of OIs by eliminating naturally occurring OIs and assessing the rate of TMD developing over time (Kirveskari *et al* 1989, 1992, 2009).

Kirveskari *et al* (1989) carried out a double blinded longitudinal study involving 5, 10 and 15 year old children who were divided into treatment and control groups. The treatment group underwent annual occlusal adjustment in order to increase the difference in the number of interfereences in each group. At the end of the 3 year study analysis was carried out and significant association was found between OIs present and signs of TMJ disorders hence children with adjustment had less signs of TMD and less OIs.

Kirveskari *et al* (1992) assessed approximately 100 5-year old and 70 10-year old children for the presence of OIs and signs of TMD over 5 years. As before the population was randomly divided into an intervention group who received occlusal adjustment and a control group who had a placebo adjustment. Minimal occlusal adjustment caused a small decrease in the number of OIs in the intervention group and a statistically significant positive association was found between the number of occlusal OIs and signs of TMD disorders in the 2 groups. This suggests that additional factors other than OIs are responsible for development of TMD.

The almost universal presence of interferences alone makes a meaningful selection of candidates for prophylaxis inappropriate. There is a lack of evidence based research in this area regarding occlusal adjustment for treatment of TMD. Studies are not controlled and little agreement exists on the type and method of OI measurement used. Furthermore patients only report short term relief of symptoms. Kirveskari *et al* (1989) concluded that occlusion does not play a major role in TMD and how it affects each individual should be determined.

### 2.3.7 Dental restorations and TMD

Kloprogge and Griethuysen (1976) undertook an EMG study on filled and intact teeth and found muscular disturbances on the restored teeth but not on intact teeth. Statistically significant differences were found regarding TMD symptoms between the two groups of 29 young adults with intact dentitions and a control group of 34 young adults with restored dentitions (Kampe *et al* 1983). Kampe postulated that the masticatrory apparatus attempts to avoid a new contact in the new filling and causing new patterns of mandibular movement. In some dentitions this may be enough to exceed the tolerance level of the system and create TMD (Kampe *et al* 1983).

Kampe *et al* (1987) previously carried out two studies on this topic. In the first study, 13 of the adolescents in the 1983 study with intact dentitions and 16 with restored dentitions were re-examined. Three years later, less severe and less

frequent dysfunction was found in the group with intact dentitions, however the symptoms were mild and were also found in both groups (Kampe *et al* 1987). The second study examined two much larger groups of 13-15 year olds regarding TMD symptoms and clinical signs. A group of 96 participants with intact dentitions were compared to 129 participants with restored dentitions. The restored group reported more headaches with more attrition and a distance of greater than 0.5mm between retruded contact position (RCP) and intercuspation position(ICP) found clinically. They concluded that dental restorations may be related to mandibular dysfunction (Kampe an d Hannerz 1987).

## 2.4 Increasing vertical dimension of occlusion

### 2.4.1 Definition of occlusal vertical dimension (OVD)

Occlusal vertical dimension (OVD) is the distance measured between two points when the occluding members are in contact (Glossary of Prosthodontic Terms, Eighth Edition 2005). Dawson (1989) states that vertical dimension occurs at optimum muscle contraction of the closing muscles and teeth erupt until they meet at this point. If an increase in tooth length occurs the muscle action is disturbed and damage to the system occurs.

Costen (1934) and (1937) described TMD as a collection of symptoms seen in different combinations (Glossary of Prosthodontic Terms, Eighth Edition 2005). He suggested that irritation of the auriculotemporal and/or chorda tympanic nerves caused reflexes. He postulated that the irritations of the nerves were due to altered anatomy or derangements of the TMJ from loss of vertical dimension, loss of posterior tooth support and other malocclusions. On the basis of this, Costen recommended increasing the vertical dimension in patients with TMD. In 1939 Clyde Schuyler discussed the consequences of altering the "bite". He felt that increasing it will cause "reflex facial pains" or subluxation of the TMJ's". Although this is now known to be incorrect, he was not completely inaccurate.

Several experiments were carried out where the vertical dimension was experimentally increased. Andersen (1962) created malocclusions having placed restorations in supra-occlusion by placing a 0.5mm metal bite-raising cap on the occlusal surface of the right lower first permanent molars in 5 human subjects aged between 19-40 years. After 23-41 days the patients were able to bring their teeth into occusal contact with the cap in place thus having created an inter-occlusal space. As no fixed reference points were used the author was unable to determine if the movement was due to the eruption of the separated teeth, intrusion of the teeth contacting the bite-raising appliance or a combination of both. Whether the patients suffered any discomfort was not noted.

### 2.4.2 Effect of increasing the OVD

Christensen (1970) used cast silver cap-splints on lower molar teeth in 20 dental students, increasing their inter-occlusal distance and observations were recorded over 3-7 days. His hypothesis was that a new rest position would be established. Some patients experienced headache after wearing the appliance for less than an hour. Others began clenching and grinding with some reporting bilateral muscle fatigue, sore teeth and occasionally pain in the TMJ region. Younger patients adapted better than the older ones (Christensen 1970). When OVD is increased excessively, patients often complain of headache, bruxism, pressure pain of the masticatory muscles, and pain around the TMJ during jaw movements (Yagi 2002).

Carlsson (1979) undertook an EMG study on 6 healthy subjects over 1 week. He reported that symptoms associated with an increased OVD resolved within 7 days, with most only lasting 2 days. However, unlike Christensen (1970) who only covered molars, Carlsson covered canines, premolars and molars perhaps explaining the short duration of symptoms. More recently Ormianer *et al* (2009) stated that adults that had an increased OVD of 3-5mm, as part of a prosthodontic treatment plan, all adapted to the new OVD. It was found that 6 patients out of 30 experienced tooth clenching or grinding which resolved fully after 3 months.

Mechanical failures such as porcelain fracture were noted in the study (Ormianer *et al* 2009). Increasing the OVD may risk producing numerous problems such as clenching, fatigue and soreness of the muscles, teeth and joints, headache, fractured porcelain and continued wear (Turner 1984). Both existing literature and clinical experience supports the masticatory systems adaption to moderate changes in OVD (Carlsson 1979).

## 2.5 Dahl concept

### 2.5.1 Original research

The Dahl concept (Dahl *et al* 1975) is the use of an anterior bite plane (Figure 2.5-1) which acts orthodontically to create increased interocclusal space without affecting the crown height (Saha *et al* 2004). The localized bite plane is placed in supraocclusion and separated occlusion is found to establish full arch contacts over time by relative axial tooth movement (Poyser *et al* 2005).

**Figure 2.5-1** Picture of removable Dahl appliance - cobalt chrome splint



(Reproduced from Mizrahi 2006)

Dahl *et al* (1975) studied 1 patient who had heavy wear of the palatal surfaces of the maxillary incisors. The patient wore a 2mm thick removable chrome-cobalt splint full time for 8 months. Changes in the vertical dimension of the face were measured, in a technique used by Bjork (1968). An increasing space was observed clinically over 8 months, when the teeth were positioned in the intercuspal

position. Full time-wear resulted in an increase of 1.7mm in face height. No discomfort was reported by the patient. Dahl concluded that at 2 months, the initial change was from intrusion of incisor teeth but that over the 8 months, the change was due to over eruption of the posterior teeth.

Dahl and Krogstad (1982) undertook a cephalometric study on 20 patients aged 18-50 years old with pathological attrition of anterior teeth. Treatment involved the placement of a partial chrome-cobalt splint on the palatal surfaces of the anterior teeth. The appliances ranged in thickness from 1.8mm to 4.7mm. Tantalum implants placed in the basal portions of the upper and lower jaws were used as references points so as to measure the amount of tooth eruption or tooth intrusion occurring. Baseline radiographs were taken with and without the splint in situ and these repeated at 2 month intervals. They found that full time wear of the splint resulted in intrusion of the covered anterior teeth and extrusion of the uncovered posterior teeth with the eruption being the primary movement in the youngest age groups.

### 2.5.2 Success of Dahl concept

Gough and Setchell (1999) reported retrospectively on 50 appliances, in adults aged 19 to 69 year old, receiving axial tooth movement treatment using both fixed and removable appliances. The success rate was 96% and the duration of the treatment was from 0.93 to 24 months with a median time of 5.9 months. They stated that re-establishment of posterior occlusion occurs within 10 months in most cases and it is not possible to predict in which patients it will fail to re-establish. They postulate in agreement by Dahl and Krogstad (1982), that the main reason for failure is lack of patient compliance. Gow and Hemmings (2002) and Redman *et al* (2003) both used fixed appliances thus eliminated poor patient compliance as a reason for failure but still reported failures of the occlusion to re-establish in several cases. Gow and Hemming (2002) placed appliances that created posterior disclusion of 1-4mm and reported failure in 17% of subjects after 6-12 months. Redman *et al* (2003) did not report on the magnitude of increase of the vertical

dimension, but reported that one third of patients did not achieve posterior contacts in the premolar region. They hypothesise that this may be due to limited premolar eruptive potential and that the premolar may be impacted behind the canine. Also these patients may not have been given sufficient time for occlusal re-establishment.

It is difficult to compare success rates across studies as different definitions of success were used. Some classify success as full or partial re-establishment of posterior occlusion while others classify partial re-establishment as failure. In a review article by Poyser *et al* (2005) it is postulated that subjects with partial re-establishment of posterior contacts result in a functional dentition, hence can be classified as successful treatment. In those who are unable to function, the provision of further restorations to increase posterior contacts can be provided. This approach is still be a much more conservative approach than if conventional prosthodontic approach was used.

### 2.5.3 Adverse effects of Dahl concept

Practitioners have been concerned regarding pulpal symptoms, periodontal problems and TMD (Poyser *et al* 2005). Gough and Setchell (1999) reported mild and moderate TMD symptoms in 6% of patient which were transient and resolves during treatment. This is the only study to report pulpal symptoms with 3 teeth in 50 study patients having symptoms, with 2 of the 3 resulting in spontaneous resolution of symptoms. The third symptomatic tooth required root canal treatment but the authors postulated that this was due to the deep restoration previously in the tooth. It therefore appears that pulpal symptoms are rare.

Mild periodontal symptoms of tenderness have been found to occur in 3% (Redman *et a*l 2003) and 10% (Gough and Setchell 1999) of patients using a Dahl appliance. These symptoms were mild in nature and resolved spontaneously. Poyser *et al* (2005) states that patients with active periodontal disease are not candidates for a Dahl appliance. With regards to TMD and facial pain symptoms it

has been postulated that patients with tooth surface loss who require such treatment are less susceptible to TMD symptoms (Seligman *et al* 2000).

### 2.5.4 Single tooth treatment

There are a limited number of studies in the literature regarding inter-occlusal space creation regarding a single tooth. These include creation of space for a resin bonded bridge retainer (Ricketts and Smith 1993), regaining lost inter occlusal space following loss of a cemented restoration and intrusion of an over erupted tooth (Gough and Setchell 1999).

### 2.5.5 Mechanism of action of Dahl appliance

In order to demonstrate whether intrusion of the covered teeth, eruption of the unopposed teeth or a combination of both occur with a Dahl appliance, fixed reference points are required. In Dahl and Krogstad's (1982) study tantalum implants were placed in the basal portions of the upper and lower jaws in the 20 participants. Radiographs were taken every second month which demonstrated that the changes in tooth position resulted from 40% intrusion and 60% overeruption. It was also stated that the percentage of eruption increased in the younger age groups. Today the awareness of the risks of frequent radiographs mean continuation of these investigations in this manner would be unethical. Some researchers have postulated that the rapid repositioning of the teeth may also involve some mandibular repositioning. The establishment of the most posterior contacts first may add weight to this theory (Hemmings *et al* 2000 and Redman *et al* 2003).

This technique can be used predictably but there is need for further research. Unanswered questions include the role of mandibular repositioning, the role of intrusion and extrusion and whether there any factors that can predict patients that will not achieve occlusal re-establishment. Further questions include the reason for lack of eruptive potential and the issue of long term stability of patients treated in this manner.

## 2.6 Tooth eruption

### 2.6.1 Tooth eruption theories

Tooth eruption is defined as the gradual movement of a tooth from its formative position in the osseous crypt through alveolar bone and into function occlusion in the oral cavity (Lal 2008). The mechanism of tooth eruption has evoked much discussion and research in the past, however the mechanism by which a tooth begins to erupt remains elusive (Proffit 2009).

Early theories regarding tooth eruption included the pulp theory and the vascular theory. It has been shown that removal of the dental pulp had no effect on tooth eruption hence eliminating the role of pulp and reducing the likelihood of the vascular system playing a role in the eruption process (Herzberger and Schour 1941).

The root elongation theory proposed that the elongation of the root is the force behind eruption however eruption of rootless teeth disproves this theory. Also a dog study where the tooth germs were removed and replaced with crown shells, synthetic substitutes or no replacement showed that the tooth itself played no role in eruption (Marks and Cahill 1984).

The role of the periodontal ligament in eruption is also controversial. It has been shown that following transection of the root of a tooth the more superficial segment continued to erupt. This implies the PDL and not bone, root growth or pulpal pressure is involved in eruption (Moxham and Berkovitz 1974).

The important role of the dental follicle has been demonstrated by Marks and Cahill (1980) who reported the dental follicle was the only structure needed for pre-functional development of an eruptive pathway and eruption. The follicle has been thought to coordinate tooth eruption (Marks and Cahill 1980).

It is now accepted, that eruption is a localised, symmetrical process which involves resorption and formation of alveolar bone that is dependent upon the dental follicle.

### 2.6.2 Control of tooth eruption

Eruption may be controlled by hormonal or physical mechanisms. It has been shown that eruption of a human tooth follows a circadian rhythm which was thought to be due to reduced intra-oral physical forces at night (Risinger and Proffitt 1996). It has been observed that eruption occurs in the late evening, when subjects may be awake and not in the early morning when the subject is asleep. It is suggested that the eruption rhythm mirrors the circardian rhythm of hormone release (Risinger and Proffitt 1996) (Figure 2.6-1). An amount of growth hormone is usually released in the evening time which correlates with the time that tooth eruption is noted (Born *et al* 1988). Animal studies have shown an increase in tooth eruption following administration of hormones (Thesleff 1987). It has also been reported that children deficient in growth hormone have delayed tooth eruption and those with deficient growth for other reasons had normal tooth eruption times (Barberia Leache *et al* 1988).

**Figure 2.6-1** Overnight eruption plot using video-fiber optic.

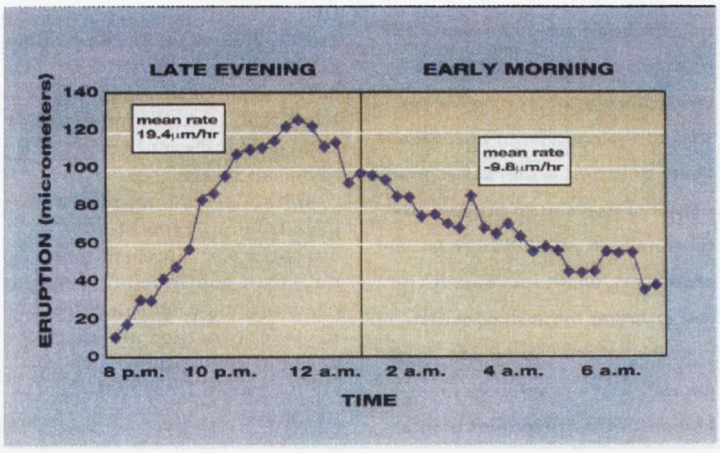



**Figure 2. Typical eruption plot from a subject observed overnight with the VFO instrumentation. Eruption occurred in the late evening but ceased at midnight, and the tooth intruded during the early morning.**

(Reproduced from Risinger and Proffitt 1996)

### 2.6.3 Post eruptive tooth movements

Post eruptive tooth movements are divided into 4 stages. Pre-functional spurt is the period from first emergence until occlusal contact is first achieved. The juvenile equilibrium, adolescent growth spurt and adult equilibrium stages are stages that parallel vertical facial growth (Proffit 2009). The rates of vertical growth have been assessed by Thilander who has examined increase in palatal height. Continuous increase of palatal height has been observed in 5 to 31 year olds. Between the ages of 5 to 16 years, the average rate of increase was approximately 0.5mm per year which reduced to 0.1mm per year for the 16 to 31 year olds. This appears to confirm continued slow eruption of the teeth and explain infraocclusion occurring within adults with implant supported crowns (Thilander 2009). It has been shown that the first permanent molars must erupt over 1 cm from the point of first contact to keep up with jaw growth i.e. through the later of the 4 stages of post eruptive movement. This observed movement along with the phenomena of over eruption following the loss of an opposing tooth late in adult life confirms that eruption process can remain active through adult life (Proffit 2009).

The mechanism for post emergent phase of tooth eruption is unknown but it is postulated that the PDL plays a role in this later part of eruption. The PDL only becomes orientated and begins to mature once the tooth has erupted into the oral cavity (Proffit 2009). Animal and human experiments have been carried out on the post emergent phase of eruption. Failure of eruption following ingestion of lathryogens, which stops collagen maturation, suggests that the mechanism of post emergent eruption involves a functioning PDL (Moxham and Berkovitz 1984).

## 2.7 Extrusion and Intrusion in orthodontics/ skeletodental adapations

Extrusion and intrusion of teeth is undertaken in orthodontics to correct malocclusions such as correction of a deep bite. Correction of such conditions is easier and the result is more stable when carried treatment is carried out in a growing patient (McDowell and Baker 1991). When bite planes increase vertical dimension, either the musculature must adapt to its new length or the bony

configuration must change to achieve stability (McDowell and Baker 1991). Mandibular changes include changes in the condyle as it can adapt to changes in position of the mandible. The condyle can increase its rate of growth "when subjected to hyperpropulsion during the active growth period" (McDowell and Baker 1991). They compared skeletal and dental changes during orthodontic reduction of deep open bite in an adult and adolescent group and found significantly greater amount of condylar adaption and posterior mandibular development in the adolescent group. Extrusion of molar teeth was responsible for most of the changes in adolescences with an average of 4.7mm of extrusion compared to only 1.3mm in the adult group (McDowell and Baker 1991).

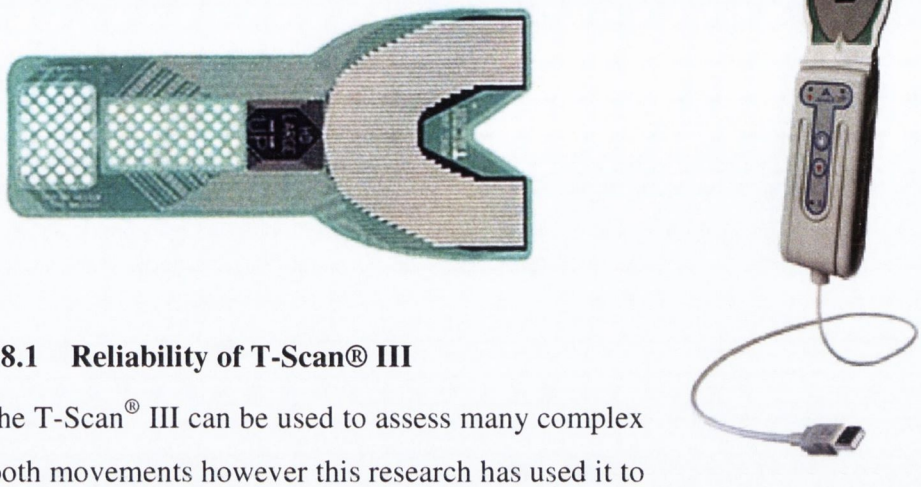
## 2.8 Occlusal contact detection instruments

Sonography was used in the 1960s to analyse occlusal patterns, however reproducibility was an issue. More recently two similar systems have been developed. Pressure sensitive film has been used in Dental Prescale system and occlusal contact sensors used in the T-Scan® system.

The *T-Scan®* Occlusal Analysis System was developed in 1987 and allows quantification of occlusal contacts. It is a computerised system that allows occlusion data to be interpreted qualitatively using time as the primary diagnostic variable (Maness *et al* 1987). Pressure sensitive film detects the distribution of tooth contacts and the relative timing of tooth contacts (Baba *et al* 2000).

Tekscan T-Scan® III Computerized Occlusal Analysis is a clinical diagnostic device that senses and analyses occlusal contact forces using thin, disposable sensors and also stores patients' occlusal recordings. The system comprises of a Microsoft-based T-Scan® III software, the associated hardware, and patented Tekscan sensors (see Figure 2.8.1). The polyester sensors are 100 microns thick, coated with a silver thread grid and bathed in a conducting ink. Force causes a reduction in electrical resistance which results in an image on the screen.

**Figure 2.8-1** T-Scan sensor and sensor in handle



### 2.8.1 Reliability of T-Scan® III

The T-Scan® III can be used to assess many complex tooth movements however this research has used it to assess MIP. The distribution of contacts in MIP, as seen in a cohort of 93 patients, has been found to correlate with patterns and conclusions of other researchers using more conventional methods (Maness and Podoloff 1989). The reproducibility and accuracy of occlusal contacts made by the T-Scan® was assessed on 10 healthy young adults (Reza Moini and Neff 1991). They used occlusal overlays on three teeth to create an artificial occlusion with only 3 contacts. They reported that with 3 teeth in contact 100% accuracy and reproducibility for all contacts was reported in the 10 participants (Reza Moini and Neff 1991). Maness in a laboratory study has been carried out which has compared Acufilm, Shimstock and the T-Scan® device. Acufilm and Shimstock created false positives especially in the anterior region, T-Scan® agreed with conventional methods of identifying actual contacts and was the most reliable indicator of simultaneous and numerous contacts (Maness 1991). A small study consisting of 2 subjects with known occlusal interferences has been carried out. It has shown that identification of non-working side interferences was clearly demonstrated by the T-Scan® however that force was not accurately measured by the machine (Lyons *et al* 1992).

Previously, several researchers in the early 1990s had cast doubt over the sensors reliability. Harvey *et al* (1991) found that the sensors were not reliable if used

more than twice. Setz *et al* (1990) stated that the sensor had poor resolution capacity and reliability. Yamamura *et al* (1990) reported the existence of non-sensitive areas causing results to be unreliable, as did Hsu (1992). Garcia Cartagena *et al* (1994) used the T-Scan® clinically and found that it was reliable in detecting number and distribution of contacts and contacts were able to be differentiated between patients and mandibular positions. This study stated that assessing the timing of contacts and force together was less reliable (Garcia Cartagena *et al* 1994). The same group of researchers assessed the reproducibility of contacts by the T-Scan® and found that it reliably measured the number and distribution of tooth contacts (Garrido Garcia *et al* 1997). Currently a 4$^{th}$ generation sensor is in use thus it may be postulated that inaccuracy of the earlier generations of sensors has now been addressed by the manufactures.

### 2.8.2 T-Scan use in children

There are no reported clinical studies on the usage of the T-Scan® device in children. A Pubmed search reveals a laboratory based Japanese study which assessed reproducibility of the sensor for use in children (Okamoto 1990). It was found that the number of contacts was more stable when the sensor had be tempered several times and an increased number of tooth contacts were detected with increased pressure (Okamoto 1990).

## 2.9 Aims and Objectives

### 2.9.1 The study aims

**PART I - T-SCAN® III REPRODUCIBILITY**

- Assessment of the T-Scan® III reproducibility in a laboratory and clinical setting in children

**PART II – CLINICAL STUDY**

- Assessment of MIP pre and post administration of LA in a child population.
- Assessment of MIP pre and post placement of a SSC in a child population.

### 2.9.2 The study objectives

**PART I - T-SCAN® III REPRODUCIBILITY**

- To assess reproducibility of T-Scan® III in a laboratory and clinical setting in children

**PART II – CLINICAL STUDY**

- To assess MIP pre treatment to establish a control for each patient.
- To assess MIP post LA and statistically compare with pre treatment occlusion.
- To assess MIP at 2 and 4 weeks and statistically compare with pre treatment levels.

### 2.9.3 The null hypothesis

**PART I - T-SCAN® III REPRODUCIBILITY**

- T-Scan® III is unable to repeatedly assess a child's occlusion.

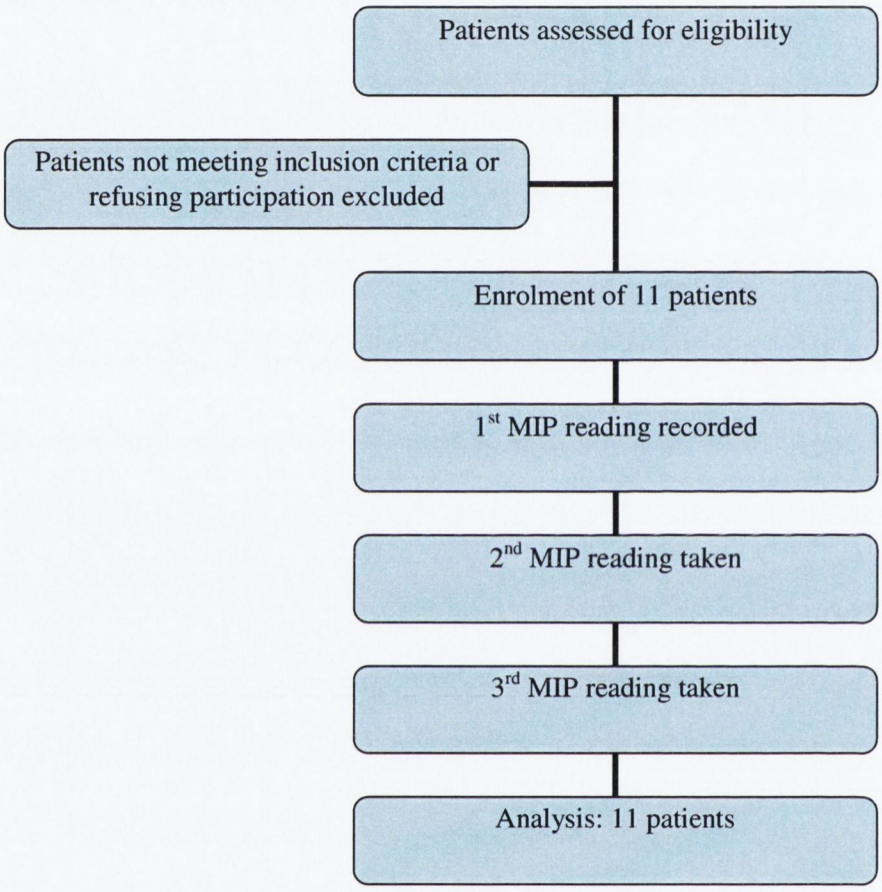
**PART II – CLINICAL STUDY**

- There will be no difference in the child's ability to reproduce MIP after LA.
- There will be no alteration in occlusion post placement of the SSC.
- There will be no difference between the preoperative occlusion and the occlusion at 2 and 4 weeks post restoration i.e. if occlusion has been disturbed normalizes within 2 to 4 weeks.

# 3 MATERIALS AND METHODS

## PART I - T-SCAN® III REPRODUCIBILITY

### 3.1 Consort diagram for clinical calibration




### 3.2 Clinical calibration of T-Scan® III

Following ethical approval from the Faculty of Health Sciences Research Ethics Committee, Trinity College Dublin (Appendix 7.1), a short calibration study was undertaken to assess how predictably the T-Scan® III measured force distribution in a child population. This population was a consecutive sample of children from the undergraduate paediatric dental clinic in the Dublin Dental School and Hospital who were having no dental treatment carried out on the day of calibration study.

**Table 3.2-1** Inclusion criteria for calibration study

| Inclusion criteria |
| --- |
| 1. ASA ≤ grade 2 |
| 2. 6-12 years old |
| 3. No treatment being carried out on day |
| 4. Co-operative patient |

**Table 3.2-2** Exclusion criteria for calibration study

| Exclusion criteria |
| --- |
| 1. ASA ≥ grade 3 |
| 2. Under 6 years old or > 12 years old |
| 3. Any treatment being carried out on day |
| 4. Un-cooperative patient |

### 3.2.1 Consent for calibration study

The patient and the parent/guardian received an information sheet (Appendix 7.2) and were requested to participate in the calibration study. The consent form (Appendix 7.3) was signed by the parent/guardian.

### 3.2.2 Confidentiality

Each participant was allocated a patient identification number. The code was a combination of the participant's initials and a number correlating to the order of recruitment in the study. Consent forms were stored in a locked compartment and the results were stored electronically on a password-protected computer only accessible to the researcher.

### 3.2.3 Data collection sequence

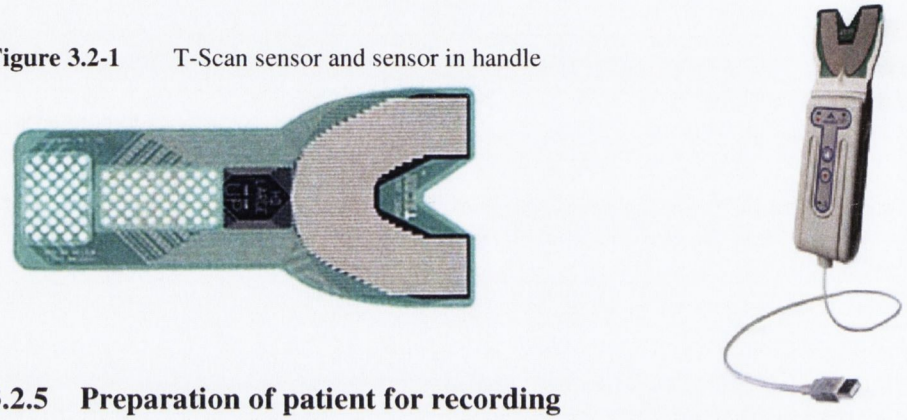
The patient's parent/guardian was approached by the gatekeeper and consent was signed if participation was agreed. Three consecutive reading of the patients MIP were taken, ensuring a minimum of 60 seconds between each reading. The readings were taken and stored with T-Scan® III (Tekscan, Inc., South Boston). The percentage of force on the most posterior occluding teeth on each side was

recorded on Microsoft Excel 2007 ® (Microsoft Inc., Redmond, WA, USA). Each patient generated 2 sets of 3 reading.

### 3.2.4 Tekscan T-Scan® III

Tekscan T-Scan® III Computerized Occlusal Analysis is a clinical diagnostic device that senses and analyses occlusal contact forces using thin, disposable sensors and also stores patients' occlusal recordings (Figure 3.2-1).

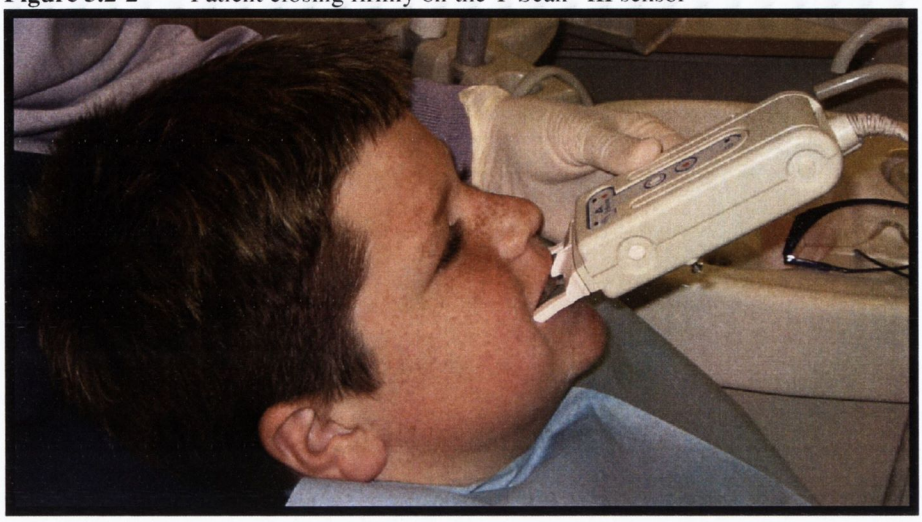
**Figure 3.2-1** T-Scan sensor and sensor in handle



### 3.2.5 Preparation of patient for recording

1) The patient was relaxed, comfortable and supine in the dental chair.
2) The patient was requested to "bite back teeth together" several times from 15-20 mm mandibular depression/opening.
3) The MIP was rehearsed to confirm repeatability.
4) The patient was requested to close firmly on the T-Scan® III sensor to their maximum force 3 times to familarise the patient with the sensor and to condition the sensor (Figure 3.2-2). This should be a complete intercuspated voluntary closure firmly on the sensor.

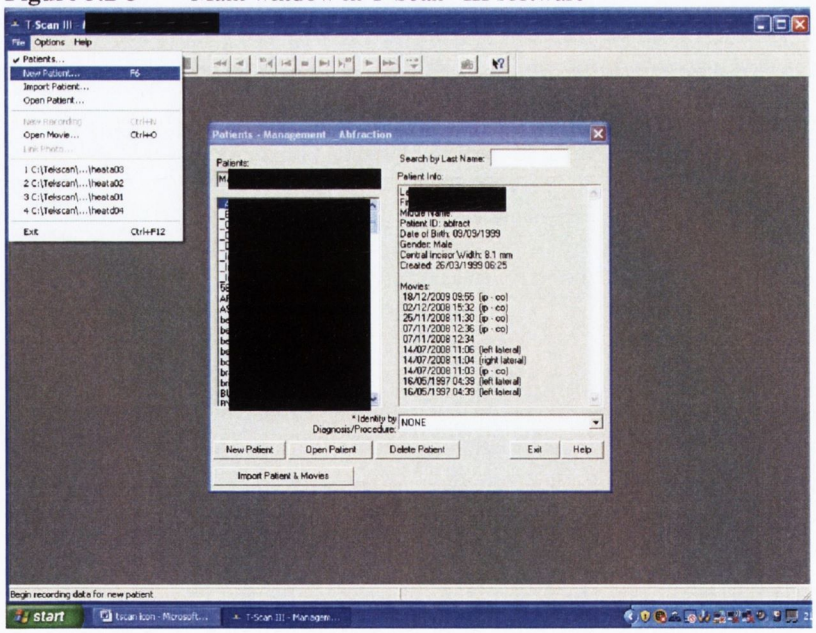
**Figure 3.2-2** Patient closing firmly on the T-Scan® III sensor



### 3.2.6 Preparation of T-Scan® III for recording

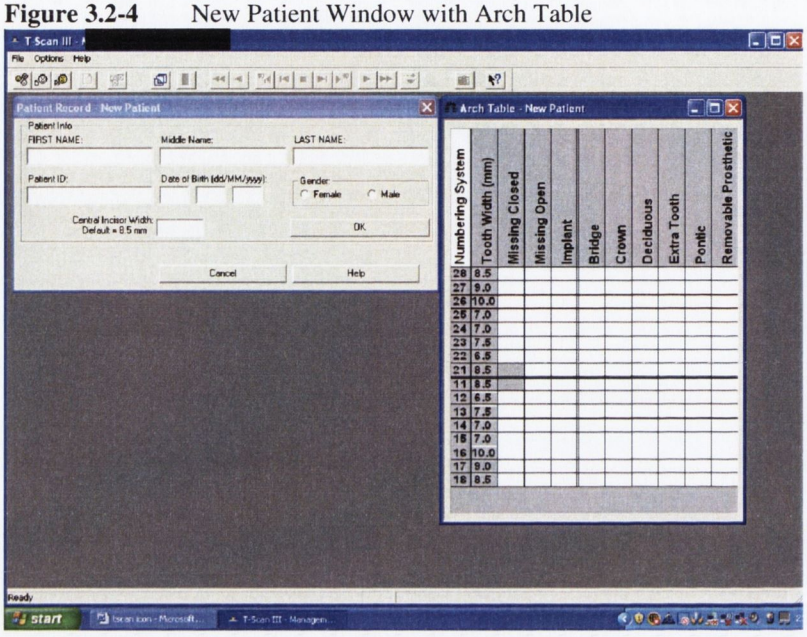
1) The sensor support and the sensor were inserted into the USB handle (Figure 3.2-1). The handle was inserted into the computers USB dock.
2) The icon was selected, on desktop to open the T-Scan® III programme.
3) The main window (Figure 3.2-3) was opened which contains the **Patient List**.

**Figure 3.2-3** Main window in T-Scan® III software



4) **New patient** was clicked to open a new patient record with the **Arch Table** (Figure 3.2-4). The patient's details, central incisor width and the teeth present were entered.

**Figure 3.2-4** New Patient Window with Arch Table




5) The **New Movie** button in the Patient Record (Figure 3.2-5) was selected and a real time window appeared (Figure 3.2-6).

**Figure 3.2-5** Patient Record in T-Scan® III software

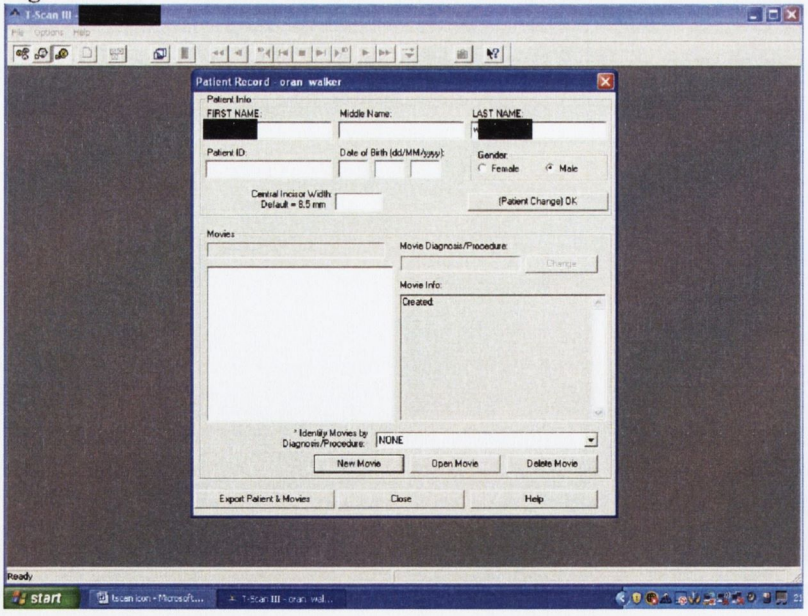
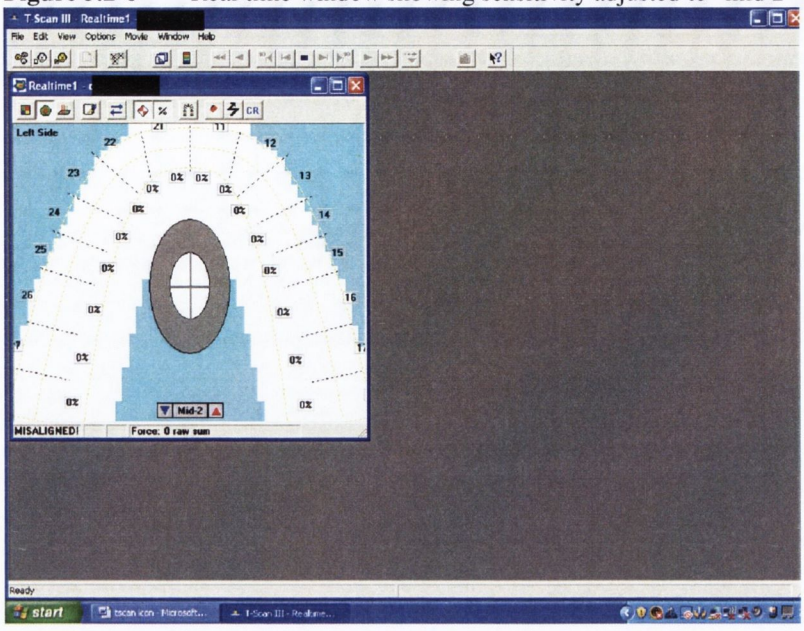
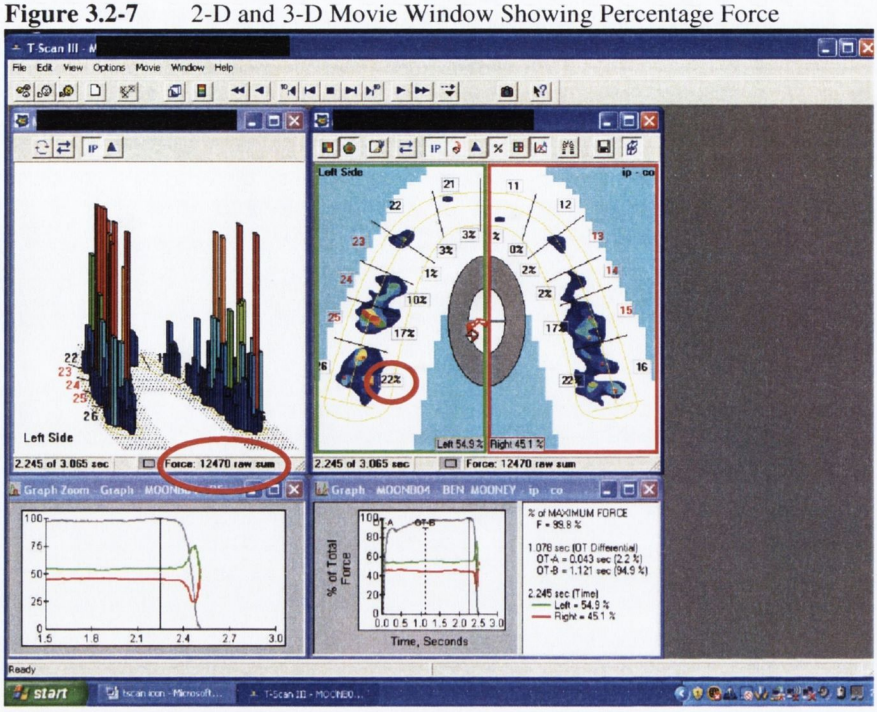


**Figure 3.2-6** Real time window showing sensitivity adjusted to "mid 2 "




6) Sensitivity was adjusted to "mid 2" level (Figure 3.2-6).
7) The patient was prepared for recording as outlined in section 3.2.5
8) The sensor was placed in the patient's mouth so that the sensor support pointer was between the two central incisors. The handle was kept as parallel to the occlusal plane as possible.
9) The **Record Start & Stop** button on the handle was pressed once.
10) The patient was instructed to bite down firmly to their maximum force on their back teeth. The first tooth contact caused the system to begin recording.
11) The **Record Start & Stop** button on the handle was pressed once again to stop the recording.
12) The real time window now becomes a 2-D movie window. A 3-D movie window, Graph Window and a Graph Zoom Window are also opened (Figure 3.2-7).

**Figure 3.2-7** 2-D and 3-D Movie Window Showing Percentage Force




13) The movie was saved by selecting **Save Movie** from the **File Menu.**

### 3.2.7 Examiners

A single examiner (Dr Shaunine Gallagher) evaluated the T-Scan® III recordings

### 3.2.8 Operators

One operator (Dr Shaunine Gallagher) carried out the recordings

### 3.2.9 Analysis of the T-Scan® III recordings

The outcome measure for each molar was the percentage of the total force in the mouth that occurred on this tooth. The % icon was selected on the 2-D window to show this reading (Figure 3.2-7). The reading for each tooth is shown in a box beside each tooth. In this example, the percentage force on 26 is 22%.

### 3.2.10 Statistical Analysis

Analysis of this component of the study was carried out by calculating the mean of each set of data and comparing the standard deviation of each reading to the mean.

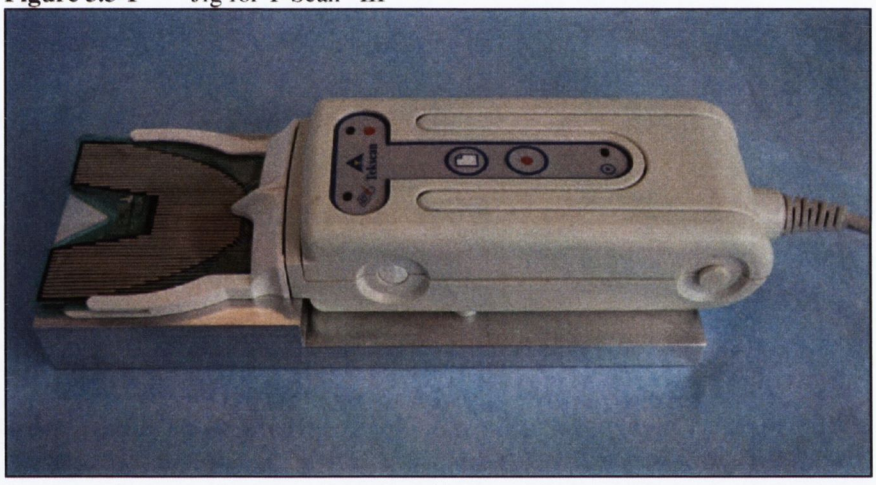
## 3.3 Laboratory Study

The ability of the T-Scan® III to measure a 25 Newton (N) force on different areas within a sensor and between different sensors was assessed. The reliability of the T-Scan® III to record a 25 N force repeatedly on one area, i.e how often the sensor can be reused, was also assessed. The force readings obtained from the T-Scan® III are recorded as raw sum. Raw sum is the number generated by the T-Scan® III which is displayed at the bottom of the 2-D movie window (Figure 3.2-7)

### 3.3.1 Intra sensor reliability

A metal jig (Figure 3.3-1) was custom fabricated to hold the Tekscan T-Scan® III in an Instron machine.

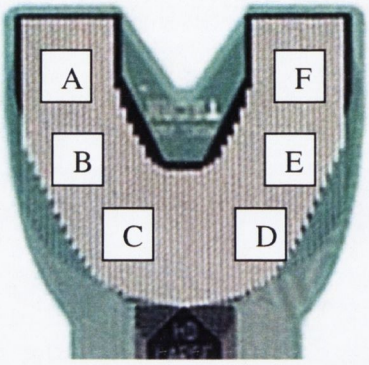
**Figure 3.3-1** Jig for T-Scan® III



1) An Instron machine was used to produce a single point force of 25 N.
2) Sensor I was placed in the T-Scan® III machine
3) The T-Scan® III on the customized jig was placed in the Instron using 2 clamps
4) The round metal tip of the Instron was placed over point A
5) A force of 25 N was applied to the sensor and the raw sum figure from the T-Scan® III recorded
6) The 25 N force was repeated a total of 10 times on point A

7) The 25 N force was repeated 10 times on point B, C, D, E, and F (Figure 3.3-2)

**Figure 3.3-2** T-Scan® III sensor showing approximate locations of pts A-F




### 3.3.2 Inter sensor reliability

The above 7 steps were carried out for sensor II and sensor III with the raw sum figure noted. This produced 6 sets of 10 readings per sensor.

### 3.3.3 Force curve

The ability of the T-Scan® III to measure an increasing single point force was assessed.

1) Sensor IV was placed in the T-Scan machine
2) The T-Scan® III was placed in the Instron using 2 clamps
3) The round metal tip of the Instron was placed over the sensor
4) Forces increasing by 5 N increments up to 100 N was placed on the sensor and the raw sum for each increasing 5 N was noted creating a force curve
5) Steps 1-4 was repeated for sensor V creating a second force curve

### 3.3.4 Statistical Analysis

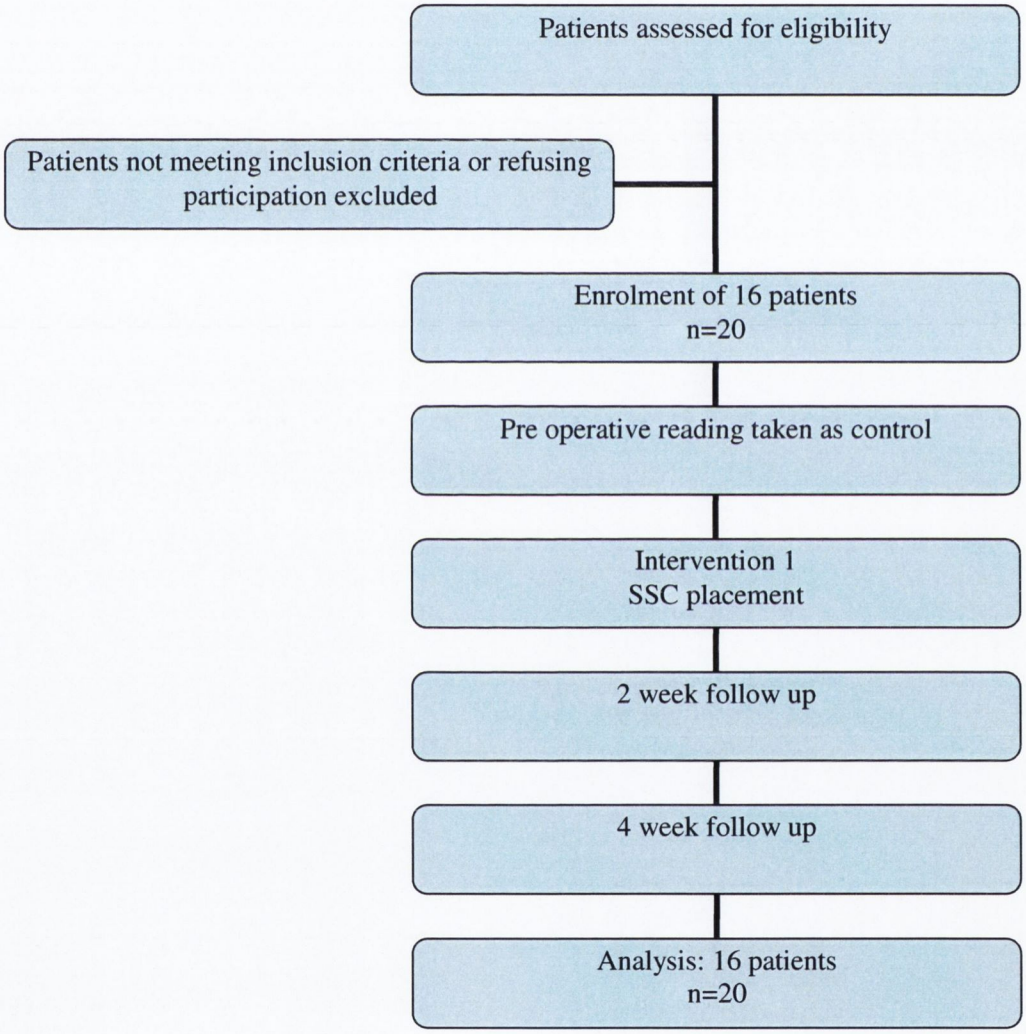
Analysis of the laboratory component of the study was carried out by calculating the mean of each set of data and comparing the standard deviation of each reading to the mean.

## PART II – CLINICAL STUDY

### 3.4 Clinical study population

The population was drawn from patients attending the Dublin Dental School and Hospital from children attending the undergraduate and postgraduate clinics for the placement of SSC.

### 3.5 Consort diagram for clinical study



## 3.6 Inclusion and exclusion criteria

**Table 3.6-1** Inclusion criteria

| Inclusion criteria | |
|---|---|
| 1. ASA ≤ grade 2 | PATIENT SPECIFIC FACTORS |
| 2. 6-12 years old | |
| 3. Cooperative patient | |
| 4. Treatment under LA or LA/$N_20$ | |
| 5. Primary and permanent molar requiring SSC | TOOTH SPECIFIC FACTORS |
| 6. Radiograph of tooth being restored | |

**Table 3.6-2** Exclusion criteria

| Exclusion criteria | |
|---|---|
| 1. ASA ≥ grade 3 | PATIENT SPECIFIC FACTORS |
| 2. Age < 6 or > 12 years old | |
| 3. Treatment under GA | |
| 4. Treatment on surfaces within previous month | |
| 5. Patient with unstable and unrepeatable occlusion | |
| 6. Un-cooperative patient | |
| 7. Premolars and anterior teeth | TOOTH SPECIFIC FACTORS |
| 8. Unopposed, partially erupted/infraoccluded tooth | |
| 9. Presence of sinus or fistula | |
| 10. Mobility of molar | |
| 11. Greater than 1/3$^{rd}$ root resorption | |

## 3.7 Study design

### 3.7.1 Permission and consent

Ethical approval was obtained from the Faculty of Health Sciences Research Ethics Committee, Trinity College Dublin (Appendix 7.1). A dental nurse was appointed as the gatekeeper who approached the potential participant. The patient and the parent/guardian received an information sheet (Appendix 7.4) and were requested to participate in the study. The parent/guardian was informed that the treatment plan did not need to be altered in order to participate in the study and

that treatment would not be altered if they did not want to participate. At the beginning of the treatment appointment the consent form was signed by the parent/guardian (Appendix 7.5).

### 3.7.2 Confidentiality

Measures to ensure confidentiality as outlined in Part I of study (section 3.2.2).

## 3.8 Data collection sequence

| | |
|---|---|
| Visit I – Patient recruitment | • Patient approached by gatekeeper and requested to participate<br>• Information sheet given<br>• Date for placement of the SSC recorded by the researcher |
| Visit II – Placement of SSC | • Consent signed prior to treatment<br>• Pre-operative recording taken (control)<br>• Post LA recording taken following administration of LA (post LA)<br>• Post-operative recording 1 taken post placement of the SSC (week 0)<br>• 2 follow up appointments made by researcher |
| Visit III – 2 week follow up | • Two week review<br>• Post-operative recording 2 taken by the researcher (week 2) |
| Visit IV – 4 week follow up | • Four week review<br>• Post-operative recording 3 taken by the researcher (week 4)<br>• Confirmation of follow up appointment for completion of treatment with operator |

### 3.9 Data collection procedure

The preparation of the patient and the T-Scan® III was carried out as outlined in Part I of the study (sections 3.2.5 and 3.2.6). A single examiner (Dr Shaunine Gallagher) undertook the evaluation of the 5 consecutive T-Scan readings taken for each of the crowns. Treatment was carried out by 3 experienced operators (Dr Rona Leith, Dr Eimear Norton and Dr Shaunine Gallagher). Occlusal measurements were carried out using a standardized protocol with the Tekscan T-Scan® III (section 3.2.6).

### 3.10 Evaluation of T-Scan® III readings

A total of 5 readings (pre operative, post local anaesthesia, post crown, 2 week post crown and 4 weeks post crown) for each patient were recorded on Microsoft Excel 2007® (Microsoft Inc., Redmond, WA, USA).

### 3.11 Statistical Analysis

All data were recorded on Microsoft Excel 2007® (Microsoft Inc., Redmond, WA, USA) with the graphical models also being generated by this software. Statistical analysis was carried out using the Wilcoxon test for non-parametric paired data and the level of significance was chosen to be $p<0.05$.

# 4 RESULTS

## PART I - T-SCAN® III REPRODUCIBILITY

### 4.1 Clinical calibration of T-Scan® III

Eleven consecutive children who were not undergoing any dental treatment were requested to occlude on the T-Scan® III sensor 3 times with the readings spaced 1 minute apart. The percentage of force on the most distal tooth - first permanent or primary molar on the left and right sided was recorded creating 6 sets of data per patient and 66 sets in total.

The means and standard deviations of each set of data were calculated to assess the spread or dispersion of the readings around the mean. All but 4 of the 22 standard deviations were less than 5% (Table 4.1-1) indicating good reliability of the T-Scan® III machine in children when the same sensor is used for each patient and placed in a standardised manner.

Since all standard deviations from the mean were less than 10%, we chose a change of greater than 10% in value as a parameter indicating a change in occlusion in the clinical component of the study.

**Table 4.1-1** Results for clinical calibration study

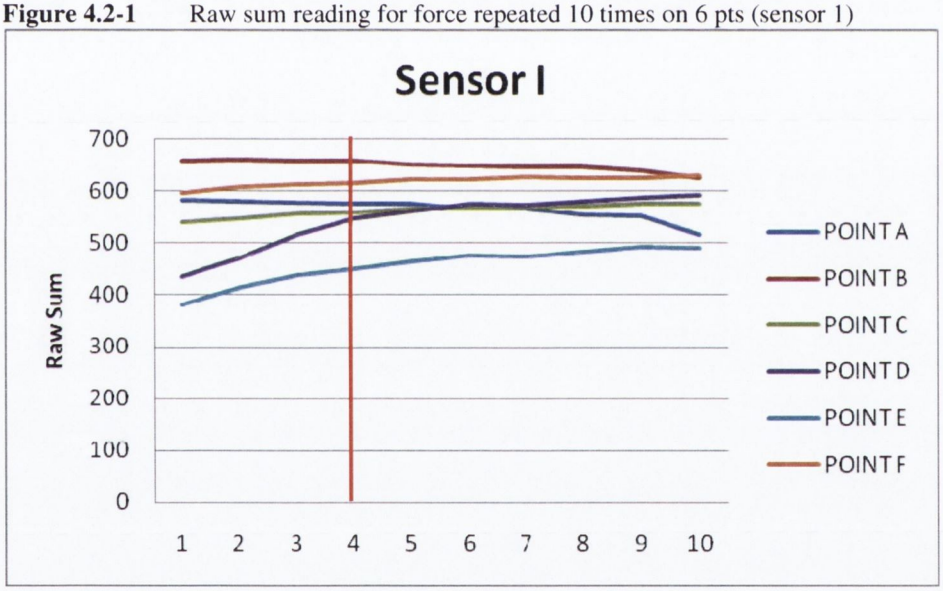
| | LEFT MOLAR | | | RIGHT MOLAR | | |
|---|---|---|---|---|---|---|
| | % FORCE | MEAN (%) | SDEV | % FORCE | MEAN (%) | SDEV |
| Patient 1 | 18 | | | 10% | | |
| | 12 | 16.6 | 4.1 | 28 | 19 | 9 |
| | 20 | | | 19 | | |
| Patient 2 | 4 | | | 29 | | |
| | 7 | 7 | 3 | 32 | 29 | 3 |
| | 10 | | | 26 | | |
| Patient 3 | 25 | | | 6 | | |
| | 24 | 24.6 | 0.6 | 23 | 16 | 8.9 |
| | 25 | | | 19 | | |
| Patient 4 | 43 | | | 23 | | |
| | 40 | 40.6 | 2.1 | 25 | 23 | 2 |
| | 39 | | | 21 | | |
| Patient 5 | 40 | | | 23 | | |
| | 40 | 37.3 | 4.6 | 28 | 24 | 3.6 |
| | 32 | | | 21 | | |
| Patient 6 | 24 | | | 13 | | |
| | 25 | 23 | 2.7 | 9 | 10 | 2.7 |
| | 20 | | | 8 | | |
| Patient 7 | 21 | | | 19 | | |
| | 21 | 20.3 | 1.2 | 4 | 10 | 7.9 |
| | 19 | | | 7 | | |
| Patient 8 | 4 | | | 2 | | |
| | 3 | 3.3 | 0.6 | 0 | 1 | 1 |
| | 3 | | | 1 | | |
| Patient 9 | 40 | | | 30 | | |
| | 38 | 36.3 | 4.7 | 28 | 28.3 | 1.5 |
| | 31 | | | 27 | | |
| Patient 10 | 13 | | | 14 | | |
| | 20 | 17.6 | 4 | 19 | 17.3 | 2.9 |
| | 20 | | | 19 | | |
| Patient 11 | 20 | | | 21 | | |
| | 21 | 20 | 1 | 19 | 23.3 | 5.9 |
| | 19 | | | 30 | | |

## 4.2 Laboratory calibration

### 4.2.1 T-Scan® III sensor reproducibility

Figure 4.2-1 shows a plot of the 10 consecutive raw sum reading from the T-Scan® III for the 25N force applied to points A to F for sensor 1. There is considerable variation for the initial 3 or 4 readings thus tempering of the sensor by occluding 3 to 4 times on the sensor prior to recording is recommended. The following 6 readings for each point are consistent, indicating that unlike other marking media that these sensors are reusable for a minimum of 6 times in children. Apart from occasional outliers this pattern is consistent for sensor 2 (Figure 4.2-2) and sensor 3 (Figure 4.2-3).

**Figure 4.2-1** Raw sum reading for force repeated 10 times on 6 pts (sensor 1)




### 4.2.2 Intra sensor reliability

There is considerable variability between the readings in different areas of sensors 1 (Figure 4.2-1), 2 (Figure 4.2-2) and 3 (Figure 4.2-3). The lowest readings indicates the least sensitivity which appeared to be found in the anterior regions of the sensor.

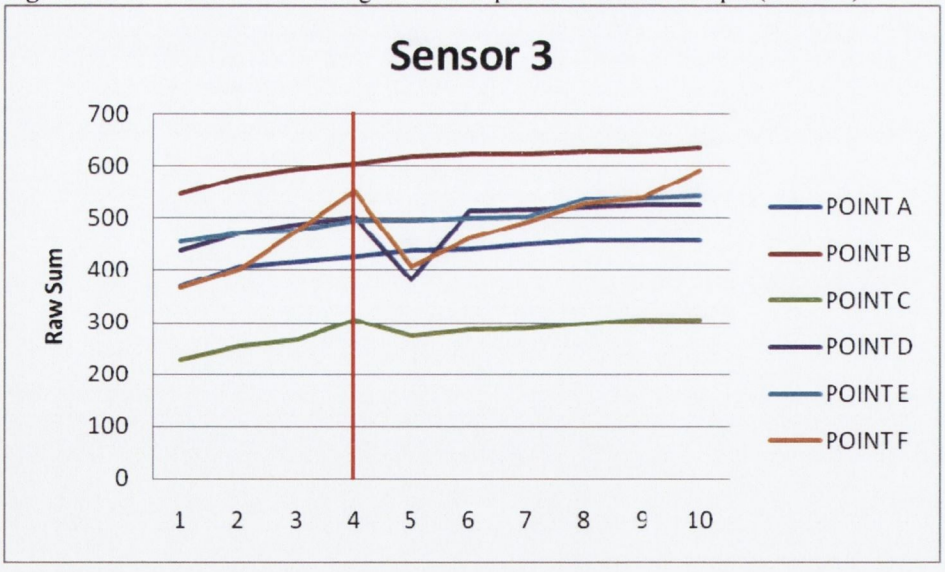
### 4.2.3 Inter sensor reliability

There is a large variation in the raw sum readings between sensors. The readings resulting from a standard 25N force varied from approximately 400 to 650 for sensor 1 (Figure 4.2-1), 300 to 600 for sensor 2 (Figure 4.2-2) and 200 to 650 for sensor 3 (Figure 4.2-3).

**Figure 4.2-2** Raw sum reading for force repeated 10 times for 6 pts (sensor 2)

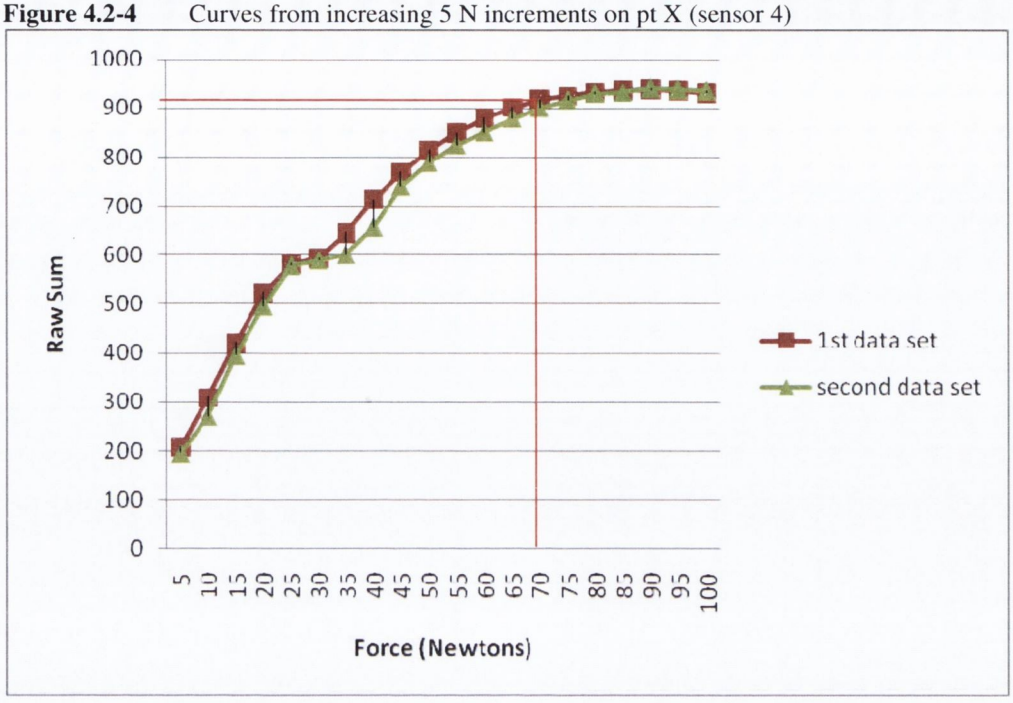



**Figure 4.2-3** Raw sum reading for force repeated 10 times for 6 pts (sensor 3)



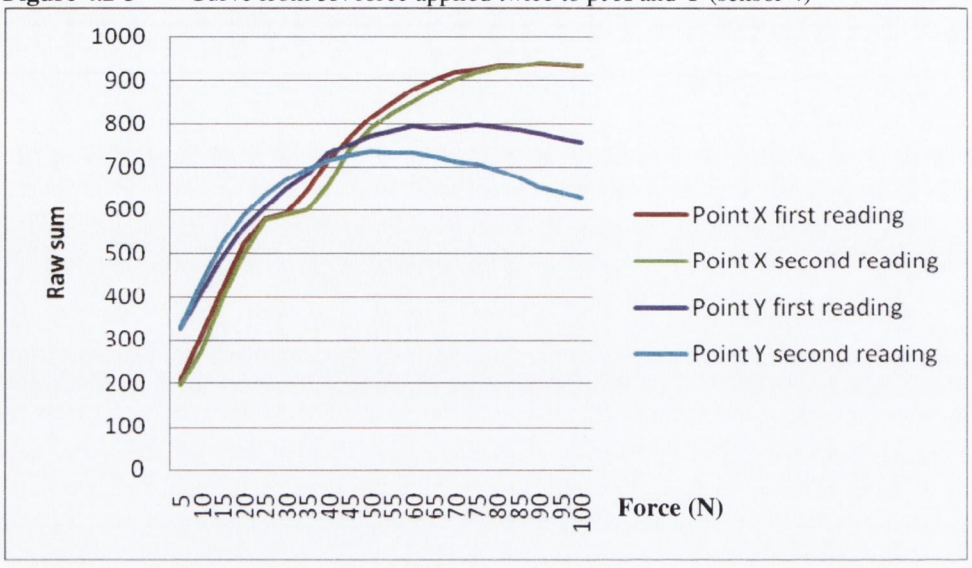
### 4.2.5 Force curve

**Figure 4.2-4** Curves from increasing 5 N increments on pt X (sensor 4)




The T-Scan® III is able to predictably measure forces up to 60-70 N at a single point, before a fall off in sensitivity is seen (Figure 4.2-4). The consistent readings found for the second set of data which was taken from the same point confirms the ability of the T-Scan® III to be reused. No reduction in sensitivity was seen for the second set of data despite application of 20 forces on the same point to obtain the first set of data.

**Figure 4.2-5** Curve from 5N force applied twice to pt X and Y (sensor 4)




The curves in Figure 4.2-5 demonstrate the consistency of readings for a single point in sensor but demonstrates the variability between two sites within the same sensor.

## PART II – CLINICAL STUDY

### 4.3 Descriptive data

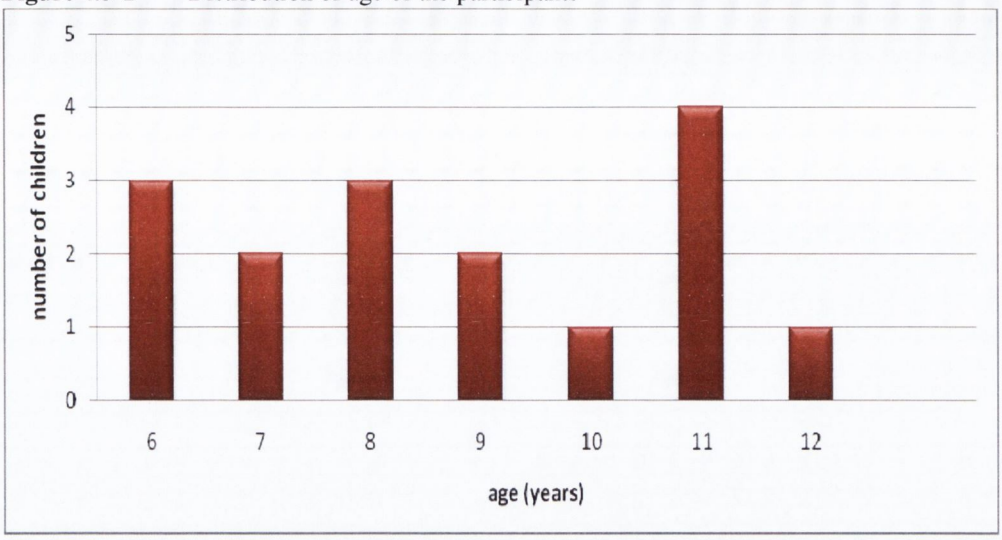
Sixteen patients received a total of 20 SSC from 3 experienced operators. The gender distribution is shown in Table 4.3-1.

**Table 4.3-1** Gender distribution in the study group

| | Number | Percentage of group |
|---|---|---|
| **Males** | 9 | **56%** |
| **Females** | **7** | **44%** |

The mean age was 8.75 years and the ages of the patients ranged from 6 to 12 years. Figure 4.3-1 shows the age distribution of the study participants.

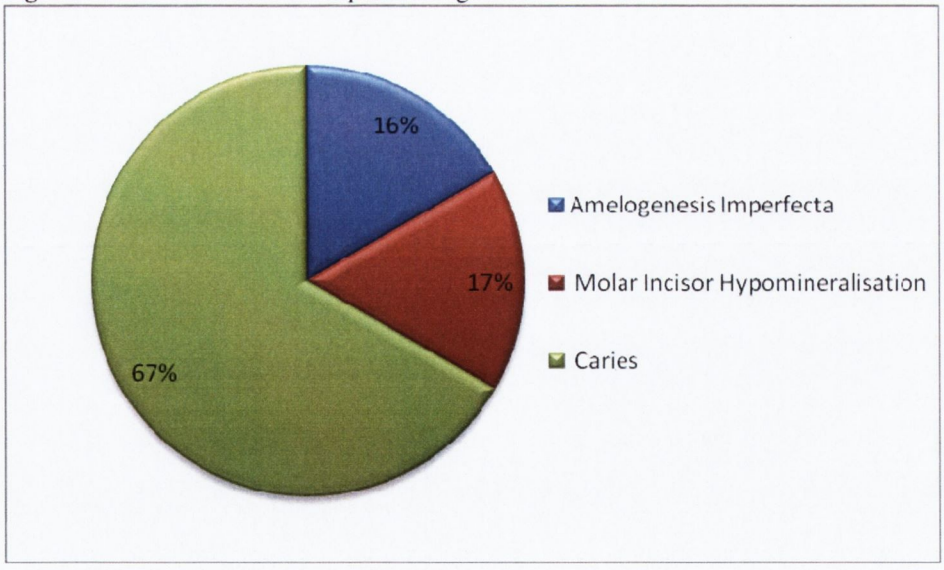
**Figure 4.3-1** Distribution of age of the participants




## 4.4 Treatment data

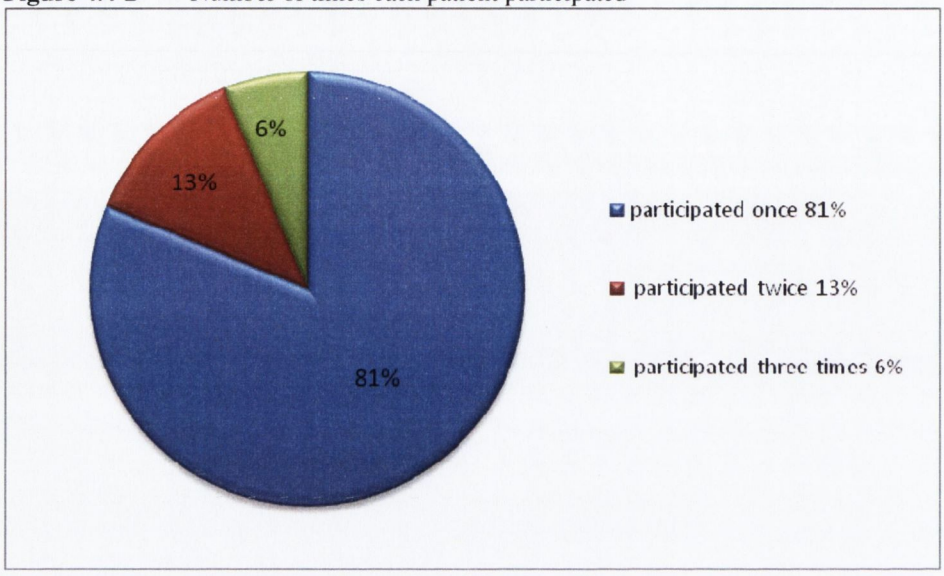
The reasons for placement of SSC included caries, amelogenesis imperfecta (AI) and molar incisor hypomineralisation (MIH). The distribution of the diagnoses of the patients is shown in figure 4.4-1.

**Figure 4.4-1** Distribution of patient diagnoses



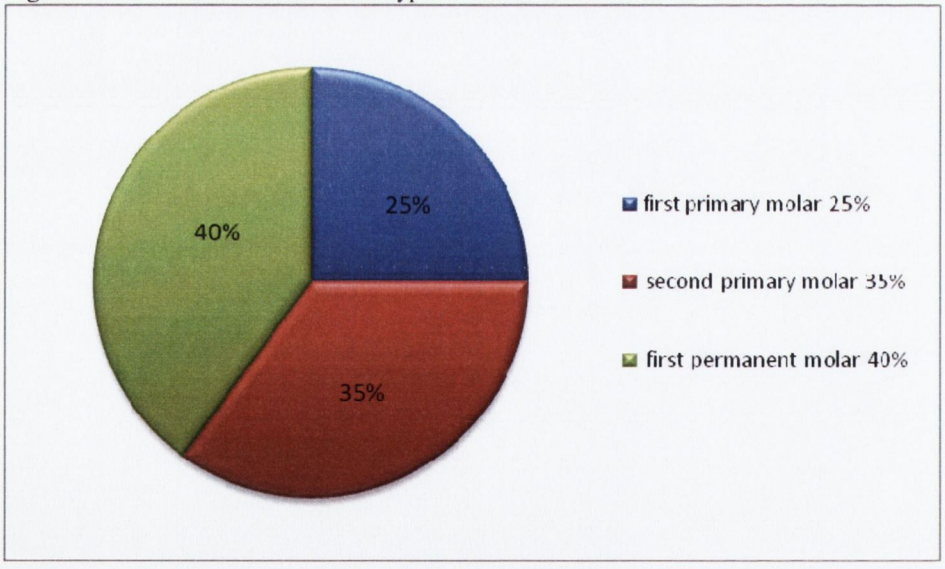

The number of times each patient participated in the study varied from 1 to 3 times. The number of times each patient participated is shown in figure 4.4-2.

**Figure 4.4-2** Number of times each patient participated



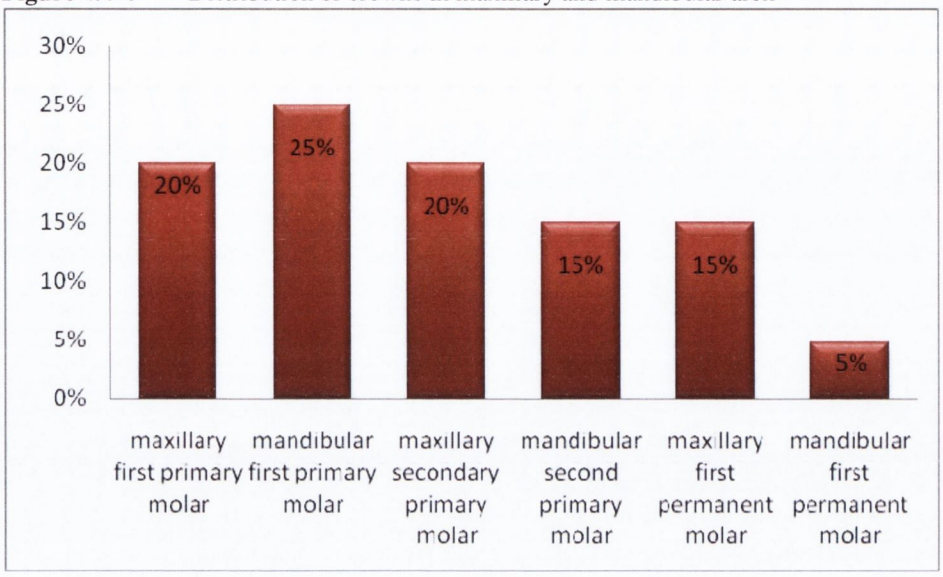

SSC were placed on both primary and permanent molars. The distribution of the type of tooth on which crowns were placed is shown in figure 4.4-3.

**Figure 4.4-3** Distribution of the type of the tooth crowned



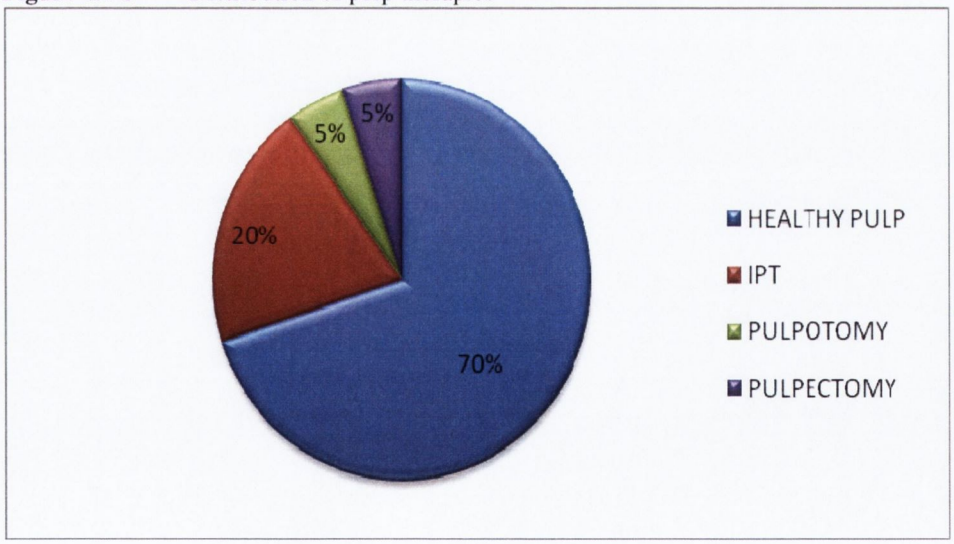
The distribution of the crown locations is shown in figure 4.4-4.

**Figure 4.4-4** Distribution of crowns in maxillary and mandibular arch




The status of the pulp was diagnosed and the appropriate pulp treatment carried out if required prior to crown placement. The distribution of pulp therapies required is shown in figure 4.4-5.

**Figure 4.4-5** Distribution of pulp therapies

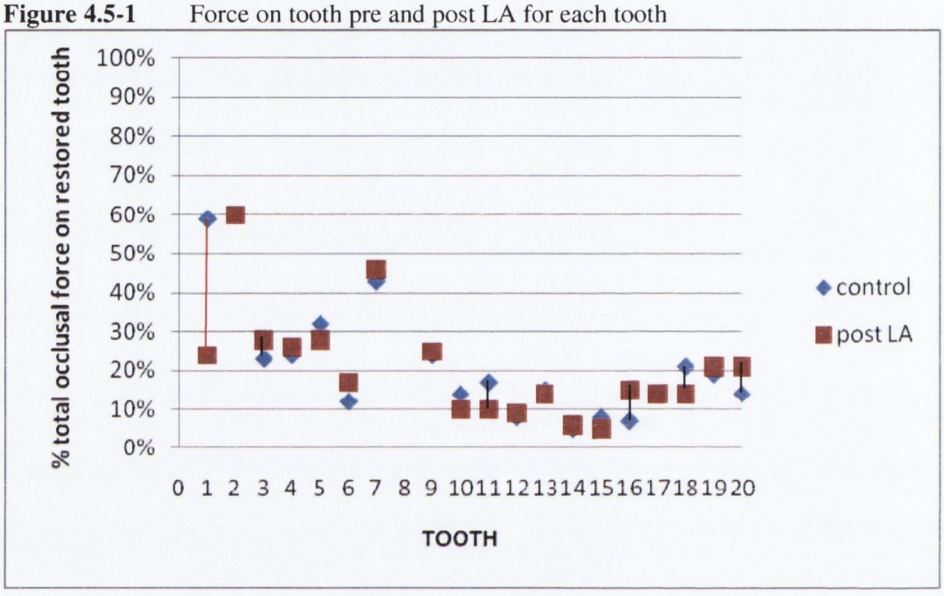


## 4.5 Clinical parameters

### 4.5.1 Effect of local anaesthesia

The ability of a child to achieve MIP after administration of LA was assessed by comparing the control reading with the reading post administration of LA. A graphical representation of the result is shown in figure 4.5-1.

**Figure 4.5-1** Force on tooth pre and post LA for each tooth




19 crowns were analysed as 1 patient had to be excluded from this reading due to becoming upset post LA. One out of the 19 sets of data differed by > 10%, indicated by a red vertical line. The data was not normally distributed thus a Wilcoxon Signed Rank test assessed significantly differences in data (Table 4.5-1).

**Table 4.5-1** Wilcoxon for occlusal force pre and post LA

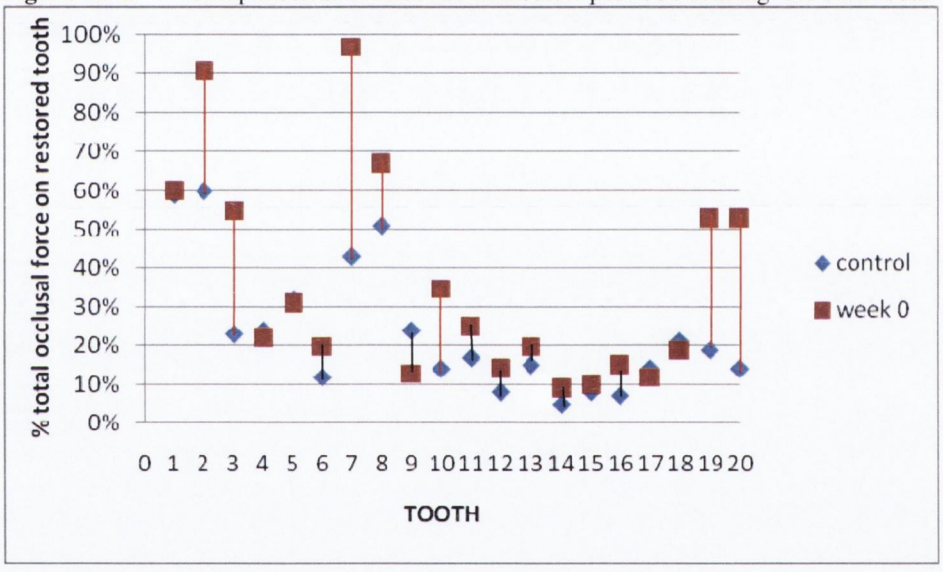
| | |
|---|---|
| **Median Difference** | 0 |
| **Interquartile range** | 0.11, 0.58 |
| **N** | 19 |
| **Wilcoxon statistic** | 73 |
| **P-value** | 0.887 |
| **No significant difference : Wilcoxon p=0.887** | |

The p-value indicates that the null hypothesis is accepted and this suggests that there is no significant difference in the readings pre and post LA.

### 4.5.2 Placement of SSC producing interferences

The effect of placement of a SSC using a standard technique under LA on the occlusion was assessed by comparing the preoperative measurement with the post crown placement measurement. A graphical representation of the comparison is shown in figure 4.5-2.

**Figure 4.5-2** Comparison of control and immediate post SSC readings for each tooth




For 13 out of 20 patients, there was no significant difference in pre-operative readings and the reading immediately post placement of crown i.e. these crowns did not cause a premature contact. Seven out of 20 SSC produced readings 10% greater than the control, indicated by a red vertical line, thus were deemed to cause a premature contact. Long vertical lines between the readings (Figure 4.5-2) graphically represents that overall, premature contacts occur immediately post SSC placement.

As the data for all 20 patients was not normally distributed a Wilcoxon Signed Rank test was used to assess if there was a statistical difference. The results are shown in Table 4.5-2.

**Table 4.5-2** Wilcoxon for occlusal force pre and post SSC

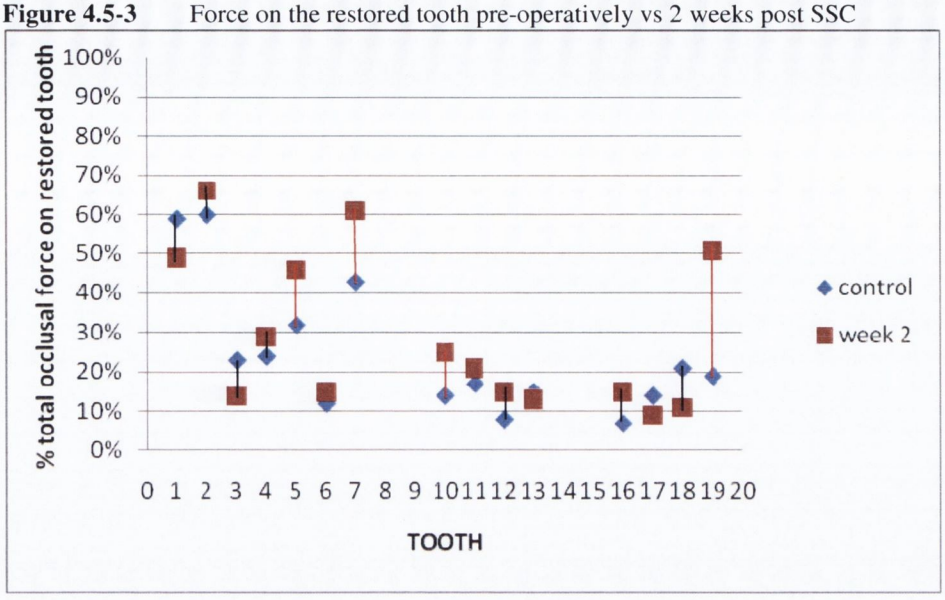
| | |
|---|---|
| **Median Difference** | 0.055 |
| **Interquartile range** | 0.125, 0.3975 |
| **N** | 20 |
| **Wilcoxon statistic** | 39.5 |
| **P-value** | 0.01521 |
| **Significant difference : Wilcoxon p=0.01521** | |

The p-value indicates that the null hypothesis is rejected and this suggests that overall there is a significant difference in percentage force on the restored tooth preoperatively and post crown placement.

### 4.5.3 Is the interference produced resolved in 2 weeks?

The patients were unable to have any dental treatment carried out that may alter their occlusion at the 2 week post operative visit. As a consequence, the return rate for this visit was only 15 out of 20 patients attending. Two of the 7 patients with high crowns immediately post placement did not attend thus 5 of the 7 SSC that caused premature contacts immediately post SSC placement were assessed at this 2 week visit. One of the 5 SSC had a reading within 10% of the control, indicating resolution of the initial premature contact and 4 out of the 5 exhibited reduced differences in the control and 2 week readings, indicating reduction of the premature contacts.

**Figure 4.5-3** Force on the restored tooth pre-operatively vs 2 weeks post SSC




As this data for the 15 teeth was also not normally distributed, a Wilcoxon Signed Rank test was used to assess if overall the data was significantly different. The results are shown in table 4.5-3.

**Table 4.5-3** Wilcoxon for occlusal force preop vs 2 weeks post SSC

| | |
|---|---|
| **Median Difference** | **0.02** |
| **Interquartile range** | 0.14, 0.33 |
| **n** | 15 |
| **Wilcoxon statistic** | 36 |
| **P-value** | 0.1876 |
| **Is no significant difference : Wilcoxon p=0.1876** | |

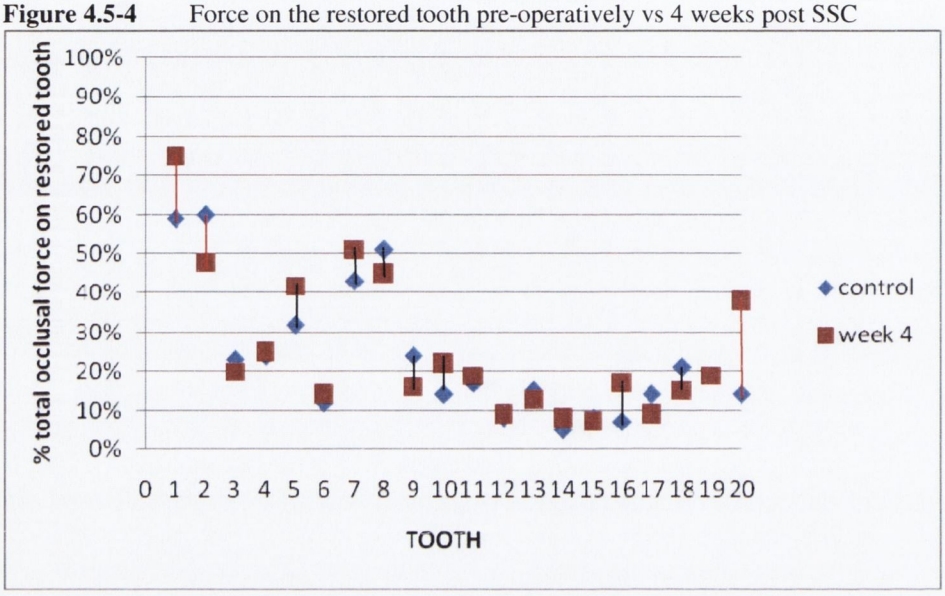
The p-value indicates that the null hypothesis is accepted and suggests that overall there is no significant difference in percentage force on the restored tooth preoperatively and 2 weeks post crown placement.

### 4.5.4 Is the interference produced resolved in 4 weeks?

The return rate was 20 out of 20. The percentage force on the restored tooth at 4 weeks compared to the pre-operative reading is shown in figure 4.5-4. Of the 7

initial crowns that caused a premature contact, 2 of these did not return to within 10% of the control reading (Figure 4.6-1, tooth 2 and 20). The difference between the control and immediate post crown reading was large for these crowns – 31% and 39%.

**Figure 4.5-4** Force on the restored tooth pre-operatively vs 4 weeks post SSC




As this data for the entire 20 crowns was also not normally distributed, a Wilcoxon Signed Rank test was used to assess if the data was significantly different.

**Table 4.5-4** Wilcoxon for occlusal force preop vs 4 weeks post SSC

| | |
|---|---|
| **Median Difference** | 0.01 |
| **Interquartile range** | 0.125, 0.2525 |
| **N** | 20 |
| **Wilcoxon statistic** | 73 |
| **P-value** | 0.3867 |
| **No significant difference : Wilcoxon p=0.3867** | |

The p-value indicates that the null hypothesis is accepted and this suggests that there is no significant difference in percentage force on the restored tooth pre

operatively and 4 weeks post crown placement. A crown that was placed high that the occlusion normalizes within a 4 week period in children.

## 4.6 Summary of results from clinical study

The results are shown in Table 4.6-1 with the SSC which caused premature contacts highlighted in green.

**Table 4.6-1** Results table for clinical data

| Tooth | Control | Post LA | Week 0 | Week 2 | Week 4 |
|---|---|---|---|---|---|
| 1 | 59% | 24% | 60% | 49% | 75% |
| 2 | 60% | 60% | 91% | 66% | 48% |
| 3 | 23% | 28% | 55% | 14% | 20% |
| 4 | 24% | 26% | 22% | 29% | 25% |
| 5 | 32% | 28% | 31% | 46% | 42% |
| 6 | 12% | 17% | 2% | 15% | 14% |
| 7 | 43% | 46% | 97% | 61% | 51% |
| 8 | 51% | - | 67% | - | 45% |
| 9 | 24% | 25% | 13% | - | 16% |
| 10 | 14% | 10% | 35% | 25% | 22% |
| 11 | 17% | 10% | 25% | 21% | 19% |
| 12 | 8% | 9% | 14% | 15% | 9% |
| 13 | 15% | 14% | 20% | 13% | 13% |
| 14 | 5% | 6% | 9% | - | 8% |
| 15 | 8% | 5% | 10% | - | 7% |
| 16 | 7% | 15% | 15% | 15% | 17% |
| 17 | 14% | 14% | 12% | 9% | 9% |
| 18 | 21% | 14% | 19% | 11% | 15% |
| 19 | 19% | 21% | 53% | 51% | 19% |
| 20 | 14% | 20% | 53% | - | 38% |
| Return Rate | 20/20 | 19/20 | 20/20 | 15/20 | 20/20 |

# 5 DISCUSSION

A search of the literature revealed that this is the first study regarding changes to a child's occlusion following restoration of a tooth with a SSC, despite the use of SSC since the 1950's. When occlusion has been addressed in the literature, it is mentioned briefly with recommendations appearing to be based on clinical opinion. Anecdotally, SSC placed high in occlusion do not cause problems for children. The current BSPD guidelines advise avoidance of interferences of greater than 1.5mm (Kindelan 2008). It has been suggested that interferences less than 1mm are well tolerated with dentoalveolar compensation occurring within a few weeks (Kindelan 2008). The Hall technique however, recommends placement of the SSC without consideration of occlusion (Innes 2007).

Two computerized occlusal analysis systems have been recently developed to assess occlusal contacts. The T-Scan® III system and the Dental Prescale Occluzer (Fuji Film, Tokyo, Japan) both utilise pressure sensitive sensors. Previously the T-Scan was unreliable as the sensor thickness and inflexibility caused mandibular shifts (Hidaka 1999). The T-Scan has since been modified so that the sensor is now 100 microns thick, which is comparable to thinnest of the Prescale sensors - 97 microns (Hidaka 1999). The T-Scan® III was used in this study as it has the ability to detect occlusal contacts and indicate the portion of the total force generated that occurs on each tooth i.e. force distribution, not actual force.

The clinical calibration of the system was undertaken on a consecutive sample of children, without excluding children unable to repeatably achieve MIP. This meant that both the reliability of children's ability to achieve MIP and the reliability of the T-Scan® III were being jointly assessed. It was found that standard deviation from the mean was less than 5% for over 80% of the patients showing good reliability for the T-Scan® III in children over 6 years old. This negates previous reports in the literature regarding children's poor ability to achieve MIP consistently. The standard deviations were less than 10% in all patients, hence any

change of greater than 10% indicated a premature contact for the clinical part of the study.

The reliability of measurement by the T-Scan® III was also assessed in a laboratory study. The sensor reliability for a 25 N force on one point on a particular sensor appeared to be good. The first 3-4 readings were variable (Figure 4.1-1, 4.2-2 and 4.2-3) however subsequent readings were consistent. This verifies the manufacturer's recommendation to temper the sensor prior to use. The variation in the readings was only approximately 5% for up to 6 additional readings taken after the initial 4 tempering readings. This also demonstrates that a T-Scan® III sensor is able to be reused up to 6 times. When assessing the ability of the T-Scan® III to measure an increasing force on a single point (Figure 4.2-4) it was found that the T-Scan® III continued to produce reliable measurements up to 40 times on a single point. This is in contrast with previous recommendations in the adult literature that sensors should be used only once (Saraçoğlu and Ozpinar 2002) where perforation of the sensor was reported with reuse in adults. This may be due to the fact that smaller forces are generated in a child's MIP compared to adults. Perforations were not found in the clinical calibration, the laboratory studies or the clinical study in children.

Substantial intra sensor variability was found when assessing repeatability of different points on a single sensor. The anterior portion of the sensor appeared to be less sensitive than the posterior segments. For the clinical study, the variability within the sensor was minimised by ensuring that the sensor was placed in the same position for each reading which was aided by the mid line pointer on the T-Scan® III handle. Variability was also observed between sensors i.e. inter sensor variability, especially when the more anterior segments of the sensors are compared. This variability was eliminated from the clinical components by using the same sensor for the 5 readings that were taken for each patient. In addition to reuse of sensors and standarised placement, use of multiple readings prior to recording is recommended when using the T-Scan® III, to reduce the risk of

recording aberrant readings which have been shown to occur when a force is applied to a single point on a sensor (Figure 4.2-4). It is important to be aware of this for future research using the T-Scan® III.

The T-Scan® III's ability to measure percentage of total force on the tooth in question and how this changes is difficult to measure as there is no gold standard in assessment of occlusal forces. No method had been developed to confirm construct validity. The laboratory validity of the T-Scan® III was estimated by applying actual force in N to the sensor. A linear relationship was found between the increasing applied load in N and the T-Scan® III reading, reported as raw sum, until approximately 60-70N where the line became horizontal (Figure 4.2-4). This level correlated to approximately 900 raw sum.

Clinically the raw sum for most child patients, spread over the occlusal surfaces in the entire mouth, ranged from 700 to 7000 with the most force on one tooth registering 1750 raw sum. Despite this high reading of 1750 raw sum, the majority of the readings in the clinical study were found to below 1000 raw sum per tooth. The forces recorded in the clinical study were therefore in the range where T-Scan® III raw sum reading directly correlated with N. These laboratory findings suggest that T-Scan® III is able to accurately measure the force in N at lower levels, up to 900 raw sum or 60-70 N per tooth. Although the T-Scan® III does not measure forces greater 60-70 N reliably (Figure 4.2-4), it does predictably measure the distribution and pattern of the forces when the same sensor is used and placed in a similar manner.

In this study no statistical difference was found between the control readings taken prior to placement of SSC and the readings taken after administration of LA. This proves that use of LA does not disturb a child's ability to reproduce MIP. Confirmation of this fact enables us to predictably compare readings taken when the child has been anaesthetised and those taken when no anesthesia has been administered. Only one pair of readings was very different and this may be due to

the inability of some children (also adults) to understand the concept of MIP despite explanation and practice. This finding also confirms the reliability of the T-Scan® III in a child population as similar readings were obtained for the majority of children for the control and post LA administration readings. These results, in addition to the clinical calibration, confirm that despite opinion in the literature, children as young as 6 years old are able to consistently attain MIP.

Despite adherence to standard operative technique, placement of SSC in children can inadvertently lead to an alteration in occlusion. The proportion of SSC that caused a premature contact has not been reported previously. In our study 35% of crowns placed caused a premature contact. The clinical calibration of the T-Scan® III in children reported that the largest deviation from the mean of the three readings was 10%. We therefore defined any change in readings of greater than 10% as a premature contact. Although only 7 of the 20 crowns placed had a premature contact the statistical analysis for the entire 20 crowns showed a statistically significantly difference between pre and post placement values ($p=0.01521$). Disturbance of occlusion following placement of a crown was anecdotally expected however the contrary was found.

At the 2 week time point, only 15 crowns were evaluated. There was no significant statistical difference in the measurements from baseline. This indicates that for the entire group the force had adjusted towards preoperative levels. All 20 crowns were evaluated at 4 weeks. As a group no significant difference was found when compared to baseline. Two of the 7 SSC with initial readings indicating premature contacts did not return to within 10% of their respective control readings. These 2 SSC (Table 4.6-1, tooth number 2 and 20) had large interferences immediately postoperatively. Both of these occlusions were examined using the T-Scan 2-D Movie readings. The force for the entire occlusion had redistributed to show a stable even occlusion, suggesting that baseline readings could no longer be achieved. We propose the large percentage force change from the SSC has resulted from either intrusion of the restored tooth or extrusion of the adjacent

teeth. The effect of increasing the vertical dimension of occlusion allowed the extrusion of the remaining teeth and some intrusion of the restored tooth as occurs in the Dahl concept. The remaining teeth have taken more of the total force in the mouth, hence the initial control readings will not be achieved.

Differences in the readings are more difficult to detect in smaller sample sizes. To ensure adequate sample size a prospective power calculation is the ideal. This ensures that any statistical tests applied to the data accurately detect any differences. In this study a prospective power calculation was not possible as no similar studies existed. In the absence of this we attempted to include all eligible patients in the study. On analysing the results it was found that when differences occurred these were quite large and easily detectable indicating that a large sample size was not required.

Statistical analysis of study result is of great importance but does have some shortcomings. Statistical significant results do not indicate the variability of the results yet this may be of utmost importance in a clinical study. In our clinical study there was statistically significant difference in the control readings and the readings taken immediately post crown placement. It was found that a small portion of the crowns had rather large differences and that the remaining crowns had little or no difference. Overall there was a statistically significant difference however clinically only the minority of crowns demonstrated a difference and when the difference occurred it was quite large and easily detectable clinically.

A review of the literature on experimental OIs has stated that OIs in adults can cause short term local effects such as pain, headache, TMJ and muscle tenderness. However, given time, these symptoms resolve and in adults that chance of developing TMD from OIs is relatively low (Clarke *et al* 1999). None of the children in our study reported any discomfort, suggesting that OIs in children under the age of 12 years old do not cause pain or dysfunction. Greater adaptability of the masticatory system to occlusal abnormalities in children has

been postulated by Geering (1974). This, in addition to the quick resolution of a premature contact, makes the development of TMD from an OI even less likely in a child population.

There is no research on occlusal interferences in children following restorative treatment. Most of the literature relates to naturally occurring OIs. A double blinded 3 year study on 5, 10 and 15 year olds which removed naturally occurring OIs, found a significant association between interferences and signs and symptoms of TMD (Kirveskari *et al* 1989) while others suggest no role for occlusion in TMD (Carlsson and Droukas 1984, Agerberg and Sandstrom 1988). Most agree that TMD is multifactorial in children as well as in adults (Egermark-Eriksson *et al* 1983). TMD may be more likely to exist when more than one aetiological factor exists in a child (Vanderas and Papagiannoulis 2002).

Detection of patients predisposed to TMD is difficult so attempts should be made to prevent introduction of interferences. This is suggested by Kampe *et al* (1983) who reported an increase in masticatory muscle disturbances in adult patients with restored teeth and postulated that, in predisposed dentitions, restorations may be enough to exceed the tolerance level of the system and create TMD (Kampe *et al* 1983). This tolerance level may be quite high in children however no research has been carried out to find this tolerance level or to investigate long term effects in children.

Even though interferences occurred immediately post placement of a crown in our study, there appears to be little effect on the adaptable masticatory system of the child as no symptoms were reported. We have shown that any interferences resolve quickly in a child within 2-4 weeks.

Many mechanisms by which the interferences caused resolve have been proposed. Possible processes include intrusion of the restored tooth, extrusion of other teeth, condylar adaption and skeletal growth.

Eruption of the non restored teeth is one possibility. Tooth eruption and increase in alveolar bone height occurs more rapidly in younger children. In 5 to 16 years old child the average rate of increase in height of palatal vault was approximately 0.5mm per year which reduced to 0.1mm per year for the 16 to 31 year olds (Thilander 2009). These eruption rates alone do not match the rapid rate of premature contact resolution found in this clinical research. Tooth eruption rhythm mirrors the circadian rhythm of hormone release (Risinger and Proffitt 1996). Children having up to 20 times the amount of plasma growth hormone compared to adults (Greenwood *et a*l 1964). Growth hormone is usually released in the evening time which correlates with the time that tooth eruption is noted (Born et al 1988). This may account for the increased rate of normalisation or eruption found in our young study group. Re-establishment of the posterior occlusion following occlusal disturbances in adults has been found to occur at a much slower rate. A time frame of 8 months for establishment of the occlusion following placement of a 2mm anterior bite plane in an adult (Dahl *et al* 1975).

Classic research regarding increasing the vertical dimension of occlusion provides valuable insights to the possible mechanism of premature contact resolution. Dahl and Krogstad (1982) used fixed reference tantalum implants to assess relative tooth movements. The placement of tantalum implants in the upper and lower basal bones of the jaw acted as fixed reference points in 2 monthly radiographs. For all age groups, it was found that 40% of movement occurred due to intrusion and 60% due to over-eruption of teeth (Dahl and Krogstad 1982). Interestingly, an even larger portion of tooth movement was due to over-eruption in younger children. The eruptive potential in younger children along with the fact that this is primary tooth movement, may go some way to explaining resolution of premature contacts in our sample.

Another factor in the adaption of the occlusion would be in skeletal as well as dental changes. When skeletal and dental changes during orthodontic reduction of

deep open bite in an adolescent group was compared to an adult group, significantly greater condylar adaptation and posterior mandibular development in the adolescent group was noted (McDowell and Baker 1991). Similar to Dahl and Krogstad (1982) extrusion of posterior molars was responsible for most of the changes in adolescents with an average of 4.7mm of extrusion compared to only 1.3mm in the adult group (McDowell and Baker 1991). In agreement with previous suggestions we propose that one of the processes responsible for rapid adaptation of a child's masticatory system is eruption of the unrestored teeth.

Design of this study was particularly difficult as no similar research exists. Assessing a child's occlusion has been described as demanding on the child as well as the examiner (Kisling 1981). No gold standard exists for measuring MIP changes in adults or children. The use of the T-Scan® III appeared to be the most useful device for our purpose as it could calculate the percentage force on each tooth and changes could be assessed over time. Although we have shown reliability, a number of factors contribute to the difficulty in measuring MIP in children. We have shown that variation exists between sensors and within areas of a sensor, hence we reused sensors for each patient and utilised a standardised technique for placement of the sensor to eliminate these variations. The main limitation of the T-Scan® III was the sensor size. Two sensor sizes are available for the T-Scan® III. The sensor length was reduced in the smaller sensor which we used however, this proved too large for the younger patients. The sensor size was a factor resulting in exclusion of several patients in the 6-7 year old age group.

In future research, inclusion of a formal assessment of the temporomandibular joints (TMJ) and a pre and postoperative questionnaire regarding any signs and symptoms would be advisable. Longer term assessment of the patients regarding TMD that have received SSC would be the gold standard in conclusively proving that SSC and the rapidly resolving interferences that they may cause, have no long term effects on the TMJ. Confirmation of the reproducibility of children's occlusion means that SSC can continue to be used without concern regarding risk

of TMD development. The finding that a child as young as 6 years of age has a repeatable MIP means that other research in this area can be undertaken reliably. It would be beneficial if a sensor with reduced length and width could be developed to allow analysis of occlusion in younger children.

The findings of this research also have implications for the use of the T-Scan® III. Standardisation in reusing the same sensor, placing it in a standard fashion, tempering the sensor 3-4 times prior to use and taking several readings are steps that we have shown to maximise the reliability of the T-Scan® III in a child population. These recommendations can now allow investigations assess if reuse of a sensor can be recommended for an adult population.

Placement of a single SSC does not cause symptoms in the dentition of the 6-12 year old age group and adaptations occur in a matter of weeks. This study did not attempt to measure the magnitude of force on a tooth but to asses the distribution of forces and how they changed during and after the placement of a SSC. We have shown how previously reported limitations of the T-Scan® III can be minimised and how it can be used in the area of children's occlusion.

# 6 CONCLUSIONS

The T-Scan® III demonstrates good reproducibility clinically in children. This holds true for a group of consecutive children despite including all patients whether or not they appeared to have a repeatable MIP.

Reproducibility at a single point in a sensor following initial tempering of the sensor was noted in a laboratory setting. However assessment of intra sensor reproducibility revealed quite substantial variability especially between the anterior and posterior regions of a sensor. Thus we have recommended taking measures to ensure the sensor is placed in a standardised manner to reduce this variability. Inter sensor variability was also observed but was eliminated in this study by reusing the sensor for all readings taken for each patient. The T-Scan® III sensors have been found to be reusable up to 40 times when used with point forces of less than 100N. We also recommend use of multiple readings prior to recording a value to reduce risk of recording an aberrant reading.

Children as young as 6 years old have been shown to have repeatable occlusions despite opinion in the literature to the contrary. Administration of LA does not affect repeatability of a child's occlusion hence occlusal measurements with and without LA are comparable.

This is the first study to assess the frequency of premature contacts associated with placement of SSC in primary and permanent molars using a conventional technique. 7 out of 20 SSC (35%) caused a premature contact with the remaining 13 SSC having no effect on the child's occlusion. No symptoms were reported from any of the participants including those in which premature contacts occurred as well as the 2 SSC in which percentage of total force did not return to within 10% of initial levels.

At 2 weeks post SSC placement there was no statistical difference between the immediate post SSC placement readings and the preoperative readings. Hence when the placement of a SSC's caused a premature contact it was found that occlusion returned to initial levels in 2 weeks.

At four weeks, 2 of the 7 crowns that caused a premature contact still had readings > 10% from the control readings. These 2 crowns caused large occlusal disturbances. Analysis of the entire occlusion however revealed that despite this, a stable occlusion was established most probably due eruption of the remaining occlusion.

In summary young children appear to have an adaptable masticatory system in which changes occur quickly. The increased condylar adaptation, mandibular development and rate of tooth eruption appear to allow the adaptations required to allow occlusal harmony occur without signs and symptoms developing.

# 7 APPENDICES

## 7.1 Appendix 1: Copy of Ethical Approval

Figure 7.1.1 Ethical Approval

1711 2011 SCHOOL OF MEDICINE TRINITY COLLEGE DUBLIN
300 YEARS OF EXCELLENCE

Ms. Shuanine Gallagher,
Dept of Public and Child Dental Health,
Dublin Dental School,
Lincoln Place,
Dublin 2.

Monday, 13th October, 2008

**Study Title:**

A clinical study to evaluate centric occlusion changes in children following placement of a stainless steel crown

Dear Ms. Gallagher,

Further to the meeting of the Faculty of Health Sciences Research Ethics Committee on 24th June 2008, I am pleased to inform you that the above project has been approved without further audit.

Yours sincerely,

Dr. Orla Sheils
Chairperson
Faculty of Health Sciences Ethics Committee

School of Medicine
Faculty of Health Sciences
Professor Dermot Kelleher
Head of School of Medicine
Vice Provost for Medical Affairs
Ms Fedelma McNamara
School Administrator
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Email: medicine@tcd.ie

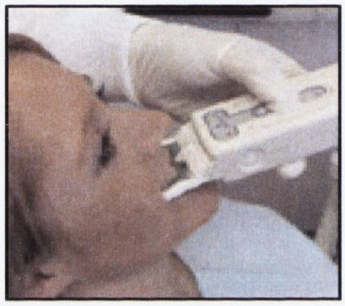
## 7.2 Appendix 2: Calibration study participant information sheet

Figure 7.2.1 Calibration study participant information sheet, page 1

PARTICIPANT INFORMATION SHEET

A clinical study to evaluate the T-Scan.

When we place a crown on a baby tooth we sometimes notice that they can be "high" or can prevent the child fully closing their teeth into the same position as before. We also notice that after about 2 weeks all children are be able to close fully again. This seems never to cause problems.



We have carried out a study to show that high crowns are not a problem. In the study we used a device to measure how well the children could bite before and after crown placement (see above).

**What are we asking you child to do?**

We want to confirm that the device works predictably on children when they have no treatment carried out on their teeth. We are asking your child to bite on this device 3 times today. The device is a thin foil sensor which will mark and record which pairs of teeth are biting together and how hard they are biting together. The sensor will be attached to a holder which in turn is connected to a computer.



Figure 7.2.2 Calibration study participant information sheet, page 2

**What are the benefits?**

The information we get from your child will help us understand how reliable the device is.

**Are there risks involved?**

There are no risks involved in having your child's bite measured. It is simply biting on some foil.

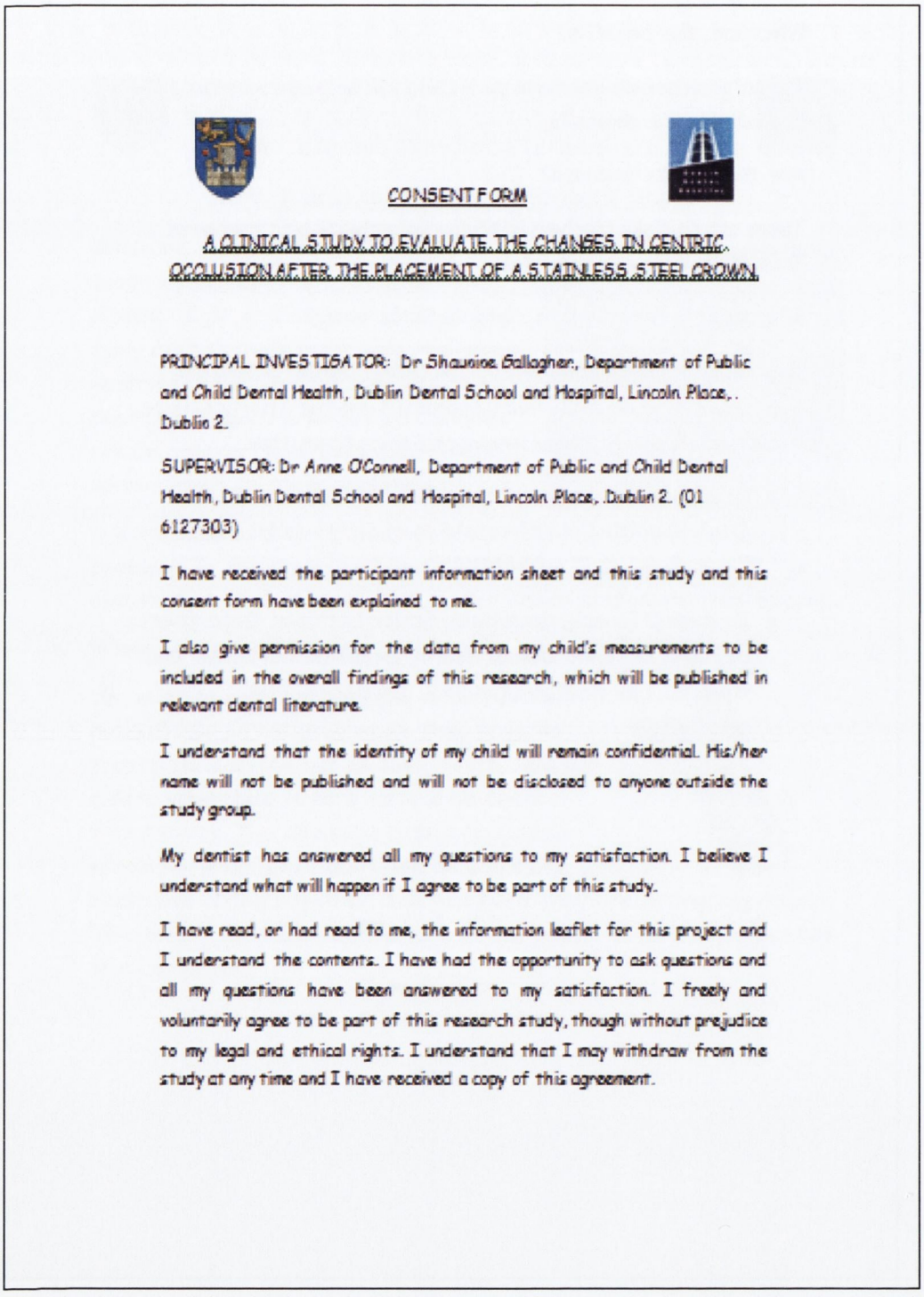
**Who grants permission to carry out this study?**

This study has been approved by the Dublin Dental School and Hospital. This study has ethical approval from the Trinity College, Faculty of Health Sciences Research Ethics Committee.

- Dr Shaunine Gallagher, Department of Public and Child Dental Health, Dublin Dental School and Hospital, Lincoln Place, Dublin 2. Tel: 01 6127303
- Dr Anne O'Connell, Consultant/Senior Lecturer, Department of Public and Child Dental Health, Dublin Dental School and Hospital, Lincoln Place, Dublin 2. Tel: 01 6127303

## 7.3 Appendix 3: Calibration Study Consent Form

Figure 7.3.1 Calibration Study Consent form, page 1



CONSENT FORM

A CLINICAL STUDY TO EVALUATE THE CHANGES IN CENTRIC OCCLUSION AFTER THE PLACEMENT OF A STAINLESS STEEL CROWN.

PRINCIPAL INVESTIGATOR: Dr Shaunice Gallagher, Department of Public and Child Dental Health, Dublin Dental School and Hospital, Lincoln Place,. Dublin 2.

SUPERVISOR: Dr Anne OConnell, Department of Public and Child Dental Health, Dublin Dental School and Hospital, Lincoln Place, .Dublin 2. (01 6127303)

I have received the participant information sheet and this study and this consent form have been explained to me.

I also give permission for the data from my child's measurements to be included in the overall findings of this research, which will be published in relevant dental literature.

I understand that the identity of my child will remain confidential. His/her name will not be published and will not be disclosed to anyone outside the study group.

My dentist has answered all my questions to my satisfaction. I believe I understand what will happen if I agree to be part of this study.

I have read, or had read to me, the information leaflet for this project and I understand the contents. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights. I understand that I may withdraw from the study at any time and I have received a copy of this agreement.

Figure 7.3.2 Calibration Study Consent form, page 2

PARTICIPANT'S NAME:_____

PARTICIPANT'S SIGNATURE:_____

Date: _____

Where the participant is incapable of comprehending the nature, significance and scope of the consent required or is under 18 years old, the form must be signed by a person legally competent to give consent.

*NAME OF CONSENTER, PARENT or GUARDIAN_:*_____

*CONSENTOR'S SIGNATURE:* _____

*RELATION TO PARTICIPANT:* _____

STATEMENT OF INVESTIGATOR'S RESPONSIBILITY: I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

INVESTIGATOR'S SIGNATURE: _____

DATE: _____

## 7.4 Appendix 4: Clinical study information sheet

Figure 7.4.1 Clinical study information sheet, page 1

PARTICIPANT INFORMATION SHEET

A clinical study to evaluate the changes in centric occlusion after the placement of a stainless steel crown.

**Why are we doing this study?**

Your child has an appointment in the Dublin Dental School and Hospital. Your child will be examined and your dentist and if your child requires treatment your dentist will describe the options open to you. If your child requires a crown or a cap on his/her baby back tooth we may ask you to participate in this study.

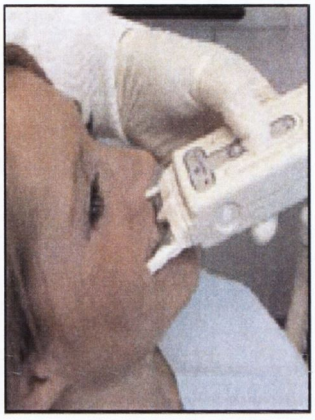
When we place a crown on a baby tooth we sometimes notice that they can be "high" or they prevent the child fully closing their teeth into the same position as before. We also notice that after about 2 weeks all children are be able to close fully again. This seems never to cause problems.

In this research project we will measure how many and which teeth, bite together before treatment, after the crown is placed and again two weeks later. We want to do this to confirm and check that the child's bite returns back to normal and to check how long it takes.



Figure 7.4.2 Clinical study information sheet, page 2

**What does this involve?**



This will involve having your child bite on a thin foil sensor which will mark and record which pairs of teeth are biting together and how hard they are biting together. The sensor will be attached to a holder which in turn is connected to a computer. We will ask your child to bite on the foil at the beginning of the appointment, after your child's mouth has been numbed, at the end of the appointment. We will then ask your child to bite on the foil 2 weeks later and then 2 weeks later again.

**Who can participate in the study?**

The study will include children between the ages of 7 and 16 years old who are receiving crowns with local anesthetic and local anesthetic and sedation.

**Who cannot participate in the study?**

You cannot participate in this study if any of the following are true: your child is under the age of 7 years, if they are receiving treatment under general anesthetic, or they have had dental fillings or sealants in the previous one month.

**What are the benefits?**

The information we get from this study will help us understand if the bite returns to normal in children after crowns.

Figure 7.4.3 Clinical study information sheet, page 3

**Are there risks involved?**

There are no risks involved in having your child's bite measured. It is simply biting on some foil.

**What about Confidentiality?**

Your child's identity will remain confidential. His/her name will not be published and will not be disclosed to any one outside the study group.

**Compensation**

Your dentists are covered by standard malpractice insurance. Nothing in this document restricts or curtails your rights.

**Do I have to participate in this study?**

If you decide to volunteer your child to participate in this study, you may withdraw him/her at any time. If you decide not to participate, or if you withdraw, you will not be penalised and will not give up any benefits that you had before entering the study.

**Stopping this study**

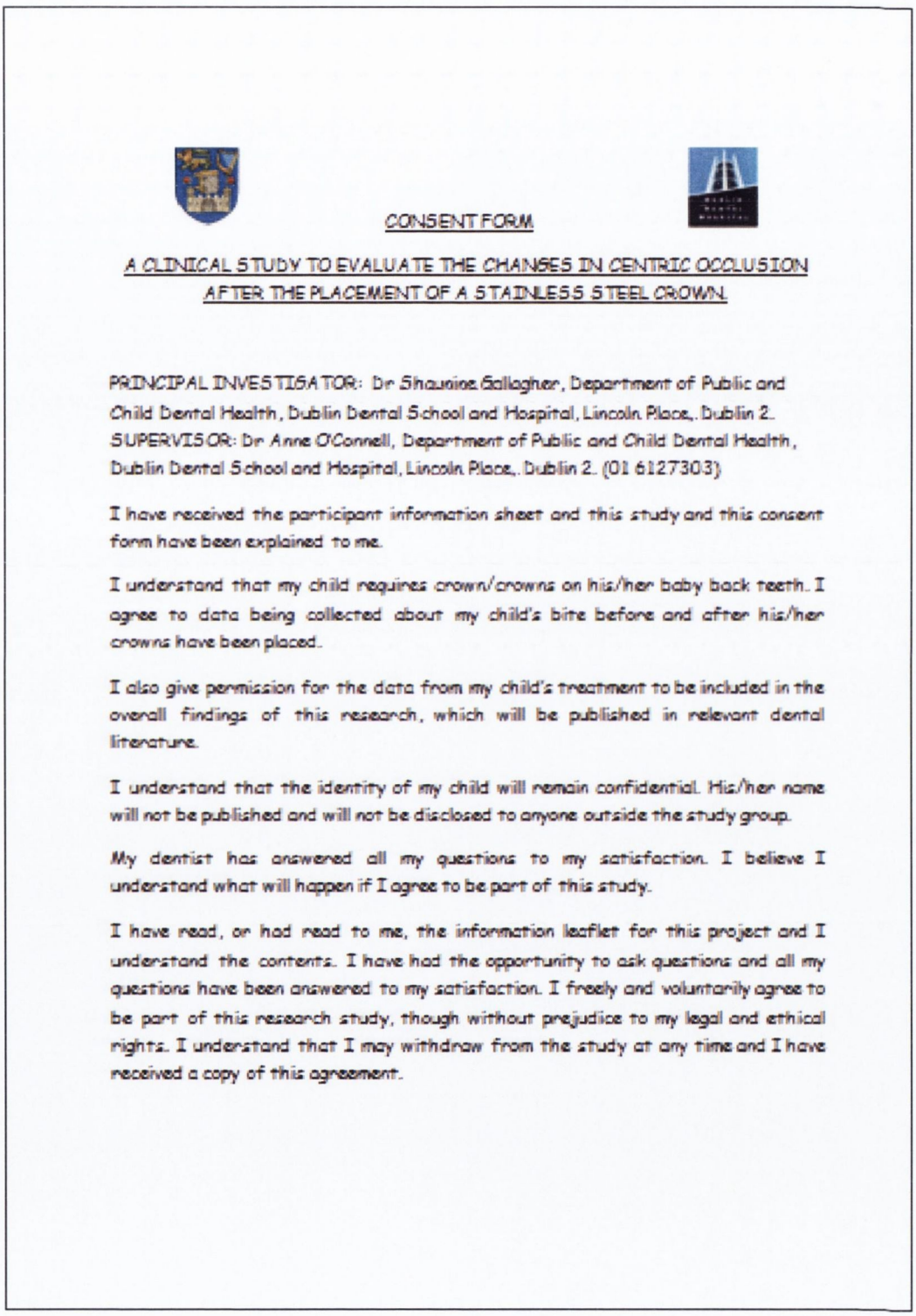
You understand that your dentist may stop your participation in the study at any time without your consent.

**Who grants permission to carry out this study?**

This study has been approved by the Dublin Dental School and Hospital. This study has ethical approval from the Trinity College, Faculty of Health Sciences Research Ethics Committee.

## 7.5 Appendix 5: Clinical study consent form

Figure 7.5.1 Clinical study consent form, page 1



CONSENT FORM

A CLINICAL STUDY TO EVALUATE THE CHANGES IN CENTRIC OCCLUSION AFTER THE PLACEMENT OF A STAINLESS STEEL CROWN

PRINCIPAL INVESTIGATOR: Dr Shaunise Gallagher, Department of Public and Child Dental Health, Dublin Dental School and Hospital, Lincoln Place, Dublin 2.
SUPERVISOR: Dr Anne O'Connell, Department of Public and Child Dental Health, Dublin Dental School and Hospital, Lincoln Place, Dublin 2. (01 6127303)

I have received the participant information sheet and this study and this consent form have been explained to me.

I understand that my child requires crown/crowns on his/her baby back teeth. I agree to data being collected about my child's bite before and after his/her crowns have been placed.

I also give permission for the data from my child's treatment to be included in the overall findings of this research, which will be published in relevant dental literature.

I understand that the identity of my child will remain confidential. His/her name will not be published and will not be disclosed to anyone outside the study group.

My dentist has answered all my questions to my satisfaction. I believe I understand what will happen if I agree to be part of this study.

I have read, or had read to me, the information leaflet for this project and I understand the contents. I have had the opportunity to ask questions and all my questions have been answered to my satisfaction. I freely and voluntarily agree to be part of this research study, though without prejudice to my legal and ethical rights. I understand that I may withdraw from the study at any time and I have received a copy of this agreement.

Figure 7.5.2 Clinical study consent form, page 2

PARTICIPANT'S NAME: _____

CONTACT DETAILS: _____

PARTICIPANT'S SIGNATURE: _____

Date: _____

Where the participant is incapable of comprehending the nature, significance and scope of the consent required or is under 18 years old, the form must be signed by a person legally competent to give consent.

*NAME OF CONSENTER, PARENT or GUARDIAN:* _____

*CONSENTOR'S SIGNATURE:* _____

*RELATION TO PARTICIPANT:* _____

STATEMENT OF INVESTIGATOR'S RESPONSIBILITY: I have explained the nature and purpose of this research study, the procedures to be undertaken and any risks that may be involved. I have offered to answer any questions and fully answered such questions. I believe that the participant understands my explanation and has freely given informed consent.

INVESTIGATOR'S SIGNATURE: _____

DATE: _____

## 7.6 Appendix 5: Glossary of Prosthodontic Terms

**Intercuspal position (ICP):** see MIP

**Maximum intercuspal position (MIP):** the complete intercuspation of the opposining teeth independent of condylar position sometimes referred to as the best fit of teeth regardless of the condylar position.

**Occlusal interference:** any tooth contact that inhibits the remaining occluding surfaces from achieving stable and harmonious contacts.

**Premature contact:** a contact that displaces a tooth or diverts the mandible from its intended movement.

**Retruded contact position (RCP):** that guided occlusal relationship occurring at the most retruded position of the condyles in the joint cavities.

**Temporomandibular disorders (TMD):** conditions producing abnormal, incomplete, or impaired function of the temporomandibular joints. 2 Collection of symptoms frequently observed in various combinations first described by Costen (1934, 1937), which he claimed to be reflexes due to irritation of the auriculotemproal and /or chorda tympanic nerves as they emerged from the tympanic plate caused by alterated anatomic relations and derangements of the temporomandibular joint associated with loss of occlusal vertical dimension, loss of posterior tooth support, and /or other malocclusions. The symptoms can include headache about the vertex and occiput, tinnitus, pain about the ear, impaired hearing and pain about the tongue.

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