A Retrospective Cohort Study of Fixed Space Maintainers and a Survey of their Use by Pediatric Dentists and Orthodontists

by

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A thesis submitted in conformity with the requirements for the degree of Master of Science in Pediatric Dentistry

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Abstract

**Purpose**: This study was conducted to evaluate the success of fixed space maintainers (fspms) placed by a sole dental practitioner in a private practice setting. The survey was conducted to evaluate the use of fspms by pediatric dentists and orthodontists.

**Methods**: 899 fspms placed in 531 patients were evaluated. An online survey was sent to 1000 pediatric dentists and 1000 orthodontists.

**Results**: The clinical success rate was 86.6%. The response rate for pediatric dentists surveyed was 43.0% but for orthodontists was only 7.0%. The vast majority of responding pediatric dentists (99.8%) and orthodontists (97.0%) placed fspms. The most common reason cited for failure by the pediatric dentists was cement loss (47.3%) and breakage by the orthodontists (30.4%).

**Conclusions**: Fixed space maintainers had a high clinical success rate (86.6%) and were placed by the vast majority of responding pediatric dentists (99.8%) and orthodontists (97.0%).
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Chapter 1
Literature Review

Space Management

Space management of the developing occlusion is an important part of interceptive and preventive dental care. Space maintenance involves using an appliance to passively hold teeth in position in order to allow for the eruption of permanent successors into occlusion. The 2008-2009 American Academy of Pediatric Dentistry (AAPD) guidelines state that the objectives of space management are to prevent the loss of arch length, arch width, and/or arch perimeter by maintaining the relative position of the existing dentition (AAPD Clinical Affairs Committee-Developing Dentition Subcommittee and AAPD Council on Clinical Affairs, 2008).

Consequences of Premature Tooth Loss

Ideal arch form is dependent on the presence and correct alignment of every erupted tooth in the mouth. The premature loss of a tooth or tooth structure, if not compensated for, may result in a loss of arch circumference, crowding and/or malocclusion due to shifting and/or drifting of adjacent teeth (Baroni, Franchini, & Rimondini, 1994; Laing, Ashley, Naini, & Gill, 2009). Eruption of succedaneous teeth can also be impeded as adjacent teeth can move into the space once occupied by a prematurely lost primary tooth. This can lead to impaction or ectopic eruption of the permanent tooth and result in malocclusion (Laing et al., 2009). Crossbite and dental midline discrepancies may also result from early tooth loss (Laing et al., 2009).

Space Loss

Premature loss of primary molars can be profoundly detrimental to arch circumference (Northway, 2000). Several studies have been conducted to quantify the deficits created by early loss of a primary molar. In 1951, Breakspear attempted to quantify space loss due to premature loss of one or two primary molars on one side of the mouth by using the retained contralateral teeth as controls. He conducted a cross-sectional analysis of schoolchildren and reported that loss of the first primary molar in either the maxillary or mandibular arch resulted in arch length reduction of 0.8 mm and 0.7 mm, respectively. When the second molar was lost, the space loss was 2.2 mm in the maxilla and 1.7 mm in the mandible. If both primary molars were lost early,
the arch length reduction was 2.0 mm in the maxilla and 1.3 mm in the mandible (Breakspear, 1951).

Ideal arch form is dependent on the presence and correct alignment of every erupted tooth in the mouth. The premature loss of a tooth or tooth structure, if not compensated for, may result in a loss of arch circumference, crowding and/or malocclusion due to shifting and/or drifting of adjacent teeth (Baroni et al., 1994; Laing et al., 2009). Eruption of succedaneous teeth can also be impeded as adjacent teeth can move into the space once occupied by a prematurely lost primary tooth. This can lead to impaction or ectopic eruption of the permanent tooth and result in malocclusion (Laing et al., 2009). Crossbite and dental midline discrepancies may also result from early tooth loss (Laing et al., 2009).

Lin and Chang (1998) observed twenty-one 5- to 7-year-old children with unilateral extraction of a primary mandibular first molar. Mandibular study casts were made 2 to 3 days post extraction and 8 months post extraction. The space between the canine and first permanent molar (D+E space, where D refers to the first primary molar and E refers to the second primary molar), intermolar arch width, length, and perimeter were measured. After 8 months, only the difference between the maxillary D+E space on the extraction side was found to be statistically significantly different from the control side (1.19 mm; P=0.03) (Lin & Chang, 1998). Although not statistically significant, the D+E space on the extraction side in the mandible was shorter than on the control side, but loss of the mandibular first molar did not result in changes in any of their measurements (Lin & Chang, 1998).

Ronnerman and Thilander (1977) conducted a study that included subjects between 5-7 years old. They found that a reduction in space following the premature loss of a first primary molar in both the maxilla and mandible was less severe and clinically insignificant compared to the premature loss of a second primary molar. A year later, the same group published another paper that reported significant space loss occurred only in the maxilla, which reflects a greater migratory tendency after early losses in the maxilla than in the mandible (Ronnerman & Thilander, 1978). Hoffding and Kisling (1978) reported that Class III molar occlusion increased in patients with premature mandibular second primary molar loss; logically, premature loss of maxillary primary second molars led to an increased incidence of class II molar relationships.

Padma Kumari and Retnakumari (2006) conducted a study of forty 6- to 9-year-olds; however,
10 were lost to follow up. The 30 remaining children were examined during the entire 13-month period. All had unilateral extractions of a primary mandibular first molar. Mandibular study models were taken before and immediately after the extraction as well as at 2, 4, 6, and 8 months post extraction. Extraction space (D space), intermolar arch width, length, and perimeter were measured on the casts. The D space decreased 0.64 mm, 1.3 mm, 1.64 mm, and 1.75 mm at the respective 2-, 4-, 6-, and 8-month time points. All of these changes were statistically significant (P<0.001). For the arch width, length, and perimeter, however, the decreases were not statistically significant at any time point (all <0.5 mm; P>0.05).

Lin, Lin & Lin (2007) examined the space loss that occurred in nineteen 4.1- to 7.1-year-old children who had a unilateral extraction of a primary maxillary first molar. Study models were made within 3 days of the extraction and 6 months after the extraction. Measurements on the casts included the D + E space, arch width, length, and perimeter, intercanine width and length. D + E space was found to decrease by 1.8 mm (P=0.001) on the extraction side, while the control side increased by an insignificant amount (0.48 mm; P=.0717). Intercanine width increased by 0.87 mm (P=0.001), arch length decreased by 0.19 mm (P=0.014), and there were no statistically significant changes in arch width, arch perimeter, or intercanine length.

In his study, Northway (2000) used three-dimensional digitized data and a central reference point to monitor tooth movement in cases of premature tooth loss versus a non-mutilated control group in patients aged 6-10 years old. By assuming that the position of the nonmutilated molar and canine positions are constant and plotting the difference between their movement and that of any of the experimental groups, he was able to quantify the changes that occur in the D + E space of experimental groups. He demonstrated that the premature loss of a maxillary D resulted in minimal mesial migration of the permanent first molar. However, when the first premolar erupted, it followed the mesial incline of the primary second molar and emerged more anteriorly than normal, which impeded the eruption of the permanent canine. When the permanent canine erupted, it assumed a more mesial and labial position. This was different from the E loss, in which the permanent molar moved an average of 3 mm in the mesial direction (Northway, 2000). Since the first premolar typically erupted prior to the second premolar, the second premolar was often vertically impacted between the first premolar and the permanent first molar. Likewise, in the D + E loss group, the mesially erupted permanent first molar often blocks the eruption path of the second premolar (Northway, 2000). Northway’s (2000) data showed that these premolars
were generally forced to erupt palatally in the case of E loss or D+E loss. Moreover, he showed that in 13 cases of premature first primary molar loss in the maxilla, all but one developed blocked-out canines; the one that did not had microdontia. He concluded that following the premature loss of the maxillary first primary molar, the permanent canine will become impacted (Northway, 2000). Thus, while there was more space loss associated with the loss of a second primary molar than with a first primary molar, the space loss caused by the latter led to the impaction of the permanent maxillary canines (Laing et al., 2009; Northway, 2000).

It is important to note that the samples included in the studies mentioned above consisted of children who were between 5-10 years old. It is possible that the permanent first molars and/or permanent laterals of some of these subjects may have erupted prior to the loss of the first primary molars. Since the majority of space loss associated with a prematurely lost first primary molar occurs as the permanent first molar and lateral erupt, the results of these studies could have potentially been confounded by their sample selection.

In summary, following the premature loss of primary molars, mesial migration of the permanent molar and distal drift of the primary canine occurred, and significant space loss at the extraction site was reported, but arch perimeter, width, or length were not significantly affected (Lin & Chang, 1998; Lin et al., 2007; Padma Kumari & Retnakumari, 2006). The timing of tooth loss, the severity of crowding, and the specific tooth lost determined the extent to which these occurred (Laing et al., 2009; Lin & Chang, 1998; Padma Kumari & Retnakumari, 2006). Thus, many clinicians believe that the benefits of and indications for space maintainers (spms) vary between patients and that blanket placement based only on early tooth loss is contraindicated (Brothwell, 1997; Kisling & Hoffding, 1979; Qudeimat & Fayle, 1998).

Types of Space Maintainers

Various appliance designs can be employed depending on which teeth are missing, which dental arch is involved, how many teeth are missing, and the stage of dental development. Spms can be unilateral or bilateral, fixed or removable. The advantages of fixed appliances are that they are less bulky, less likely to be lost or damaged and patient compliance is not as critical (Bijoor & Kohli, 2005; Laing et al., 2009). The disadvantages are that oral hygiene may be more challenging, it may be difficult to make adjustments to the appliances once they are cemented, a
suitable abutment tooth must be present, supra-eruption of the opposing tooth is not prevented (Bijoor & Kohli, 2005), and cement loss has been cited as one of the most frequent problems encountered with fspms (Baroni et al., 1994; Fathian, Kennedy, & Nouri, 2007; Hill, Sorenson, & Mink, 1975; Moore & Kennedy, 2006; Qudeimat & Fayle, 1998; Rajab, 2002; Sasa, Hasan, & Qudeimat, 2009; Tulunoglu, Ulusu, & Genc, 2005).

Unilateral Fixed Space Maintainers

Band and loop. The band and loop consists of a band that is placed on the abutment tooth with a loop soldered to the band to span the edentulous space (Bijoor & Kohli, 2005). It must be wide enough bucco-lingually to allow the complete eruption of the succedaneous tooth without interferences (Bijoor & Kohli, 2005). The band and loop can be used after the loss of any tooth provided a suitable abutment tooth is available (Bijoor & Kohli, 2005). The loop should be adapted a minimum of 0.5 mm from the gingival tissue contacting the adjacent tooth at the contact point and be as free as possible from the forces of mastication (Faculty of Dentistry, Department of Pediatric Dentistry, University of Toronto, 2006).

Distal shoe. The distal shoe, or intra-alveolar appliance consists of a band with a distal loop and an intra-alveolar spike extending from the loop. The intra-alveolar spike is positioned at the center, buccal-lingually, of the alveolar ridge. The spike should extend approximately 5-7 mm deep to the gingival surface contacting the surface of the bone at the mesial aspect of the developing first molar (Bijoor & Kohli, 2005; Faculty of Dentistry, Department of Pediatric Dentistry, University of Toronto, 2006; Laing et al., 2009). The spike acts as a guide plane for the emergence of the first permanent molar through the bone (Bijoor & Kohli, 2005; Faculty of Dentistry, Department of Pediatric Dentistry, University of Toronto, 2006; Laing et al., 2009). The distal shoe, or intra-alveolar appliance, can be used after the loss of the primary second molar prior to the eruption of the first permanent molar, to prevent the mesial migration of the erupting permanent first molar (Dhindsa & Pandit, 2008). Once the molar erupts, the intra-alveolar spike can be removed and the appliance refitted or the distal shoe can be replaced with a new band and loop (Laing et al., 2009).
Bilateral Fixed Space Maintainers

**Lingual arch.** The lingual arch is a bilateral fspm that consists of a 0.036-inch (0.9 mm) stainless steel arch wire that is most commonly soldered directly onto bands cemented onto contralateral molars (Kupietzky & Tal, 2007). Another method uses prefabricated lingual attachments welded to the molar bands, into which the arch form is inserted and may also be removed (Kupietzky & Tal, 2007). It is used to maintain the space of bilaterally missing teeth by preventing the abutment teeth from drifting or shifting mesially (Pinkham, J., Casamassimo, P., Fields, H.W., McTique, D.J., & Nowak, A., 2005). It can also be used in the case of multiple loss of teeth either unilaterally and bilaterally (Pinkham, 2005) or as a passive spm to help resolve anterior mandibular crowding by preserving the leeway space in mixed dentition cases (Ferdianakis, Laskou, & Spyrou, 1998). Lower lingual holding arches (LLHA) are best used following the eruption of the permanent incisors, as permanent incisor tooth buds tend to develop lingual to their primary precursors, and a wire resting against the lingual surfaces of primary incisors might interfere with the eruption of the permanent dentition (Pinkham, 2005). Use of an upper lingual holding arch (ULHA) is feasible in the primary dentition because it can be constructed to rest away from the incisors (Pinkham, 2005). Inclusion of Wilson loops into the design of the lingual arches may allow the arch to be adjusted to the position of the newly erupted permanent incisors.

**Nance appliance.** A modified upper lingual holding arch was described by Nance (1947) and has subsequently been known as the Nance appliance. The Nance appliance is a bilateral spm used to stabilize and prevent the rotation and/or mesial drift of the first permanent maxillary molars prior to the eruption of the bicuspids. Like the lingual arch, the Nance appliance consists of a 0.036-inch (0.9 mm) stainless steel arch wire that is soldered directly onto bands cemented onto contralateral molars or inserted into prefabricated lingual attachments welded to the molar bands (Kupietzky & Tal, 2007). This appliance approximates the palate as opposed to contacting the anterior teeth (Kupietzky & Tal, 2007). The palatal portion incorporates an acrylic button that contacts the palatal tissue, providing resistance to anterior movement of the posterior teeth (Pinkham, 2005; Kupietzky & Tal, 2007). The Nance can be an effective spm; however, inflammation beneath the acrylic button may occur, and it may become embedded in the soft tissue rendering oral hygiene of the appliance a challenge (Kupietzky & Tal, 2007).
Transpalatal arch. Like the Nance appliance, the transpalatal arch (TPA) is another variation of the ULHA (Pinkham, 2005); however, the issue of palatal soft tissue irritation and inflammation is avoided when using a TPA (Kupietzky & Tal, 2007). The TPA runs across the palatal vault, avoiding contact with the soft tissue (Kupietzky & Tal, 2007). The wire follows the vault of the palate, is comfortable, and does not interfere with normal speech (Kupietzky & Tal, 2007). The TPA offers the option of expansion, rotation, contraction, and torque of the molars due to an omega loop in the center of the vault (Kupietzky & Tal, 2007). It, too, is constructed from a 0.036-inch (0.9 mm) stainless steel wire that is soldered directly onto bands cemented onto contralateral molars or inserted into prefabricated lingual attachments welded to the molar bands (Kupietzky & Tal, 2007). A central loop in the wire is oriented either mesially or distally (Kupietzky & Tal, 2007). Although the TPA is a more hygienic and simple appliance to construct (Pinkham, 2005), care must be taken to ensure that the TPA is passive when cemented (Kupietzky & Tal, 2007). If the appliance is not passive, unexpected vertical and transverse movements of the permanent molars may occur (Kupietzky & Tal, 2007).

Removable Space Maintainers

Removable appliances can also be used to maintain space. These appliances are typically used when more than one tooth has been lost in a quadrant. The removable appliance is an option if there are no suitable abutment teeth and because the cantilever design of the band and loop or distal shoe is too weak to withstand the occlusal forces over a multiple tooth span (Pinkham, 2005). Not only can it replace multiple missing teeth, but it can also replace occlusal function (Pinkham, 2005).

Two disadvantages of the appliance are retention and compliance. Retention is a problem because primary canines lack significant undercuts for clasp engagement (Pinkham, 2005). If multiple tooth loss is unilateral, a clasp can be placed on the opposite side of the arch, improving retention (Pinkham, 2005). Retention also affects compliance; young children will not tolerate an ill-fitting appliance (Pinkham, 2005). Clasp adjustments and acrylic modification are also occasionally required to maintain adequate retention and allow for eruption of underlying or adjacent permanent teeth (Pinkham, 2005). If the appliance and the underlying tissue are not properly cleaned, tooth decay, tissue irritation and hyperplasia may occur (Pinkham, 2005).
The uncooperative or noncompliant patient presents a substantial problem during treatment with removable orthodontic appliances since the degree of treatment outcome largely depends on patient cooperation (Allan & Hodgson, 1968; Gross, Samson, & Dierkes, 1985; Slakter, Albino, Fox, & Lewis, 1980). The prevailing opinion based on empirical data is that the success of any orthodontic treatment with a removable appliance depends critically on its being worn 13–16 hours per day (Schott & Goz, 2010). One study, however, indicated that patients generally wore their appliances barely more than 9 hours per day; thus, the required wear time is rarely complied with (Schott & Goz, 2010). The most common reasons cited for non-compliance with removable orthodontic appliances were speech difficulties at school and inconvenience in games and sports (Schott & Goz, 2010). Tang and Wei (1990) compared orthodontic treatment with fixed versus removable appliances and reported that both the treatment effectiveness and the treatment results of the removable appliance were found to be inferior to those of the fixed appliances largely due to issues with compliance.

**Indications for Space Maintainers**

Indications for placement of space maintainers include:

i) Interproximal caries with cavitation

ii) Early loss of primary incisors prior to the eruption of the primary cuspids

iii) Early loss of a primary cuspid

iv) Early loss of the first primary molar prior to the eruption of the first permanent molar and the permanent lateral incisor in the same quadrant

v) Early loss of a primary second molar

vi) Permanent tooth loss

vii) Preservation of arch length through maintenance of leeway space

In addition, a space analysis should always be conducted prior to treatment planning a spm. (Nowak & Casamassimo, 2007).
Space Analyses

The Conventional Space Analysis

The conventional or canine space analysis was first proposed by Nance in 1947 (Nance, 1947). This analysis consists of comparing the amount of space available for the alignment of the teeth to the amount of space required for proper alignment. The space available is estimated by measuring the arch perimeter from the mesial contact of the permanent first molar from one side of the dental arch to the mesial contact of the permanent first molar on the opposite side of the dental arch (Ngan, Alkire, & Fields, 1999). This can be accomplished either by separating the dental arch into segments that can be measured as straight-line approximations of the arch or by contouring a piece of wire to the line of occlusion and then straightening out the wire for measurement. The space required is the summation of the mesiodistal widths of the erupted mandibular permanent incisors and the estimated mesiodistal widths of the unerupted permanent canines and premolars. The size of the unerupted permanent teeth can be estimated using one of the following methods: measuring the teeth on a radiograph and adjusting for the magnification by use of a simple proportional relationship; estimating the size of the unerupted teeth from a prediction table; or using a combination of both methods (Staley & Kerber, 1980).

The Tanaka Johnson Space Analysis

The Tanaka and Johnston (1974) method (Tanaka & Johnston, 1974) is recommended as a predictive technique because it has reasonable accuracy, does not require radiographs, requires no prediction tables and predicts the sizes of the unerupted permanent canines and premolars in maxillary and mandibular teeth. The Tanaka and Johnston (1974) analysis is completed by taking one-half of the mesio-distal widths of the four lower incisors and adding 10.5 mm, which is equal to the estimated width of the mandibular canines and premolars in one quadrant. Also, one-half of the mesiodistal width of the four lower incisors plus 11.0 mm equals the estimated width of the maxillary canine and premolar in one quadrant. However, the limitations of the conventional space analysis and the Tanaka and Johnston (1974) method are that neither take into account the axial inclination of the mandibular anterior teeth, the effects of the curve of Spee, innate prediction bias, ethnic group biases or facial profile, all of which can affect the amount of crowding and space required in the analyses (Ngan et al., 1999).
Crowding

Crowding is defined as tooth-size arch size discrepancy (Gianelly, 2005). The diagnosis of potential space loss/crowding and identification of the need for space management is an important responsibility of all dental clinicians (Bijoor & Kohli, 2005). Three signs have been described to identify the potential for crowding in the permanent dentition (Gianelly, 2005). The first is lack of interdental spaces in the primary dentition, however this has been shown by Baume (1950) to be an inaccurate predictor, as 9 of 16 subjects with no interdental spaces in the primary dentition did not have crowded permanent dentitions (Gianelly, 2005). The second sign is crowding of the permanent incisors in the mixed dentition (Gianelly, 2005). The third sign is premature loss of a primary canine, presumably reflecting inadequate space for the eruption of the lateral incisor (Gianelly, 2005). In crowded arches, the erupting lateral incisor causes premature root resorption of the primary canine leading to early exfoliation (Gianelly, 2005).

Severity of Crowding

The severity of space problems can be categorized into mild crowding (space shortage of less than 2 mm), moderate crowding (space shortage of 2 to 4 mm), severe crowding (space shortage of 5 to 9 mm) and extremely severe crowding (space shortage of 10 mm or more) (Proffit, 2000). In addition to preserving space for prematurely lost teeth/tooth structure, spms may also be used to prevent crowding and/or resolve mild crowding by preserving the leeway space (Gianelly, 1995).

Leeway Space Preservation

In order to resolve crowding, space is needed (Gianelly, 1995). Leeway space is defined as the size differential between the primary canine, first molar and second molar versus the permanent canine and first and second premolars. Usually the sum of the primary tooth widths is greater than that of their permanent successors. Therefore, when these primary teeth exfoliate, there is usually about 2.5mm of space per side in the mandibular arch and 1.5mm of space per side in the maxillary arch that can be used to help relieve crowding. If nothing is done to preserve the leeway space, the permanent first molars almost always move mesially into this space and arch length decreases (Bijoor & Kohli, 2005; Viglianisi, 2010). However, maintaining the arch length
with passive appliances can preserve this space (Singer, 1974). It has been shown that appropriately timed maintenance of existing arch circumference may reduce or eliminate the need for future orthodontic treatment (Laing et al., 2009).

In preventive and interceptive orthodontics, the LLHA is commonly used to maintain arch perimeter by preventing the mesial movement of the first permanent molars and to prevent the collapse of the mandibular incisors in a lingual direction, thus preserving the available space, including the leeway space in mixed dentition cases (Ferdianakis et al., 1998; Singer, 1974; Viglianisi, 2010).

Several studies have investigated the effects of LLHAs on arch length; however, only two studies presented the data for the control group and had subjects who had no other dental treatment done simultaneously (Rebellato et al., 1997; Villalobos, Sinha, & Nanda, 2000). Villalobos et al (2000) treated 23 patients with a LLHA on the first permanent molars. At the time of initial records, the patients were in the late mixed dentition stage, with the mandibular second deciduous molars already exfoliated or about to exfoliate. The mean ages of the subjects were 10.4 ± 0.6 years at the beginning of treatment and 12.3 ± 0.4 years at the end of treatment. The mean observation period for the experimental group was 18.3 ± 0.6 months. Longitudinal records of 24 untreated subjects with similar characteristics as the experimental group (ethnic origin, age, sex, Frankfurt mandibular angle, and time of observation) served as a control (Villalobos et al., 2000). At least two lateral cephalometric radiographs were taken: one at the start of treatment and the other at the removal of the appliance.

Measurements for the treatment group reflected a minimal mesial drift of 0.15 ± 0.67 mm and a distal tip of -0.54° ± 1.78° at 1 year. In the control group, the mandibular molars drifted mesially 1.15 ± 0.53 mm and tipped mesially 2.10° ± 1.54°. The differences were all statistically significant (P < 0.0001). In the treatment group, the mandibular incisors tipped posteriorly by -0.14° ± 0.73 mm and tipped distally by -0.51° ± 1.92°; in the control group, the incisal edge also tipped posteriorly by -0.84° ± 0.63 mm, and the incisal angulation also had distal repositioning of -2.87° ± 1.36°. Both measurements were statistically significant at P < 0.0001 and P < 0.01, respectively (Villalobos et al., 2000).

In the control group for the 24-month observation period, the mandibular molars moved further
mesially by an average of 1.81\(^\pm\) 0.75 mm, and the angular position showed anterior tipping of 2.68\(^\circ\)\(^\pm\) 0.98\(^\circ\). The mandibular incisors showed their incisal edges with greater distal tipping, which measured \(-1.24\)\(^\pm\) 0.91 mm. The incisal angulation had distal repositioning (up-righting) of \(-3.85\)\(^\circ\)\(^\pm\) 1.59\(^\circ\). All variables when compared between groups (LLHA versus control at 24 months) were statistically significant (P < 0.0001) (Villalobos et al., 2000). It is important to note that since the mandibular molars of some of the patients had exfoliated prior to the onset of the study, some space loss may have already occurred. Therefore, the absolute values of the space maintained should be viewed as a minimum.

The second study was conducted by Rebellato et al (1997) on thirty subjects who had both mandibular second primary molars with some clinical mobility, mandibular crowding of 3 mm or more, permanent molar relationships of end to end or Class I, overbite of 1 mm or greater. The treatment group contained 14 patients who had only LLHA appliances; the control group contained 16 patients, with similar features, who received no treatment. Records consisted of one baseline cephalometric radiograph, one tomographic radiograph of the randomly selected left or right buccal segment, and study models. All patients were observed at least monthly (Rebellato et al., 1997).

In the treatment group, molar tipping was \(-0.54\)\(^\circ\) (backward tip), the center of resistance shifted anteriorly 0.33 mm, and the cusp tip shifted anteriorly 0.29 mm. The same measurements for the control group were 2.19\(^\circ\), 1.44 mm, and 1.73 mm, respectively. The differences were all statistically significant (P < 0.001). The data for the treatment group indicated a 0.73\(^\circ\) forward tip of the incisor, a 0.32-mm advancement of the center of resistance, and a 0.44-mm advancement of the incisal edge. In the control group, the incisor angulation change was \(-2.28\)\(^\circ\) (backward tip), the center of resistance came back 0.34 mm, and the incisal edge came back 0.65 mm. These differences were all statistically significant (P < 0.0001) (Rebellato et al., 1997).

The study models showed increases in intermolar widths in both the treatment group (1.15 mm) and the control group (0.14 mm). A decrease in total arch length of 2.54 mm in the control group was found, whereas the treatment group actually had a slight increase of 0.07 mm. All differences between the treatment and control groups were statistically significant (P < 0.01) (Rebellato et al., 1997).
These results support the use of the LLHA for preserving arch length. A LLHA placed during the early mixed dentition will restrict the mesial migration and tipping and make use of the leeway space by the molars, and should even cause a slight increase of the total arch length and prevent the mandibular incisors from tipping lingually (Rebellato et al., 1997).

In addition, the stability of the lower incisors after passive lingual arch therapy appeared to be satisfactory. For example, Dugoni, Lee, Varela, and Dugoni (1995) indicated that lower incisor alignment of 76% of patients treated successfully with only a lingual arch in the mixed dentition were considered stable 9 years post-retention.

Use of Upper/Lower Lingual Holding Arch for Anchorage

Bilateral spms can also be used in the late-mixed dentition stage to preserve anchorage in a serial extraction case (Dale & Brandt, 1976). Serial extraction involves the sequential removal of primary and, ultimately, permanent teeth to resolve a severe (10 mm or more) tooth-size/arch-length discrepancy (Proffit, 2000). A sequence of extractions begins with removal of the primary canines as the permanent lateral incisors erupt (Ngan et al., 1999). Then, the primary first molars are extracted to speed the eruption of the first premolars. Next, the permanent first premolars are removed to allow the permanent canines to erupt in the first premolar space (Ngan et al., 1999). To preserve the extraction space and prevent the mesial movement of the permanent molars, a Nance appliance and/or a LLHA can be used (Dale & Brandt, 1976).

Adverse Effects Associated with Space Maintainers

Although the benefits of spms have been suggested in the literature, their use has also been associated with adverse effects including: soft tissue irritation/impingement, interference with eruption of successors or adjacent teeth, pain, plaque retention, gingival inflammation, dental caries, undesirable tooth movement, and fractured, dislodged or lost appliances (AAPD, 2004; Brothwell, 1997; Laing et al., 2009; Qudeimat & Fayle, 1998). Distal shoes may be associated with some additional problems, which include: difficulty in the accurate construction of the appliance, the presence of a constant foreign body in a sensitive area in the mouth, and a possible route of infection between intraoral and submucosal areas (Ngan, 1999).
Contraindications for Space Maintainers

Contraindications for the use of spms are poor oral hygiene, patients that cannot commit to regular follow up and patients that are high caries risk (Bijoor & Kohli, 2005; Laing et al., 2009). Although a high risk for caries is cited as a contraindication in the literature, it should be considered a relative contraindication: the goal of treatment should be to have rehabilitated the patient with an emphasis on improved oral hygiene. Thus, space maintenance should still be provided to prevent space loss from occurring. Ongoing assessments should be executed to ensure that the patient’s level of oral hygiene is maintained. If oral hygiene is not kept at an acceptable level and the space maintainer cannot be maintained without the risk for decay, it should then be removed.

If the succedaneous tooth is very close to eruption (Bijoor & Kohli, 2005) or beyond the height of the furcation and in contact with the root of the approximating tooth, space maintenance may not be required, as the position of the erupting permanent tooth acts as a physical barrier to the mesial movement of the adjacent tooth into the space (Faculty of Dentistry, Department of Pediatric Dentistry, University of Toronto, 2006). Similarly, if the second primary molar is lost prematurely and its successor is clearly further along its eruption path than the second permanent molar in that quadrant, a spm may not be required (Faculty of Dentistry, Department of Pediatric Dentistry, University of Toronto, 2006).

Follow-up Care for Space Maintainers

The placement and retention of space maintaining appliances requires ongoing compliant behaviour (AAPD Clinical Affairs Committee-Developing Dentition, Subcommittee & AAPD Council on Clinical Affairs, 2008). Follow up of patients with spms is crucial to assess the integrity of the cement and to evaluate and clean the abutment teeth (Qudeimat & Fayle, 1998). It is also necessary to monitor the development of succedaneous teeth and to ensure that their eruption is not hindered by the appliance (Bijoor & Kohli, 2005).

Case Selection

An important aspect of successful space management is careful case selection. Factors to
consider prior to treatment planning a spm are:

i) Strategic importance of the tooth

ii) Time elapsed since tooth loss

iii) Pre-existing occlusion

iv) Favourable space analysis

v) Degree of root development of the permanent successor

vi) Amount of alveolar bone covering the permanent successor

vii) Oral hygiene

viii) Patient’s medical history

ix) Family commitment to follow-up

x) Patient cooperation (AAPD, 2004)

Ideal Time for Placement of Space Maintainers

If a tooth is lost prematurely, and a spm is not placed as indicated, space loss may occur. The degree to which space is affected varies according to the arch affected, site in the arch and time elapsed since tooth loss (AAPD Clinical Affairs Committee-Developing Dentition Subcommittee & AAPD Council on Clinical Affairs, 2008). Kumari and Retnakumari (1998) found that the rate of space loss decreased 4 months post extraction. Cuoghi, Bertoz, de Mendonca, and Santos (1998) found that most space loss occurs in the first 6 months. This suggests that if a spm is not placed shortly after the loss of the primary tooth, often the opportunity to prevent space loss at the extraction site may have passed.

Similarly, non-restored carious teeth commonly lead to space loss (Terlaje & Donly, 2001). In the event of the extraction of a severely decayed primary tooth, space loss may have occurred before the extraction (Tunison, Flores-Mir, ElBadrawy, Nassar, & El-Bialy, 2008). Thus, pretreatment planning, including a mixed dentition analysis, is vital before fitting a spm (AAPD
Clinical Affairs Committee-Developing Dentition Subcommittee & AAPD Council on Clinical Affairs, 2005).

**Space Regaining Appliances**

If space is not managed in a timely manner, space loss may occur. To compensate for clinically significant space loss, a space-regaining appliance may be indicated. The goal of space regaining intervention is the recovery of lost arch width and perimeter and/or improved eruption position of succedaneous teeth (AAPD Clinical Affairs Committee-Developing Dentition Subcommittee & AAPD Council on Clinical Affairs, 2008). Treatment modalities may include fixed or removable appliances such as a Hawley retainer with an active component to move the molar in a distal direction, a transpalatal arch with activation, a headgear, or a pendulum (AAPD Clinical Affairs Committee-Developing Dentition Subcommittee & AAPD Council on Clinical Affairs, 2008; Northway, 2000). Space regained must then be maintained until adjacent permanent teeth have erupted completely and/or until a subsequent comprehensive orthodontic treatment plan is initiated (AAPD Clinical Affairs Committee-Developing Dentition Subcommittee & AAPD Council on Clinical Affairs, 2008).

**Cements**

Several cements have been used in the literature for luting fsmps: zinc phosphate, zinc polycarboxylate, zinc oxide eugenol (ZOE), glass ionomer (GI), resin-modified glass ionomer (RMGIC), compomer and resin cements (Gillgrass, Benington, Millett, Newell, & Gilmour, 2001; Millett & Gordon, 1992).

In the past three decades, glass ionomer cements (GICs) have become popular for band cementation. These adhere to enamel and metal (DeSchepper, White, & von der Lehr, 1989), release and uptake fluoride (Forsten, 1977), and inhibit microbial activity (Hotz, McLean, Sced, & Wilson, 1977). They are, however, susceptible to moisture contamination during the setting reaction and maximum strength is only attained after 24 hours (Gillgrass et al., 2001; Millett & Gordon, 1992). Conventional glass ionomers have been shown to be more clinically effective in the retention of molar bands, when compared with zinc phosphate (Maijer & Smith, 1988; Stirrups, 1991). Fricker and McLachlan (1985) also found that a conventional glass ionomer,
Ketac-Cem (ESPE, Gmbh, Seefeld Oberbay, Germany), was more clinically effective than Band-Lok (Reliance Orthodontic Products, Itasca, Ill), a modified composite, in a randomized clinical trial over a 12-month period.

Millett et al (1992) conducted a study in which the shear-peel bond strength of micro-etched orthodontic bands cemented with RMGIC, modified composite or conventional GIC was assessed and reported no significant difference between them (Millett & Gordon, 1992). The Weibull modulus, an indicator of bond reliability, was greatest with the conventional GIC and least with the modified composite (Millett & Gordon, 1992). A criticism of Millett et al’s (1992) study, however, was that only one assessor, who was familiar with the appearance of the various cement types, evaluated the predominant mode of bond failure, and this may have introduced some bias.

Conventional glass ionomers release fluoride and have been shown to inhibit the formation of white spot lesions on banded teeth when compared with non-fluoride–releasing cements (Kvam, Broch, & Nissen-Meyer, 1983; Maijer & Smith, 1988). They also form a stronger bond with enamel than with stainless steel, resulting in a position of bond failure mainly at the band-cement interface, both in vitro and in vivo (Fricker & McLachlan, 1985; Millett & Gordon, 1992; Norris, McInnes-Ledoux, Schwaninger, & Weinberg, 1986). This tends to leave a protective layer of cement over the enamel, which may help to prevent demineralization under loose bands (Gillgrass et al., 2001). The failure rates of single bands cemented with GIC range from 1% to almost 20% (Fricker & McLachlan, 1985; Gillgrass et al., 2001; Maijer & Smith, 1988; Millett & Gordon, 1992).

Longevity and Success Rates of Space Maintainers

Reports on the longevity and success rates of spms in the published literature are scarce and variable (Baroni et al., 1994; Bijoor & Kohli, 2005; Fathian et al., 2007; Laing et al., 2009; Moore & Kennedy, 2006; Qudeimat & Fayle, 1998; Rajab, 2002; Sasa et al., 2009). There are only eight studies published to date, with failure rates ranging from 12.5-63.0% (Table 1) (Baroni et al., 1994; Fathian et al., 2007; Hill et al., 1975; Moore & Kennedy, 2006; Qudeimat & Fayle, 1998; Rajab, 2002; Sasa et al., 2009; Tulunoglu et al., 2005).
Table 1. Overall failure rates of fixed space maintainers in the published literature

<table>
<thead>
<tr>
<th>Authors</th>
<th>Failure Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hill, Sorenson &amp; Mink (1975)</td>
<td>43.0%</td>
</tr>
<tr>
<td>Baroni, Franchini &amp; Rimondini (1994)</td>
<td>30.5%</td>
</tr>
<tr>
<td>Qudeimat and Fayle (1998)</td>
<td>63.0%</td>
</tr>
<tr>
<td>Rajab (2002)</td>
<td>30.7%</td>
</tr>
<tr>
<td>Tulunoglu, Ulusu &amp; Genc (2005)</td>
<td>12.5%</td>
</tr>
<tr>
<td>Moore and Kennedy (2006)</td>
<td>24.0%</td>
</tr>
<tr>
<td>Fathian, Kennedy &amp; Nouri (2007)</td>
<td>32.0%</td>
</tr>
<tr>
<td>Sasa, Hasan &amp; Qudeimat (2009)</td>
<td>57.5%</td>
</tr>
</tbody>
</table>

Several factors may have had an impact on this large range. Many were education center-based studies with multiple operators performing the procedures, which may have led to methodological inconsistencies (Baroni et al., 1994; Hill et al., 1975; Qudeimat & Fayle, 1998; Rajab, 2002; Sasa et al., 2009; Tulunoglu et al., 2005). Moreover, sample sizes ranged from 63-663 (Table 2) and some lost a significant number to follow up (Qudeimat & Fayle, 1998; Rajab, 2002; Tulunoglu et al., 2005). For example, Tulunoglu et al (2005) studied a total of 663 spms. They reported the lowest failure rate (13%), but experienced the highest loss to follow up (52%) (Tulunoglu et al., 2005). Qudeimat and Fayle (1998) studied 303 appliances, the majority of which were placed by students. They lost 21% to follow up and reported the highest failure rate (63%) (Qudeimat & Fayle, 1998). The only two private practice-based studies were by Moore and Kennedy (2006) and Fathian et al (2007) who lost only 2% and 5% to follow up respectively, and, not surprisingly, reported relatively low failure rates (24% and 32% respectively).
Table 2. Sample sizes of the published fixed space maintainer literature

<table>
<thead>
<tr>
<th>Authors</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hill et al (1975)</td>
<td>196</td>
</tr>
<tr>
<td>Baroni et al (1994)</td>
<td>88</td>
</tr>
<tr>
<td>Qudeimat and Fayle (1998)</td>
<td>301</td>
</tr>
<tr>
<td>Rajab (2002)</td>
<td>387</td>
</tr>
<tr>
<td>Tulunoglu et al (2005)</td>
<td>663</td>
</tr>
<tr>
<td>Sasa et al (2009)</td>
<td>40</td>
</tr>
<tr>
<td>Moore and Kennedy (2006)</td>
<td>482</td>
</tr>
<tr>
<td>Fathian et al (2007)</td>
<td>323</td>
</tr>
</tbody>
</table>

The age range included in the samples also varied widely (Table 3). For example, Sasa et al (2009) included 3.4-7.3 year olds, Rajab (2002) included 3-9 year olds, Baroni et al (1994) included 5-9 year olds, Moore and Kennedy (2006) included 7-13 year olds, Tulunoglu et al (2005) included a wider age range of 4-15 year olds, and Qudeimat and Fayle (1998) had an exceptionally wide age range of 3.4-22.1 year olds included in their study. The age of the patients may have confounded the success rates in that younger patients may have been more uncooperative, therefore fabrication and cementation of the appliances may have been less than ideal. Moreover, the reason for placement of the spm may have been an important factor: younger patients having spms placed because of primary tooth extraction due to caries may be less motivated and may have poorer oral hygiene than older patients in whom appliances were placed for orthodontic reasons. Also, the first permanent molar clinical crowns of older children may be more amenable to banding than in the younger children (Moore & Kennedy, 2006). For example, Moore and Kennedy’s (2006) patient sample came from their private orthodontic clinic, with the mean starting age of 10.9 years, which may be one of the factors leading to this study’s improved results. Also, all of their patients were in the late mixed dentition stage of development, so the appliances were required to function for a reduced period of time, from
approximately 10.9 to 12 years of age (Moore & Kennedy, 2006). This is when second molar eruption occurs and phase two orthodontics begins (Moore & Kennedy, 2006). Moore and Kennedy (2006) expected their appliances to last between 15 and 30 months, and the majority were successful. These factors may help explain why these results are superior to the longevity of appliances reported for the pediatric patient (Baroni et al., 1994; Hill et al., 1975; Qudeimat & Fayle, 1999; Rajab, 2002).

The study conducted by Fathian et al (2007) was almost identical to that of Moore and Kennedy, except that it was conducted on younger patients in a private pediatric dental practice, all the teeth were extracted due to caries and failure rates were slightly higher. Although these factors may have affected the results, no associations can be drawn between the age of the patients and the success rates.

**Table 3.** Age ranges (years) of the subjects at time of appliance placement in the published fixed space maintainer literature

<table>
<thead>
<tr>
<th>Authors</th>
<th>N</th>
<th>Age Range of Sample (years)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baroni et al (1994)</td>
<td>88</td>
<td>5.0-9.0</td>
</tr>
<tr>
<td>Qudeimat and Fayle (1998)</td>
<td>301</td>
<td>3.4-22.1</td>
</tr>
<tr>
<td>Tulunoglu et al (2005)</td>
<td>663</td>
<td>4.0-15.0</td>
</tr>
<tr>
<td>Sasa et al (2009)</td>
<td>40</td>
<td>3.4-7.3</td>
</tr>
<tr>
<td>Moore and Kennedy (2006)</td>
<td>482</td>
<td>7.0-13.0</td>
</tr>
<tr>
<td>Fathian et al (2007)</td>
<td>323</td>
<td>5.0-7.0</td>
</tr>
</tbody>
</table>

Reported success rates also vary depending on the appliance type. For example, out of a total of 387 appliances, the Nance appliance showed the highest survival rate (24 months) followed by the band and loop (20 months), and the lingual arch showed the lowest (14 months) in a study conducted by Rajab (2002). Similarly, Baroni et al (1994) found that at the 24 to 36 month
interval, Nance appliances and band and loops maintained a constant survival of 70%, while the lingual arches survival rapidly fell to 40%. Qudeimat and Fayle (1998) found that soft tissue lesions occurred more often with bilateral spms than with unilateral appliances and that unilateral spms survived more than twice as long as bilateral appliances (P<0.0005). Band and loops had a statistically significantly longer mean survival time (13 months) than both the Nance appliances (6 months) and the LLHA (4 months) (Qudeimat & Fayle, 1998). Interestingly, both Qudeimat and Fayle (1998) and Sasa et al (2009) found that the survival time of the band and loop spms placed in both the maxillary and mandibular left quadrants was statistically significantly higher than those placed on the right side, and suggested that isolation for a right handed clinician might be easier on the left side or that patients tend to chew preferentially on the right side of the mouth.

**Failure of Space Maintainers**

There are various reasons cited for the failure of fspms in the published literature, with the leading cause cited as cement loss followed by breakage (Table 4). Appliances that failed due to cement loss were usually re-cemented and reintroduced into the study. Since it can be expected that intra-oral appliances may require a minimal amount of maintenance, re-cementation of an appliance could arguably be considered “in need of minor maintenance” instead of a “failure”. If this definition were applied to the previous studies, failure rates would be considerably lower. Similarly, Moore and Kennedy (2006) reported 29 lingual arches and 15 Nance appliances out of a total of 482 appliances were considered failures even though they were not remade or recemented as they felt the appliances served their purpose and the failures likely occurred late into the appliances’ lifetimes. They also mention that while these were considered failures, the appliances actually did their job (Moore & Kennedy, 2006). Had they been considered successful, the overall success rates would have increased to 81% and 82% for the lingual arch and the Nance, respectively.
Table 4. Examples of the most common modes of failure of fixed space maintainers in the published literature

<table>
<thead>
<tr>
<th>Authors</th>
<th>Most common modes of failure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baroni et al (1994)</td>
<td>Cement loss&lt;br&gt;Solder Failure&lt;br&gt;Soft tissue lesion&lt;br&gt;Interference with eruption</td>
</tr>
<tr>
<td>Qudeimat and Fayle (1998)</td>
<td>Cement loss&lt;br&gt;Breakage&lt;br&gt;Design problems&lt;br&gt;Lost</td>
</tr>
<tr>
<td>Rajab (2002)</td>
<td>Cement loss&lt;br&gt;Solder Failure&lt;br&gt;Soft tissue lesion&lt;br&gt;Interference with eruption</td>
</tr>
<tr>
<td>Moore and Kennedy (2006)</td>
<td>Cement loss&lt;br&gt;Solder breakage&lt;br&gt;Reason not specified&lt;br&gt;Band split&lt;br&gt;Eruption interference&lt;br&gt;Soft tissue lesion&lt;br&gt;Bent wire&lt;br&gt;Complete loss</td>
</tr>
<tr>
<td>Fathian et al (2007)</td>
<td>Cement loss&lt;br&gt;Not specified&lt;br&gt;Band split&lt;br&gt;Eruption interference&lt;br&gt;Bent wire&lt;br&gt;Complete loss</td>
</tr>
</tbody>
</table>

Survey Design

Postal surveys of health professionals have traditionally been used to assess their knowledge, views and attitudes toward various subject matters (Braithwaite, Emery, De Lusignan, & Sutton, 2003). Web-based health-related research, however, including survey studies, has increased exponentially in the past two decades (Cantrell & Lupinacci, 2007). In an article on conducting Internet-based research, Ahern (2005) summarizes the advantages listed in the published literature that online research offers as: (1) being less expensive, (2) reaching a larger pool of potential study participants, (3) increasing access to study sensitive issues, cultural groups, and “hidden populations”, (4) decreasing data collection time, (5) increasing methodological rigour
and control, (6) increasing accuracy and efficiency of data entry and analysis, and (7) having the ability to follow-up with participants.

Simple questionnaires do not require extensive programming skills or time, and the cost of sending multiple e-mail invitations and reminders is negligible (Braithwaite et al., 2003). Other benefits relate to graphical and interactive design on the Web. Ideally, Internet survey forms enhance data collection, compared with conventional surveys, because of their use of color, innovative screen designs, question formatting, and other features not available with paper questionnaires (Braithwaite et al., 2003). They can prohibit multiple or blank responses by not allowing the participant to continue on or to submit the survey without first correcting the response error (Schleyer & Forrest, 2000). The program can provide notifications to make sure the respondent does not inadvertently skip a question. In addition, coding errors and data entry mistakes are reduced or eliminated and results can be automatically compiled (Schleyer & Forrest, 2000).

Greenlaw and Brown-Welty (2009) looked at the response rate and cost efficiency of mail compared to email or mixed mode survey distribution amongst a highly educated population. The web-based survey was associated with a higher response rate (52.46%) than the mail based administration (42.03%) and was substantially less costly to administer ($0.64 USD /response, $4.78 USD/response respectively) (Greenlaw & Brown-Welty, 2009). The authors concluded that web based administration is the clear choice for overall cost efficiency while still producing a very respectable response rate (Greenlaw & Brown-Welty, 2009).

There are also several advantages for study participants involved in web-based research: (1) convenience and ease of use (2) ability to provide information at their own pace, (3) increased sense of control, (4) increased willingness to participate because of it being a novel approach to research, and (5) increased anonymity (Ahern, 2005). The anonymity that online surveys offer has positive implications for data quality. This anonymity is thought to foster a greater sense of confidence among participants to respond to sensitive questions more freely, and thus it decreases social response bias and researcher-influenced bias and thereby enhances the veracity of the data (Cantrell & Lupinacci, 2007).

Although web-based surveys do have their advantages, there are also some disadvantages to this mode of study. The generality of the results is restricted to those who are keyboard and Internet
literate (Wyatt, 2000), and it is not possible to estimate the number of individuals of interest who have access to computers and the Internet (Fawcett & Buhle, 1995). Errors that may reduce data validity are more likely in Web than paper surveys, including participants not scrolling down to see a whole page of questions or list of options in a list box and not understanding how to correct a mistaken response (Wyatt, 2000). These problems are more substantial with the Web than with paper questionnaires, because each user experiences a subtly different questionnaire according to their screen size, hardware platform, operating system, browser, and Internet service provider (Wyatt, 2000). Participants may even have changed their default screen colours or fonts in a way that obscures significant detail in the questionnaire (Wyatt, 2000).

Striving for very high response rates will reduce the effects of nonresponse bias caused by socio-demographic and behavioural differences between responders and non-responders (Parashos, Morgan, & Messer, 2005). The response rate of a questionnaire survey is defined as the number of completed and partially completed surveys divided by the number of eligible sample units (Locker, 2000). A high response rate from any sample is essential for the data to be representative of the entire population (Fink, 2003; Tambor et al., 1993).

Opinions differ as to an optimal response rate high enough to eliminate nonresponse bias, but the range reported is 70–80% (Brennan, Ryan, Spencer, & Szuster, 2000; Evans, 1991; Gough & Hall, 1977), although lower response rates may be acceptable (Wyatt, 2000). For example, if the community surveyed is homogeneous with respect to a key variable, a lower response rate is less of a problem (Wyatt, 2000). Unfortunately, reported response rates from questionnaire surveys also vary depending on the method used for calculating the response rates (Parashos et al., 2005). Confusion between completion rate and response rate will continue until a standard definition is adopted (Parashos et al., 2005).
Rationale

Due to the inconsistency in the literature regarding survival and success rates of fspms, the clinician may find it difficult to advocate their use. Though the published success rates are generally low, space management remains an important part of interceptive and preventive dental care. It would be beneficial to present data from a private pediatric practice based retrospective cohort study. A private practice based study with a solo practitioner has the benefit of utilizing a strict clinical protocol and clearly defined clinically relevant success versus failure criteria. Furthermore, an online survey of a representative sample of North American pediatric dentists and orthodontists regarding their personal experience with fspms would compliment the results of the retrospective cohort study. The survey data may provide insight into the attitudes and clinical experiences of the two groups of dental specialists who use space maintainers.
Aims and Objectives

Aims

1) To evaluate the success and longevity of fspms placed by a sole dental practitioner in a private pediatric dental office.

2) To evaluate the use of, attitudes toward, and perceived difficulties with fspms by a representative sample of North American pediatric dentists and orthodontists.

Objectives

1) To determine the success and longevity of fspms placed by a sole dental practitioner in a private pediatric dental office

2) To determine if the success rates are high enough to support the use of fspms

3) To investigate and identify the causes for failure or success of fspm therapy

4) To evaluate the use of, attitudes toward, and perceived difficulties with fspms by a representative sample of North American pediatric dentists and orthodontists
Expected Study Outcomes

1) A higher rate of success and longevity than in the current published literature will be observed.

2) This study will demonstrate that with careful case selection, a strict clinical protocol and appropriate follow up, fspms are effective appliances that should be utilized whenever indicated.

3) Despite the generally low success rates in the published literature, fspms are expected to be viewed as a valuable part of interceptive and preventive dental care by North American Pediatric Dentists and Orthodontists.

4) Recementation of fspms will be viewed by the majority of responding North American pediatric dentists and orthodontists as maintenance rather than failure.
Chapter 2
Materials and Methods

1. Retrospective Cohort Study

Study Design

A retrospective cohort study was conducted of patients who required fspms, at a private pediatric dental practice with a solo practitioner (S.P.). The inclusion criteria included healthy children or those with mild systemic disease as defined by the American Society of Anesthesiologists (ASA, 1963) Physical Status Classification System as being either ASA I or ASA II in which at least one fspm was placed between January 2000 and December 2010, with a minimum follow-up period of 6 months.

Informed Consent

Informed consent for treatment was obtained prior to fabricating the fspms (Appendix A). Since a specific request for the collection and use of data for research purposes and/or obtaining a graduate qualification was not included at the time of treatment, a letter was mailed to inform patients/parents that patient records will be used on an anonymous basis for research purposes and to obtain graduate qualification (Appendix B). Included in the letter were a brief description of the study being conducted and the option of withdrawing from the study with instructions on how to do so.

Standard Space Maintainer Protocol

**Construction.** Band selection (Cerum™), seating, and impression taking were always performed by the same clinician (S.P.). The bands were seated at the height of the mesial and distal marginal ridges and adapted to the coronal tooth structure in order to minimize cement thickness. Impressions were performed using warm green compound or alginate.

Bands were fixed into the compound impressions by melting the compound or seated by the lab
on the stone model from the alginate impression. Stone models were poured up ensuring correct band orientation. The spms were all constructed by dental technicians at the R & S Orthodontic Laboratory, Ltd., Oshawa, Ontario, Canada using a combination of silver, copper, zinc, tin, nickel and magnesium for soldering.

**Tooth Extraction.** Fabrication of the appliance was done prior to extraction whenever possible (asymptomatic tooth and non spreading infection); otherwise, the impression was taken on the day of the extraction.

**Cementation.** Abutment teeth were all cleaned with prophy paste and dried, and bands were cemented using glass ionomer cement (Shofu™). The cement was mixed to a thick creamy consistency. A dry field was maintained with high and low-volume suction during cementation. A dry field was maintained until initial set of the GIC was achieved. Excess cement was cleared using an air-water syringe, pigtail explorer and moist cotton gauze.

**Post-operative instructions.** Patients were instructed to leave the office with firm biting on a cotton roll for 10 minutes post insertion and not to chew or eat for 60 minutes post cementation. Oral hygiene instructions were provided to each patient along with instructions to avoid hard/sticky foods and to avoid manipulating the wire with tongue or fingers.

**Follow Up.** The spms were re-assessed every 3-6 months or as necessary. Assessment of the need for continued appliance therapy, appliance integrity, periodontal health, cement seal, and appliance position were performed at each follow-up appointment.

**Data Collection**

All of the patients in whom band and loops, distal shoes, Nance appliances, LLHAs and/or ULHAs were placed by S.P. from January 1, 2000- Dec. 31, 2010, who met the inclusion criteria and for whom consent was obtained, were assessed. There were no subjects who actively withdrew from the study. Appliances were followed until they were removed or, if they were still in use, to the study’s end point (June 1, 2011).

Data was collected for 899 fspms (226 band and loops, 10 distal shoes, 267 LLHA, 98 Nance appliances, and 298 ULHA). Data was entered into a Microsoft Excel spreadsheet (Microsoft ©
Excel ® 2008 for Mac) by the principle investigator (L.G.). Descriptive data including (1) gender; (2) radiographs taken; (3) type of spm; (4) location; (5) Angle molar classification; (6) overbite; (7) overjet; (8) impression pre/post-extraction; (9) alginate or compound impression material were recorded. The following dates were recorded: (1) patient’s birth; (2) appliance insert; (3) re-cementation; (4) repair; and (5) removal. The fate of the appliance was noted as: (1) successful (the appliance was removed because it was no longer needed without any complications); (2) still in use; (3) required minimal maintenance (re-cementation and/or minor adjustment); (4) failed; (5) lost to follow-up; or (6) transferred to new care.

Successful appliances were either still in use or had been removed by the pediatric dentist having been deemed clinically successful either without complication or had required minor adjustment and/or recementation. The end date for a successful appliance was the date of removal. If an appliance failed, the mode of failure was recorded. Failure categories were as follows: (1) wire breakage; (2) split band; (3) lost appliance; (4) other. Appliance failures were then classified as no longer needed, repaired or remade.

**Data Analysis**

Data were entered into an Excel spreadsheet (Microsoft Excel for Mac 2011). All statistical analyses were tested with an alpha, or type I error, rate set at 0.05, and using IBM SPSS version 19 for OS X. Descriptive statistics, including frequencies of successes and failures, types of failures, and means and standard deviations of survival times, were obtained using the Frequencies and Descriptives functions. The influence of covariates, such as age, and gender, was tested using Cox Regression.

The Pearson Chi-Square test was conducted to assess if there were any significant differences between the successes and failures of the appliances. The Fisher's Exact Test correction was used to correct for cells with low expected frequencies. To find out if there was a difference in the average survival time between the failed appliances, omnibus ANOVAs (using the Welch test to account for heterogeneity of variance) were conducted to test the equality of the mean survival times of the failed appliances. To test the differences between specific pairs’ means, the Games Howell post-hoc analysis, which also accounts for heterogeneity of variance between groups, was conducted. The same statistical tests were used to assess if there were any
significant differences in the mean time elapsed until the successful appliances were removed.

2. Survey Study

Study Design

North American pediatric dentists and orthodontists were surveyed about their personal background, as well as their use of and attitudes toward fspms. This survey was developed at the University of Toronto, Faculty of Dentistry in September 2010. Pre-testing was done by dental faculty at the University of Toronto and The Hospital for Sick Children, Toronto, Canada, none of whom were involved in the original development of the instrument. Changes were made to the survey to improve clarity and validity based on comments and critiques from pre-testers. A web-based version of the survey ([www.surveymonkey.com](http://www.surveymonkey.com)) was developed. This survey consisted of 27 questions divided into 3 main sections: demographics and professional background; attitudes toward fspms; and use of fspms in practice, and were customized for pediatric dentists (Appendix C) and orthodontists (Appendix D). The survey tool and research proposal were submitted to, and approved by the Research Ethics Board at the University of Toronto, in October 2010.

To obtain a random sample of respondents, the email addresses of all of the active members of the AAPD was transferred to an excel spreadsheet from the listerv provided by the AAPD. A random number algorithm was generated for the column in which the email addresses were placed and then sorted from smallest to largest. The first 1000 email addresses were then listed as the potential respondents. A similar method was used by the AAO to generate a random list of 1000 active orthodontists. An email was sent to the pediatric dentists and orthodontists on July 4, 2011. It contained an introduction to the study, stated the study’s purpose, a description of the survey and assurance of confidentiality (see appendix E). Embedded in the cover letter was a link to the self-administered online survey on the Survey Monkey web site ([www.surveymonkey.com](http://www.surveymonkey.com)). The recipient was then freely and voluntarily able to choose whether to participate in the study by completing and submitting the survey through Survey Monkey. The survey was programmed to require completion of each question prior to being able to submit the survey. Two weeks after the initial email was sent, a reminder email containing the same information was sent to the sample of pediatric dentists and orthodontists. The survey was
closed 8 weeks after the initial email was sent.

Data Analysis

The Survey Monkey website was used to compile and analyze the results to facilitate data management. Visual summaries of the responses were generated via the Survey Monkey website.
Chapter 3

Results

1. Retrospective Cohort Study

Five hundred and thirty one subjects with a mean age of 9.43 years, SD +/- 2.83 and a range of 2 years 3 months to 17 years 11 months were included in the study. The mean ages of the participants are listed in Table 5. A total of 899 appliances were included which consisted of 226 band and loops (25.2%), 10 distal shoes (1.1%), 267 LLHAs (29.7%), 98 Nance appliances (10.9%), and 298 ULHAs (33.1%) (Figure 1).

Table 5. Mean ages (years) of the patients at the time of insertion of the fixed space maintainers

<table>
<thead>
<tr>
<th>Appliances</th>
<th>N</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>Standard Error</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band and Loop</td>
<td>226</td>
<td>6.57</td>
<td>1.35</td>
<td>0.09</td>
<td>6.39</td>
<td>6.75</td>
</tr>
<tr>
<td>Distal Shoe</td>
<td>10</td>
<td>6.19</td>
<td>0.53</td>
<td>0.17</td>
<td>5.81</td>
<td>6.56</td>
</tr>
<tr>
<td>LLHA</td>
<td>267</td>
<td>9.53</td>
<td>1.61</td>
<td>0.10</td>
<td>9.33</td>
<td>9.72</td>
</tr>
<tr>
<td>Nance</td>
<td>98</td>
<td>13.93</td>
<td>1.96</td>
<td>0.20</td>
<td>13.54</td>
<td>14.33</td>
</tr>
<tr>
<td>ULHA</td>
<td>298</td>
<td>10.18</td>
<td>2.29</td>
<td>0.14</td>
<td>9.91</td>
<td>10.45</td>
</tr>
<tr>
<td>Total</td>
<td>899</td>
<td>9.43</td>
<td>2.83</td>
<td>0.10</td>
<td>9.24</td>
<td>9.62</td>
</tr>
</tbody>
</table>
Four hundred and sixty appliances were placed in males and 439 were placed in females. There were no statistically significant differences in the sample representation of device type by gender, \( \chi^2 (4) = 8.57, p = 0.07 \). There was a significant difference of average age at the time of placement between the device types, \( F (4, 76.95) = 403.14, p < 0.001 \), using the Welch correction for heterogeneous variance. The significant differences between the mean ages of the patients according to the Games-Howell procedure are listed in Table 6.
Table 6. Mean differences in ages according to the Games-Howell procedure

<table>
<thead>
<tr>
<th>Type (I)</th>
<th>Type (J)</th>
<th>Mean Difference (I-J)</th>
<th>Standard Error</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band and Loop</td>
<td>Distal Shoe</td>
<td>0.38</td>
<td>0.19</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>LLHA</td>
<td>-2.96*</td>
<td>0.13</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Nance</td>
<td>-7.36*</td>
<td>0.22</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>ULHA</td>
<td>-3.61*</td>
<td>0.16</td>
<td>0.00</td>
</tr>
<tr>
<td>Distal Shoe</td>
<td>Band and Loop</td>
<td>-0.38</td>
<td>0.19</td>
<td>0.30</td>
</tr>
<tr>
<td></td>
<td>LLHA</td>
<td>-3.34*</td>
<td>0.19</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Nance</td>
<td>-7.75*</td>
<td>0.26</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>ULHA</td>
<td>-3.99*</td>
<td>0.21</td>
<td>0.00</td>
</tr>
<tr>
<td>LLHA</td>
<td>Band and Loop</td>
<td>2.96*</td>
<td>0.13</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Distal Shoe</td>
<td>3.34*</td>
<td>0.19</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Nance</td>
<td>-4.40*</td>
<td>0.22</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>ULHA</td>
<td>-0.65*</td>
<td>0.17</td>
<td>0.00</td>
</tr>
<tr>
<td>Nance</td>
<td>Band and Loop</td>
<td>7.36*</td>
<td>0.22</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Distal Shoe</td>
<td>7.75*</td>
<td>0.26</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>LLHA</td>
<td>4.40*</td>
<td>0.22</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>ULHA</td>
<td>3.75*</td>
<td>0.24</td>
<td>0.00</td>
</tr>
<tr>
<td>ULHA</td>
<td>Band and Loop</td>
<td>3.61*</td>
<td>0.16</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Distal Shoe</td>
<td>3.99*</td>
<td>0.21</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>LLHA</td>
<td>0.65*</td>
<td>0.17</td>
<td>0.00</td>
</tr>
<tr>
<td></td>
<td>Nance</td>
<td>-3.75*</td>
<td>0.24</td>
<td>0.00</td>
</tr>
</tbody>
</table>

* p < 0.05
However, a Cox regression analysis on clinical outcome (success versus failure) showed no relationship between gender, device type, or age at the time of placement of the appliances and clinical success (all \( p \)'s > 0.05, the chi-square difference between null model and full model, \( \chi^2 (6) = 9.64, p = 0.14 \)).

**Clinical Outcomes**

**Unfavourable Events.** Eighty-nine (10.0%) of the appliances were associated with unfavourable events. There were 39 (4.3%) broken spms, 33 (3.7%) were lost completely, 12 (1.3%) had spit bands, and 11 (1.2%) failed for other reasons such as pulpal, periapical or furcation pathosis (Table 7, Figure 2). A chi-square test of independence, using the Fisher's exact test correction, yielded a significant result, \( \chi^2 (12) = 53.52, p < 0.001 \). There were statistically significantly more observed "other" failures for the Nance than would have been expected by chance alone. The band and loops had significantly fewer “broken devices” than would have been expected, and significantly more “lost appliances” and “other” failures. The observed and the expected frequencies are summarized in Table 7.
**Table 7.** Observed and expected frequencies and chi square values for the unfavourable outcomes (N=89)

<table>
<thead>
<tr>
<th></th>
<th>Band and Loop</th>
<th>Distal Shoe</th>
<th>LLHA</th>
<th>Nance</th>
<th>ULHA</th>
<th>Row Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broken</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>0</td>
<td>0</td>
<td>10</td>
<td>0</td>
<td>27</td>
<td>37</td>
</tr>
<tr>
<td>Expected N</td>
<td>8.31</td>
<td>0.42</td>
<td>8.31</td>
<td>0.83</td>
<td>19.12</td>
<td></td>
</tr>
<tr>
<td>$\chi^2$ Contribution</td>
<td><strong>8.31</strong>*</td>
<td>0.42</td>
<td>0.34</td>
<td>0.83</td>
<td>3.24</td>
<td></td>
</tr>
<tr>
<td>Split Band</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>0</td>
<td>5</td>
<td>10</td>
</tr>
<tr>
<td>Expected N</td>
<td>2.25</td>
<td>0.12</td>
<td>2.25</td>
<td>0.22</td>
<td>5.17</td>
<td></td>
</tr>
<tr>
<td>$\chi^2$ Contribution</td>
<td>2.25</td>
<td>0.12</td>
<td>3.37</td>
<td>0.22</td>
<td>0.00</td>
<td></td>
</tr>
<tr>
<td>Lost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>13</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>12</td>
<td>31</td>
</tr>
<tr>
<td>Expected N</td>
<td>7.00</td>
<td>0.35</td>
<td>6.97</td>
<td>0.70</td>
<td>16.02</td>
<td></td>
</tr>
<tr>
<td>$\chi^2$ Contribution</td>
<td><strong>5.22</strong>*</td>
<td>1.22</td>
<td>0.55</td>
<td>0.70</td>
<td>1.01</td>
<td></td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>N</td>
<td>7</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>11</td>
</tr>
<tr>
<td>Expected N</td>
<td>2.47</td>
<td>0.12</td>
<td>2.47</td>
<td>0.25</td>
<td>5.68</td>
<td></td>
</tr>
<tr>
<td>$\chi^2$ Contribution</td>
<td><strong>8.29</strong>*</td>
<td>0.12</td>
<td>2.47</td>
<td><strong>12.43</strong>*</td>
<td>2.40</td>
<td></td>
</tr>
<tr>
<td>Column Total</td>
<td>20</td>
<td>1</td>
<td>20</td>
<td>2</td>
<td>46</td>
<td>89</td>
</tr>
</tbody>
</table>

* $p < 0.05$
**Figure 2.** Graphical representation of the incidence of unfavourable outcomes for those fixed space maintainers that experienced an unfavourable outcome (N=89)

The unfavourable outcomes were subdivided into two categories: “no longer needed” or “required repair” (Table 8). Fifty-nine spms (6.6%) were no longer needed and were added to the successful group. The remaining 30 appliances (3.3%) required repair and were considered failed appliances. In addition, 91 appliances (10.1%) were lost to follow up or transferred to new care.
Table 8. Frequency of unfavourable events subdivided into two groups: “repaired/remade” and “no longer needed” (N=89)

<table>
<thead>
<tr>
<th>Subgroup</th>
<th>Band and loop</th>
<th>Distal shoe</th>
<th>LLHA</th>
<th>Nance</th>
<th>ULHA</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Broken</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repaired/Remade</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>18</td>
<td>22</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No longer needed</td>
<td>0</td>
<td>0</td>
<td>4</td>
<td>0</td>
<td>8</td>
<td>12</td>
</tr>
<tr>
<td>Split band</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repaired/Remade</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>1</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No longer needed</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>0</td>
<td>4</td>
<td>7</td>
</tr>
<tr>
<td>Lost</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repaired/Remade</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No longer needed</td>
<td>12</td>
<td>1</td>
<td>5</td>
<td>0</td>
<td>12</td>
<td>30</td>
</tr>
<tr>
<td>Other</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Repaired/Remade</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No longer needed</td>
<td>6</td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>2</td>
<td>10</td>
</tr>
</tbody>
</table>

Successful Appliances. There were 609 appliances (67.7%) that were removed uneventfully and were successful. There were 110 appliances (12.2%) intact and in use at the end of the study period that were not associated with any adverse events. The 609 successful appliances, 110 intact appliances, and the 59 appliances mentioned above that were no longer needed were combined for a total of 778 (86.5%) successful appliances (Figures 3a and 3b).
Figure 3a. Distribution of specific clinical outcomes of the fixed space maintainers

Among the devices in the study (excluding those that were lost to follow up or transferred to new care) the proportions of successful versus failed appliances are listed in Table 5 and illustrated in
Figure 4. There were no significant differences between the success and failure rates of the various appliances, $\chi^2(4) = 4.52$, $p = 0.34$. Since two of the expected cell frequencies in Table 9 were less than 5, the Fisher’s Exact Test correction was used to correct the $p$-value ($p = 0.37$).

**Table 9.** Failure versus success rates of the fixed space maintainers (n= 808*)

<table>
<thead>
<tr>
<th></th>
<th>Band and Loop</th>
<th>Distal Shoe</th>
<th>LLHA</th>
<th>Nance</th>
<th>ULHA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure</td>
<td>8</td>
<td>0</td>
<td>6</td>
<td>2</td>
<td>14</td>
</tr>
<tr>
<td>Success</td>
<td>143</td>
<td>9</td>
<td>253</td>
<td>95</td>
<td>278</td>
</tr>
<tr>
<td>Failure Rate</td>
<td>5.30%</td>
<td>0.00%</td>
<td>2.32%</td>
<td>2.06%</td>
<td>4.70%</td>
</tr>
</tbody>
</table>

*Appliances that were lost to follow up or transferred to new care were excluded.
**Figure 4.** Number of space maintainers that failed overall versus the number of appliances that were considered successful overall (n= 808*)

![Bar chart showing number of space maintainers](chart.png)

*Appliances that were lost to follow up or transferred to new care were excluded.

**Time to Failure**

The average time elapsed for the appliances to fail are listed in Table 10a. The result of the one-way ANOVA shown in Table 10b was significant, $F (3, 12.40) = 6.04, p = 0.01$ (using the Welch correction for heterogeneity of variance), indicating that there was a significant difference between the mean times until the appliances failed. The results of the Games-Howell post-hoc analysis are displayed in Table 10c. It highlights that there were no significant differences between the means of the group, however, some were close: the band and loop (Mean = 24.93) had a longer time to failure than the Nance appliance (Mean = 2.94), $p = .056$, and the ULHA (Mean = 19.27) had a longer time to failure than the Nance (Mean = 2.94), $p = 0.08$. Figures 5a and 5b illustrate the mean time in months before the first failures occurred.
**Table 10a.** Average amount of time (months) elapsed for the appliances that failed to fail (N=30)

<table>
<thead>
<tr>
<th></th>
<th>Mean (months)</th>
<th>Standard Deviation (months)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band and Loop</td>
<td>24.93</td>
<td>19.17</td>
<td>8</td>
</tr>
<tr>
<td>LLHA</td>
<td>19.08</td>
<td>16.19</td>
<td>6</td>
</tr>
<tr>
<td>Nance</td>
<td>2.94</td>
<td>2.30</td>
<td>2</td>
</tr>
<tr>
<td>ULHA</td>
<td>19.27</td>
<td>22.54</td>
<td>14</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>19.65</strong></td>
<td><strong>19.72</strong></td>
<td><strong>30</strong></td>
</tr>
</tbody>
</table>

**Table 10b.** One-way ANOVA of the mean time elapsed for the failed appliances to fail

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Between Groups</strong></td>
<td>785.50</td>
<td>3</td>
<td>261.83</td>
<td>0.65</td>
<td>0.59</td>
</tr>
<tr>
<td><strong>Within Groups</strong></td>
<td>10495.87</td>
<td>26</td>
<td>403.59</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>11281.37</td>
<td>29</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Table 10c. Games-Howell post-hoc analysis for mean time elapsed for failed appliances to fail

<table>
<thead>
<tr>
<th>TYPE (I)</th>
<th>TYPE (J)</th>
<th>Mean Difference (I-J)</th>
<th>Standard Error</th>
<th>Significance</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band and Loop</td>
<td>LLA</td>
<td>5.85</td>
<td>9.47</td>
<td>0.92</td>
<td>-22.34</td>
<td>34.05</td>
</tr>
<tr>
<td></td>
<td>Nance</td>
<td>21.99</td>
<td>6.97</td>
<td>0.06</td>
<td>-0.57</td>
<td>44.55</td>
</tr>
<tr>
<td></td>
<td>ULHA</td>
<td>5.66</td>
<td>9.07</td>
<td>0.92</td>
<td>-20.15</td>
<td>31.47</td>
</tr>
<tr>
<td>LLHA</td>
<td>Band and Loop</td>
<td>-5.85</td>
<td>9.47</td>
<td>0.92</td>
<td>-34.05</td>
<td>22.34</td>
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<tr>
<td></td>
<td>Nance</td>
<td>16.14</td>
<td>6.81</td>
<td>0.19</td>
<td>-8.09</td>
<td>40.36</td>
</tr>
<tr>
<td></td>
<td>ULHA</td>
<td>-0.19</td>
<td>8.94</td>
<td>1.00</td>
<td>-26.38</td>
<td>25.99</td>
</tr>
<tr>
<td>Nance</td>
<td>Band and Loop</td>
<td>-21.99</td>
<td>6.97</td>
<td>0.06</td>
<td>-44.55</td>
<td>0.57</td>
</tr>
<tr>
<td></td>
<td>LLHA</td>
<td>-16.14</td>
<td>6.81</td>
<td>0.19</td>
<td>-40.36</td>
<td>8.09</td>
</tr>
<tr>
<td></td>
<td>ULHA</td>
<td>-16.33</td>
<td>6.24</td>
<td>0.08</td>
<td>-34.47</td>
<td>1.81</td>
</tr>
<tr>
<td>ULHA</td>
<td>Band and Loop</td>
<td>-5.66</td>
<td>9.07</td>
<td>0.92</td>
<td>-31.47</td>
<td>20.15</td>
</tr>
<tr>
<td></td>
<td>LLHA</td>
<td>0.19</td>
<td>8.94</td>
<td>1.00</td>
<td>-25.99</td>
<td>26.38</td>
</tr>
</tbody>
</table>
**Figure 5a.** Mean time (months) elapsed before the first failure occurred for each appliance type

**Figure 5b.** Mean time (months) elapsed before the first failure occurred for each appliance type
Time to Success

Of the successful appliances, the LLHA, on average, was the appliance that required the longest amount of time to successfully complete its treatment course (28.4 months), followed by the distal shoe (27.3 months), the band and loop (27.1 months), and the ULHA (25.7 months). The Nance appliance required the shortest amount of time, on average, to complete its course of treatment (15.4 months). Censored data, values that were only partially known, were excluded from this analysis (Table 11a).

The result of the one-way ANOVA shown in Table 11b was significant, $F(4, 56.59) = 20.46$, $p < .001$ (using the Welch correction for heterogeneity of variance), indicating that there was a significant difference between the mean times until the successful appliances were removed. The results of the Games-Howell post-hoc analysis are displayed in Table 11c. Figures 6a and 6b illustrate the mean time in months until the appliances were considered successful.

**Table 11a.** Average time elapsed for the successful appliances to achieve success (N = 668*)

<table>
<thead>
<tr>
<th></th>
<th>Mean (months)</th>
<th>Standard Deviation (months)</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band and loop</td>
<td>27.13</td>
<td>17.94</td>
<td>131</td>
</tr>
<tr>
<td>Distal shoe</td>
<td>27.25</td>
<td>10.17</td>
<td>9</td>
</tr>
<tr>
<td>LLHA</td>
<td>28.37</td>
<td>11.63</td>
<td>225</td>
</tr>
<tr>
<td>Nance</td>
<td>15.39</td>
<td>9.44</td>
<td>61</td>
</tr>
<tr>
<td>ULHA</td>
<td>25.71</td>
<td>13.32</td>
<td>242</td>
</tr>
<tr>
<td>Overall</td>
<td>25.96</td>
<td>13.93</td>
<td>668</td>
</tr>
</tbody>
</table>

* Censored data was excluded from this analysis.
Table 11b. One-way ANOVA of the average amount of time elapsed for the successful appliances to succeed

<table>
<thead>
<tr>
<th></th>
<th>Sum of Squares</th>
<th>DF</th>
<th>Mean Square</th>
<th>F</th>
<th>Significance</th>
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<tr>
<td>Between Groups</td>
<td>8328.16</td>
<td>4</td>
<td>2082.04</td>
<td>11.40</td>
<td>0.001</td>
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<tr>
<td>Within Groups</td>
<td>121067.93</td>
<td>663</td>
<td>182.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>129396.09</td>
<td>667</td>
<td></td>
<td></td>
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</tr>
</tbody>
</table>

Table 11c. Games-Howell post-hoc analysis for the average amount of time elapsed for the successful appliances to succeed

<table>
<thead>
<tr>
<th>TYPE (I)</th>
<th>TYPE (J)</th>
<th>Mean Difference (I-J)</th>
<th>Standard Error</th>
<th>Significance</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Band and Loop</td>
<td>Distal Shoe</td>
<td>-0.12</td>
<td>3.73</td>
<td>1.00</td>
<td>-12.06</td>
<td>11.82</td>
</tr>
<tr>
<td>LLHA</td>
<td>-1.24</td>
<td>1.75</td>
<td>0.95</td>
<td>-6.06</td>
<td>3.58</td>
<td></td>
</tr>
<tr>
<td>Nance</td>
<td>11.73</td>
<td>1.98</td>
<td>0.00</td>
<td>6.29</td>
<td>17.19</td>
<td></td>
</tr>
<tr>
<td>ULHA</td>
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<td>1.79</td>
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<td>-3.49</td>
<td>6.33</td>
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<tr>
<td>Distal Shoe</td>
<td>Band and Loop</td>
<td>0.12</td>
<td>3.73</td>
<td>1.00</td>
<td>-11.82</td>
<td>12.06</td>
</tr>
<tr>
<td>LLHA</td>
<td>-1.12</td>
<td>3.48</td>
<td>1.00</td>
<td>-12.85</td>
<td>10.61</td>
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<td>0.05</td>
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<td></td>
<td>ULHA</td>
<td>LLHA</td>
<td>Distal Shoe</td>
<td>Nance</td>
<td>ULHA</td>
<td>Nance</td>
</tr>
<tr>
<td>----------------</td>
<td>------</td>
<td>------</td>
<td>-------------</td>
<td>-------</td>
<td>------</td>
<td>-------</td>
</tr>
<tr>
<td>LLHA Band and Loop</td>
<td>1.24</td>
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<td>0.95</td>
<td>-11.74</td>
<td>1.98</td>
</tr>
<tr>
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<td>1.75</td>
<td>3.48</td>
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<td>-3.58</td>
<td>1.75</td>
<td>1.98</td>
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<td>-10.61</td>
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<td>0.00</td>
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<td>-6.22</td>
<td>0.51</td>
<td>6.22</td>
</tr>
<tr>
<td></td>
<td>1.44</td>
<td>1.44</td>
<td>1.48</td>
<td>16.96</td>
<td>1.44</td>
<td>1.44</td>
</tr>
<tr>
<td>ULHA Band and Loop</td>
<td>2.66</td>
<td>2.66</td>
<td>-10.32</td>
<td>-6.22</td>
<td>2.66</td>
<td>-6.22</td>
</tr>
<tr>
<td></td>
<td>1.16</td>
<td>1.16</td>
<td>1.48</td>
<td>5.82</td>
<td>1.16</td>
<td>1.48</td>
</tr>
<tr>
<td></td>
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<td>0.93</td>
<td>-6.33</td>
<td>0.15</td>
<td>0.93</td>
</tr>
<tr>
<td>Distal Shoe</td>
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<td>-0.50</td>
<td>-14.42</td>
<td>-6.22</td>
<td>-0.50</td>
<td>-6.22</td>
</tr>
<tr>
<td></td>
<td>5.82</td>
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<td>6.33</td>
<td>10.20</td>
<td>5.82</td>
<td>10.20</td>
</tr>
<tr>
<td>LLHA</td>
<td>-2.66</td>
<td>-2.66</td>
<td>-1.54</td>
<td>-5.82</td>
<td>-2.66</td>
<td>-5.82</td>
</tr>
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<td>1.54</td>
<td>0.51</td>
<td>1.15</td>
<td>0.51</td>
</tr>
<tr>
<td>Nance</td>
<td>10.32</td>
<td>10.32</td>
<td>1.12</td>
<td>6.22</td>
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<td>1.48</td>
<td>3.49</td>
<td>14.42</td>
<td>1.48</td>
<td>14.42</td>
</tr>
</tbody>
</table>
Figure 6a. Mean time (months) until successful appliances achieved success
**Figure 6b.** Mean time (months) until successful appliances achieved success
2. Survey Study

Responses

The survey instrument was e-mailed to a random sample of 1000 active members of the AAPD and 1000 active members of the AAO from the online membership roster. Fifteen of the emails sent to the pediatric dentists and 12 sent to the orthodontists were unable to be delivered for technical reasons such as, “email address no longer valid”, “email inbox full”, or “user not accepting unsolicited emails”. Therefore the total number of potential pediatric dentistry respondents was \( n = 985 \) and potential orthodontic respondents was \( n = 988 \). The survey was available online for 2 months (July 4, 2011 to Sept 4, 2011). Four hundred and twenty-three pediatric dentists and 69 orthodontists responded which represents a response rate of 43.0% and 7.0% for pediatric dentists and orthodontists, respectively.

Personal and Professional Background

**Demographic Information.** Sixty one percent of pediatric dentists that responded and 87.0% of orthodontists that responded were male. Only 7 respondents were in the 20 to 29 year old age group; all other pediatric dentists were evenly distributed amongst all of the age categories (Figure 7a). There were no orthodontists in the 20-29 year old age group and the most respondents were in the 50 to 59 year old age category (Figure 7b).
**Figure 7a.** Age distribution of responding pediatric dentists to the survey

![Bar chart showing age distribution of pediatric dentists](image)

**Figure 7b.** Age distribution of responding orthodontists to the survey

![Bar chart showing age distribution of orthodontists](image)

The pediatric dentists who responded to the survey showed a decreasing trend in number of respondents as the number of years in practice increased (Figure 8a). The number of years practicing orthodontics was fairly evenly distributed, with the smallest number of respondents practicing for $\geq 40$ years (Figure 8b).
**Figure 8a.** Distribution of the number of years that the pediatric dentists have been in practice

**Figure 8b.** Distribution of the number of years that the orthodontists have been in practice

**Education.** Just over half of the pediatric dentists (53.7%) classified their program as “combined” where training occurred in both a hospital and a university setting. The vast majority of the orthodontists (92.8%), however, attended university-based programs. The percentages of pediatric dentists who trained in a hospital based program, or in a university setting were 16.8% and 29.6% respectively. The percentages of orthodontists who trained in a hospital based program, or in a combined program were 2.9% and 4.3% respectively.
The vast majority of the pediatric dentists (99.5%) and the orthodontists (88.4%) attended programs that advocated and provided training for the use of fspms.

**Current Practice**

There was an even distribution of pediatric dentists (Figure 9a) and orthodontists (Figure 9b) in all of the districts defined by the AAPD (Figure 10).

**Figure 9a.** Distribution of districts in which the pediatric dentists primarily practiced
**Figure 9b.** Distribution of districts in which the orthodontists primarily practiced

- **District 1 (CT, ME, MA, NH, NY, RI, VT, NL, NS, PEI, NB, QC)**
- **District 2 (DE, DC, MD, NJ, PA)**
- **District 3 (AL, FL, GA, KY, MS, NC, SC, TN, VA, WV, PR)**
- **District 4 (IL, IN, IA, ON, MB, OH, MI, MN, NE, ND, SD, WI)**
- **District 5 (AR, CO, KS, LA, MO, NM, OK, TX, MX)**
- **District 6 (AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY, SK, AB, BC, NT, NU, YT)**

**Figure 10.** Diagrammatic representation of the AAPD district and state sites (Canadian provinces not illustrated)

(AAPD District and State Sites, 2011)
Tables 12a and 12b show the percentage of time spent by pediatric dentists and orthodontists, respectively, in various practice settings. Most of the respondents worked mainly in private practice.

**Table 12a.** Distribution of time spent practicing pediatric dentistry in various locations by the pediatric dentistry survey respondents

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private practice</td>
<td>30</td>
<td>13</td>
<td>12</td>
<td>15</td>
<td>45</td>
<td>308</td>
</tr>
<tr>
<td>Academic</td>
<td>295</td>
<td>84</td>
<td>12</td>
<td>10</td>
<td>6</td>
<td>16</td>
</tr>
<tr>
<td>Hospital</td>
<td>220</td>
<td>157</td>
<td>25</td>
<td>7</td>
<td>2</td>
<td>12</td>
</tr>
<tr>
<td>Public clinic*</td>
<td>380</td>
<td>21</td>
<td>5</td>
<td>4</td>
<td>1</td>
<td>12</td>
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<tr>
<td>Retired</td>
<td>418</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>3</td>
</tr>
</tbody>
</table>

* Examples: public health clinic, Medicaid clinic, military clinic
Table 12b. Distribution of time spent practicing orthodontics in various locations by the orthodontic survey respondents

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private practice</td>
<td>1</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>3</td>
<td>64</td>
</tr>
<tr>
<td>Academic</td>
<td>59</td>
<td>7</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>2</td>
</tr>
<tr>
<td>Hospital</td>
<td>67</td>
<td>2</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Public clinic*</td>
<td>68</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Retired</td>
<td>68</td>
<td>1</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
</tbody>
</table>

* Examples: public health clinic, Medicaid clinic, military clinic

The majority of the orthodontists (68.1%) did not treat children who were in the primary dentition stage of occlusal development. Eighty-to-100% of the patients treated by 30.4% of the orthodontists were in the permanent dentition stage of occlusal development (Tables 13a).
Table 13a. Distribution of patients treated by orthodontists in the various stages of occlusal development

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>47</td>
<td>22</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Mixed</td>
<td>0</td>
<td>25</td>
<td>32</td>
<td>11</td>
<td>1</td>
<td>0</td>
</tr>
<tr>
<td>Permanent</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>13</td>
<td>32</td>
<td>21</td>
</tr>
</tbody>
</table>

The pediatric dentists, however, have a more even distribution of patients in all three stages of occlusal development; <20% of the patients seen by about half of the pediatric dentists were in the permanent dentition stage of occlusal development (Table 13b)

Table 13b. Distribution of patients treated by pediatric dentists in the various stages of occlusal development

<table>
<thead>
<tr>
<th>Answer Options</th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>10</td>
<td>28</td>
<td>213</td>
<td>148</td>
<td>19</td>
<td>5</td>
</tr>
<tr>
<td>Mixed</td>
<td>2</td>
<td>20</td>
<td>200</td>
<td>181</td>
<td>19</td>
<td>1</td>
</tr>
<tr>
<td>Permanent</td>
<td>10</td>
<td>227</td>
<td>154</td>
<td>18</td>
<td>7</td>
<td>7</td>
</tr>
</tbody>
</table>

The vast majority of both the pediatric dentists (99.8%) and the orthodontists (97.0%) provided fspms in their practice.
Figures 11a and 11b demonstrate that the majority of the pediatric dentists and the orthodontist respectively stated that there was no deterrent to their use of fspms.

**Figure 11a.** Greatest deterrents to pediatric dentists’ use of fixed space maintainers

![Pie chart showing the percentages of deterrents to pediatric dentists](chart)

- Failure rate: 4%
- Cost: 68%
- Patients are not compliant with follow up care: 10%
- Most patients intend to seek orthodontic care: 15%
- Lack of training: 2%
- None: 1%

**Figure 11b.** Greatest deterrents to orthodontists’ use of fixed space maintainers

![Pie chart showing the percentages of deterrents to orthodontists](chart)

- Failure rate: 3%
- Cost: 9%
- Patients are not compliant for follow up care: 3%
- Most patients intend to seek advanced orthodontic care: 8%
- Lack of training: 77%
- None: 0%
Treatment Considerations Associated with Fixed Space Maintainers

The majority of the pediatric dentists (97.6%) and orthodontists (89.9%) considered spms to be a standard of care. When asked if they consider space management issues when treatment planning a primary tooth extraction, 97.6% of the pediatric dentists and 95.7% of the orthodontists answered positively. The vast majority of the pediatric dentists (97.8%) and the orthodontists (92.8%) considered space maintenance to be an important part of interceptive and preventive dental care. The strategic importance of the extracted/missing tooth in the arch was an important factor to consider when treatment planning a spm by 97.8% and 98.6% of the pediatric dentists and the orthodontists, respectively.

Causes of Failure of Fixed Space Maintainers

Cement loss (47.6%, 27.5%) and breakage (23.4%, 30.4%) were considered by the pediatric dentists and the orthodontists, respectively, to be the most common causes of fixed spm failure (Figure 12).
**Figure 12.** Most common causes of failure of fixed space maintainers cited by pediatric dentists and orthodontists

![Bar chart showing the percentage of pediatric dentists and orthodontists who cited each cause of failure.](chart.png)

**Maintenance Versus Failure of Re-cemented Appliances**

Only 14.5% of the orthodontists and 11.1% of the pediatric dentists considered an appliance that requires re-cementation due to cement loss a failure. Similarly, based upon the responses from a separate question, 72.5% of the orthodontists and 85.0% of the pediatric dentists considered re-cementation of a fspm as maintenance rather than a failure (Figures 13a and 13b).
**Figure 13a.** Pediatric dentists’ and orthodontists’ opinions regarding whether re-cementation of a fixed space maintainer should be considered a failure.
**Figure 13b.** Pediatric dentists’ and orthodontists’ opinions regarding whether re-cementation of a fixed space maintainer should be considered maintenance of an appliance rather than a failure

Follow-Up

The majority of the orthodontists (56.5%) believe that FSPMS should be followed up every 6 months. Pediatric dentists were divided between following up the FSPMS every 6 months (49.3%) and at recall appointments (33.8%) (Figure 14).
Figure 14. Pediatric dentists’ and orthodontists’ opinions regarding how frequently fixed space maintainers should be followed-up

Among the orthodontists, 85.5% provided 1-10 fpsms per month, whereas 58.9% of the pediatric dentists provided 1-10 fpsms per month; 36.2% of pediatric dentists provided 10-30 fpsms per month (Figure 15).
**Figure 15.** Number of fixed space maintainers provided by pediatric dentists and orthodontists per month

![Figure 15](image.png)

**Types of Fixed Space Maintainers Placed**

The most common type of fspm placed by orthodontists (95.5%) was the lingual arch, followed by the Nance appliance (65.2%) and band and loops (57.6%). The least commonly placed fspm was the distal shoe. Lingual arches and band and loops were the fspm placed most often by pediatric dentists (98.3% and 94.5%, respectively). The least commonly placed fspms were the transpalatal arch and the distal shoe (51.5% and 44.6%, respectively) (Figure 16).
**Figure 16.** Types of fixed space maintainers placed by pediatric dentists and orthodontists

![Bar chart showing types of fixed space maintainers](image)

The vast majority of the orthodontists (87.9%) exclusively provided custom lab fabricated spms, while only 49.3% of pediatric dentists exclusively provided custom lab fabricated fspms. A combination of custom lab fabricated and prefabricated fspms were provided by 44.9% of pediatric dentist.

**Reasons for Placement of Fixed Space Maintainers**

Most of the fspms provided by the vast majority of the pediatric dentists (93.2%) were placed to compensate for teeth extracted due to caries. Only 54.7% of the orthodontists provide fspms for the same reason.
Dental Insurance Coverage

A patient’s dental insurance coverage did not affect the decision to provide a spm when indicated for 86.8% of the pediatric dentists and 95.5% of the orthodontists.

Cements

The majority of pediatric dentists (88.5%) use glass ionomer cement (GIC) to secure their fspms, while 59.1% of orthodontists use GIC for the same purpose (Figure 17).

Figure 17. Types of cements used by pediatric dentists to cement fixed space maintainers
Chapter 4

Discussion

The present study was conducted in a private pediatric dental office by a sole clinician with 25 years of experience treating children and adolescents. A strict protocol was followed for the fabrication and placement of the space maintainers (spms) followed by recall appointments that were rarely missed. The overall clinical success for the fixed space maintainers (fspms) in this study was 86.6%. Only 3.0% of the appliances failed. It took an average of 20 months for the appliances that failed to fail and an average of 26 months for appliances that succeeded to achieve success. There were no significant differences between the successes and failures of the various appliances. Thus, the results of this study suggest that, despite the poor success rates in the published literature, fspms can be reliable and dependable appliances that should be placed whenever they are indicated.

In fact, according to the results of the survey, the vast majority of respondent pediatric dentists (99.8%) and orthodontists (97.0%) provided fspms in their practice, and 97.6% of the pediatric dentists and 89.9% of the orthodontists considered spms to be a standard of care. Since it would be both time consuming and of poor financial merit to recommend and place appliances that were ineffective and continuously failed, it can be assumed that the published fspm studies do not necessarily reflect the actual experience of these two groups of specialists.

1. Retrospective Cohort Study

Advantages of the Study

The retrospective nature of this study allowed for a large sample size that enabled the detection of small differences in the results. It was previously determined that a sample size of 63 subjects would have been sufficient to allow for 80% power at a 5% level of statistical significance. The number of fixed spms included in this study was 899. This was the largest sample reported in any fixed spm study to date. Previously published studies contained various sample sizes ranging from 40-663 appliances (See Table 2, Pg. 18).
Included in the study were 298 ULHAs, 267 LLHAs, 226 band and loops, 98 Nance appliances and 10 distal shoes. This was the only study to report the success and longevity of ULHAs and, albeit a small number, of conventional distal shoes.

The charts in the published fspm studies were reviewed between 4-7 years. The charts in this study were reviewed over a 10 year period allowing for several follow-up visits and appliance assessments to be recorded.

The mean age of the sample was 9.43 years, SD +/- 2.83 with a range of 2 years 3 months to 17 years 11 months. The Pearson chi square test showed no statistically significant differences in the sample representation by age (p=0.498). Similar age ranges were included in Qudiemat and Fayle’s (1998) study. The age ranges in the published space maintainer studies varied widely and were summarized in Table 3, Pg. 20.

It could have been postulated that the younger the patients were at the time of placement, the higher the failure rates would have been since they may have been less likely to follow the post operative instructions, such as to avoid sticky or chewy food. Moreover, the first permanent molar clinical crowns might have been more amenable to banding in a nine year old than they would have been in a six or seven year old when less of the clinical crown is erupted (Moore & Kennedy, 2006). Fitting bands may have been more challenging in younger children as they may have been less cooperative, thus the retention rates may have been lower (Moore & Kennedy, 2006). Logistic regression analysis, however, showed no correlation between age at the time of placement of the appliances and clinical outcomes (p > 0.05). Baroni et al (1994) similarly found no difference between frequencies of failures among appliances cemented on permanent or primary molars.

The most common unfavourable outcomes that occurred in this sample were: appliance breakages, split bands and appliances that were lost completely (See Table 4, Pg. 22). Other untoward events that occurred were pulpal, periapical and/or furcation pathosis of the abutment tooth, and soft tissue irritation. These were grouped together as “other” unfavourable outcomes.

The results of the present study indicate there was no statistically significant difference between the failure rates of any of the fspms. This finding contradicts the previously reported literature probably due to the rigorous clinical protocol utilized by the single operator in the present study.
Hill et al (1975) found that LLHAs were the most commonly broken appliances. Qudeimat and Fayle (1998) reported that unilateral appliances survived more than twice as long as bilateral appliances. Rajab (2002) also reported that solder breakage most commonly occurred in association with the LLHA. The LLHA spans a longer distance creating a longer lever arm that would exert greater force on the insertion point of the wire at the solder joint. Patients may be more inclined to place their tongue under the wire of bilateral appliances, eventually weakening the metal causing breakage, or they may be subjected to greater occlusal stress than unilateral appliances (Qudeimat & Fayle, 1998). Rajab (2002) has even suggested avoiding the LLHA whenever possible due to their poor survival rate. The results of the present study would not support this recommendation, as the difference in failure rates was not statistically significant.

Overall Failure Rate

The overall failure rate in this study was 3.3%. This is substantially lower than the reported failure rates in the published literature (See Table 1, Pg. 17). Several reasons may account for this difference. The unfavourable outcomes in this study were subdivided into two categories: “no longer needed” or “required repair”. Appliances that were grouped as “no longer needed” were the ones to which an unfavourable event had occurred, but since they were no longer needed they were not repaired or remade. In other words, they were successful at maintaining the space, even though they experienced an untoward event, and were, therefore, added to the group of appliances considered successful.

Brill et al (2002) suggested that a clinically valid definition of success is that the appliance did what it was designed to do for the patient, even though it required service or repair during the course of treatment. They also state that since the treatment of a child by a pediatric dentist is a dynamic rather than a static relationship, it is the end point of therapy that should be used as a marker for success (Brill, 2002). This is contrary to the criteria for success of the other fixed spm literature in which appliances that required service or repair, regardless of whether or not they were no longer needed, were considered failures.

For example, Moore and Kennedy (2006) reported that 29 LLHAs and 15 Nance appliances out of a total of 482 appliances were considered failures even though they were not remade or recemented. They stated that although the appliances served their purpose, and the failures likely
occurred late into the appliances’ lifetimes, they still considered them failures (Moore & Kennedy, 2006). Under the criteria of the present study, these appliances would have been considered successful, and their reported failure rates would have decreased considerably. The corrected LLHA success rates would rise to 81% and 82% for the LLHAs and Nance appliances, respectively. Similarly, if the percentages of the appliances in the Fathian et al (2007) study that were no longer needed were added to the successful group, the success rates would rise from 66% to 77% for LLHAs and from 64% to 79% for the Nance appliances.

The second major reason for the discrepancy was that all of the published fixed spm studies considered cement loss to be a failure whereas the present study considered cement loss and chair side adjustments as “required maintenance” rather than failures.

Recementation was considered maintenance rather than failure in this project, which was supported by the majority of the survey respondents. Only 14.5% of orthodontists and 11.1% of pediatric dentists considered an appliance that requires re-cementation due to cement loss a failure. When asked if they considered recementation of an appliance as maintenance rather than a failure, 85% of the pediatric dentists and 72.5% of the orthodontists answered positively.

Many appliances in dentistry require maintenance over their lifetime in order to keep them functioning optimally. An example is the orthodontic bracket. Orthodontic brackets are frequently dislodged from the surface of the tooth during routine orthodontic treatment, yet they are still widely used and considered successful (Gorelick, Geiger, & Gwinnett, 1984).

Similarly, the need for minimal maintenance such as recementation or chair side adjustment of fixed spms should be expected to occur occasionally, as with other intraoral appliances. If the failure rates in the published literature were adjusted to exclude cement loss from the category of failures, a substantial decrease in the failure rates would be observed (Table 14). For example, in the study conducted by Fathian et al (2007), the failure rate was reported to be 32%, with cement loss occurring in 17.6% of the appliances. If the failure rate in this study were adjusted to exclude cement loss, the failure rate would drop to 14.4%. This also illustrates the importance of strict follow up for fixed spms so that maintenance procedures can be preformed (Baroni et al., 1994).
Several of the published spm studies were conducted in education centers where multiple operators performed the procedures (Baroni et al., 1994; Hill, Sorenson, & Mink, 1975; Qudeimat & Fayle, 1998; Rajab, 2002; Sasa et al., 2009; Tulunoglu et al., 2005). This may have led to methodological inconsistencies in treatment and higher failure rates. A significant number of patients were lost to follow up in these studies as well (Qudeimat & Fayle, 1998; Rajab, 2002; Tulunoglu et al., 2005). For example, Tulunoglu et al (2005) studied a total of 663 spms. They reported the lowest failure rate (13%), but experienced the highest loss to follow up (52%) (Tulunoglu et al., 2005). Qudeimat and Fayle (1998) studied 303 appliances, the majority of which were placed by students. They lost 21% to follow up and reported the highest failure rate (63%). The only two private practice-based studies were by Moore and Kennedy (2006) and Fathian et al (2007) who lost only 2% and 5% to follow up respectively, and reported relatively low failure rates (24% and 32% respectively).

The present study was conducted in a private pediatric dental practice by a sole experienced pediatric dentist with a strong recall program. The percentage of the sample that was lost to follow up or transferred to new care was 10%, which is higher than the numbers lost by the other private practice based studies of Moore and Kennedy (2006) (2%) and Fathian et al (2007) (5%) but much lower than Tulunoglu et al (2005) (52%). Moore and Kennedy’s (2006) recall protocol included two phone calls followed by a reminder card to elicit a patient’s response. If there was still no response, they sent a registered letter recommending that their fixed appliance required monitoring. They postulated that this accounted for their extremely low loss to follow up.

Table 14. Cement loss and failure rates in the published literature and adjusted failure rates

<table>
<thead>
<tr>
<th>Authors</th>
<th>Cement loss</th>
<th>Published Failure Rate</th>
<th>Adjusted Failure Rate</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baroni et al (1994)</td>
<td>10.2%</td>
<td>30.5%</td>
<td>20.3%</td>
</tr>
<tr>
<td>Qudeimat and Fayle (1998)</td>
<td>19.9%</td>
<td>63%</td>
<td>43.1%</td>
</tr>
<tr>
<td>Rajab (2002)</td>
<td>10.1%</td>
<td>30.7%</td>
<td>20.6%</td>
</tr>
<tr>
<td>Moore and Kennedy (2006)</td>
<td>14.1%</td>
<td>24%</td>
<td>9.9%</td>
</tr>
<tr>
<td>Fathian et al (2007)</td>
<td>17.6%</td>
<td>32%</td>
<td>14.4%</td>
</tr>
<tr>
<td>Sasa et al (2009)</td>
<td>18.9%</td>
<td>57.5%</td>
<td>38.5%</td>
</tr>
</tbody>
</table>
Moreover, the loss to follow up in an orthodontic practice, such as Moore and Kennedy’s, would be expected to be lower than in a pediatric dental practice, as orthodontic patients are more likely to follow through with the treatment plan to which they have committed and for which they have likely begun payment.

Eruption interference has been cited as a cause for failure of fixed spms, usually associated with LLHAs. This may be because LLHAs were placed prior to the eruption of the permanent mandibular incisors (Baroni et al., 1994). Baroni et al (1994) found that 10% of their spms failed due to eruption interferences and all involved lower permanent incisors. In the current study LLHAs were not placed until after the lower incisors had erupted, and none of the appliances failed due to eruption interferences. Quidiemat and Fayle (1998) reported that only a few (3%) of their appliances failed due to eruption interferences; however the majority of these were premolars which may indicate the eruption interference could have resulted from a design flaw.

Lastly, the laboratory that fabricates the spms can also contribute to the success or failure of the appliances. If the laboratory fabricates an appliance that seats properly and is well adapted to the patient’s intraoral anatomy, fewer adjustments will be required. Since all of the components of the appliances are soldered together to create a single unit, if any part of an appliance requires adjustment, distortion to the band(s) may occur. This may, in turn, compromise the fit of the band(s) and the longevity of the appliance.

Some have suggested that most of the mechanical failures that occur to orthodontic appliances are due to poor construction quality. Incomplete solder joints (Baroni et al., 1994; Baume, 1950; Hill, Sorenson, & Mink, 1975; Thornton, 1982), overheating the wire during soldering, thinning the wire by polishing, remnants of flux on the wire, and failure to encase the wire in the solder (Wright & Kennedy, 1978), have all been suggested in the literature as causes for failure that are under the control of the laboratory. Quidiemat and Fayle (1998) agree that spm construction may play an important role in their failure.

In the present study, the operator had been utilizing a single laboratory exclusively (R & S Orthodontic Laboratory, Ltd., Oshawa, Ontario, Canada) to fabricate all of the bilateral appliances for the past 25 years and unilateral appliances for the last 10 years. Similarly, Moore and Kennedy (2006) and Fathian et al (2007) used the same orthodontic laboratory to fabricate all of their spms and had relatively high success rates.
Survival Analyses

In many fields, treatment based interventions are evaluated using specific statistical tests. A common test that healthcare researchers use is the survival analysis – a statistical procedure that describes the length of time it takes for a particular event to occur. It may be useful for comparing average survival times between groups. However, this is not always valid or appropriate. In fact, survival analysis makes some very stringent assumptions about the data: the researcher should be modeling time until failure (in the traditional sense, the death of the patient), and any cases that do not exhibit such failures are “censored”. A censored case is thought of as an individual who is still on his/her way toward failure but, due to loss to follow up or some other intervening circumstance, the researcher was not able to obtain the date of the failure. As such, censored values included in the analysis pertain to the last time a researcher obtained information from a particular participant.

Within many applied circumstances, however, this black and white discrimination between censored cases and failures is not appropriate. In fact, in many studies there is a third alternative - clinical success – an outcome that is not acknowledged in typical survival analysis procedures. What this means is that, if clinical success is a plausible outcome and it occurs, the final session date is incorporated into the analysis as the last date information was gathered on the participant and it is deemed censored (rather than as a failure) at that time, even though the case was not actually censored at all.

In the present study, clinical success was defined as device removal because it had completed its required duty for a given patient. If successes and censored cases (devices still intact at the end of the study, lost to follow up or transferred to new care) were lumped together, as they were in the other published spm studies then mean survival times would have been estimated for each device type, under the assumption that the only events of interest are the failures and that all devices not yet failed will do so in the future; however, this is was not actually the case, since aside from failure, success was another possible outcome for which valuable information can be gathered.

Most of the published fixed spm studies utilized the survival analysis to calculate expected appliance longevity (Baroni et al., 1994; Fathian et al., 2007; Moore & Kennedy, 2006;
Qudeimat & Fayle, 1998; Rajab, 2002). This calculation allows for the pooling of information from cases followed for less than the entire study’s duration, thus calculating an average survival rate for the entire sample (Thylstrup & Rolling, 1975).

In the present study, it was decided to calculate the time elapsed for an appliance to complete its duty without complications- time to success- and the time elapsed for the appliances that failed to fail, eliminating the need for survival estimations.

**Disadvantages of the study**

In the present study, a sole experienced pediatric dentist meticulously and consistently treatment planned, designed, cemented and assessed all of the spms under a strict protocol; therefore, a low failure rate was anticipated. While a single operator and site may produce consistent and reproducible results, the disadvantages are that the results obtained can be biased and may neither be generalizable to all practitioners nor to all patient populations. However, this can be countered by the advantage of consistency of care.

The present study was not blinded as the operator was also the assessor, which may have biased the results. In addition, the data collected was completely reliant on the availability and accuracy of the dental records. There was no control group nor were the appliances randomized, therefore a cause and effect relationship could not be established.

Lastly, only appliances with a minimum follow up time of 6 months were included in the study. It is possible that an appliance may have failed or was lost to follow up prior to this period; however, these were not included in the study.

**2. Survey Study**

In the current study, the response rate for the pediatric dentists was fair (43%), which may be suggestive of the general interest in space management among pediatric dentists. The response rate for the orthodontists, however, was poor (7%), which could be due to several factors: There could have been less interest in space maintenance by orthodontists. This may have been because spms are generally placed by primary dental care practitioners, as they are most often placed for teeth extracted due to caries. Since orthodontists are not involved in primary dental
care, they may infrequently place space maintainers, and thus may have been less interested in the topic of space management. Likewise, a major portion of the treatment provided by orthodontists is the correction of spacing issues, including regaining space; therefore, space maintenance may not be as widely performed by orthodontists. In contrast, only about a third of American Board certified pediatric dentists (ABPDs) surveyed by the Association of Pedodontic Diplomates in 1983 provided comprehensive orthodontic treatment. A more recent survey reported that the amount of time pediatric dentists spent providing orthodontic treatment generally decreased since the ABPD diplomates were surveyed in 1983 (Hilgers, Redford-Badwal, & Reisine, 2003). They concluded that while some practitioners provided comprehensive orthodontic treatment, more provided limited treatment, such as space management, or did not provide orthodontic treatment at all. This could explain why pediatric dentists might have been more interested in the topic of space management than the orthodontists.

Kumari and Retnakumari (1998) found that the rate of space loss decreased 4 months post extraction and Cuoghi (1998) reported that the majority of space loss occurs in the first 6 months. This suggests that if a spm is not placed shortly after the loss of the primary tooth, the opportunity to prevent space loss at the extraction site may have passed. Orthodontists often do not treat patients until all of their primary teeth have exfoliated and their permanent successors have erupted. Indeed, the majority of the orthodontists surveyed in this study, did not treat children in the primary dentition stage of occlusal development and only place one to ten fixed spms per month. The American Dental Association 2005-06 Survey of Dental Services Rendered found that only 0.1% of patients treated by orthodontists were younger than age five, whereas 19% of patients in that age group were treated by pediatric dentists. Similarly, only 7% of patients from the ages of five to nine were treated by orthodontists, whereas 42% of patients in that age group were treated by pediatric dentists. The majority of patients treated by orthodontists (72%) were between 10 to 19 years old. Thus, the time frame within which a spm should ideally be placed would likely have lapsed, and space regaining may be required.

Most pediatric dentists generally provide primary dental care, including extractions. The pediatric dentists surveyed provided between one to thirty fixed spms per month, had a more even distribution of patients in all three stages of occlusal development and, not surprisingly, provided most of their fixed spms (93.2%) to compensate for teeth extracted due to caries.
Hilgers et al (2003) reported that space maintenance was the most common orthodontic treatment provided by pediatric dentists surveyed (95%). They also found that pediatric dentists provided orthodontic treatment to patients in the primary dentition (65%), early mixed dentition (85%), and late mixed dentition (58%). It was estimated by The American Dental Association 2005-06 Survey of Dental Services Rendered that pediatric dentists provided approximately 320 000 fixed spms between 2005-2006 and orthodontists provided 227 000 fixed spms during that time period. This could explain the higher interest, and hence elevated response rate, by pediatric dentists versus orthodontists.

Another possible reason for the difference in response rates was that both the initial survey invitation and the reminder email were sent to the pediatric dentists directly by the investigator; however, all correspondence with the orthodontists was via the AAO per AAO policy. All emails sent to this group of specialists were written by the investigator but forwarded by the AAO. This could have deterred some orthodontists from responding, as they were not receiving the email directly from the investigator. They may have also thought that they were receiving unsolicited bulk messages indiscriminately since the emails were sent by an organization rather than directly and personally from the investigator.

Another web-based survey of orthodontists conducted by a non-orthodontic group (dental public health) to assess clinical procedures of overweight screening and nutrition intervention among youth in the United States was conducted in 2006 (Huang, Becerra, Walker, & Hovell, 2006). They reported a response rate of 92%; however, they defined their response rate as the number of clinicians that participated (111) divided by the number who accessed the link (121). Had they reported the number who responded divided by the number who had active email addresses and were sent the link (3956), the response rate would have been 3%.

Although there have been no studies published regarding the most common time for clinicians to take vacations, the summer is a very popular time for practices to close. Since the survey was sent out via email during the summer (July 4, 2011 to Sept 4, 2011), often to the clinicians’ professional email addresses, they may not have been read in time to respond to the survey. If the survey was sent out at another time of the year, the response rates might have been higher.

Non-responder bias is a major concern with any type of survey study. While it is best controlled by maximizing response rates its effect must always be considered (Braithwaite et al., 2003). A
high response rate is essential for the data to be considered representative of an entire population (Fink, 2003; Tambor et al., 1993).

Web-based surveys have the advantages of being more economical, and less time consuming to distribute, and are able to survey people of a wide geographical location (Greenlaw & Brown-Welty, 2009; Schleyer & Forrest, 2000). They do, however, suffer from several disadvantages. First, there is an inability to accurately control the sample size, as email inboxes can be full, emails can be rejected by web mailer programs, and email addresses can expire or become invalid (Braithwaite et al., 2003). In the current study, several emails were returned because of full inboxes; recipients were “out of the office”; emails were “undeliverable” because of invalid email addresses, and some potential recipients did not accept emails from unknown senders. Fifteen emails sent to pediatric dentists and twelve sent to orthodontists were sent back for the above stated reasons, but it is possible that there were other similar situations that the investigator was not made aware of. While postal addresses can have similar problems, postal services have more formalized processes to deal with those situations, allowing the researcher to accurately adjust the sample size for statistical analysis (Braithwaite et al., 2003).

A few complaints were received by potential respondents regarding technical difficulties experienced with the Survey Monkey website. This could have been due to a problem with their Internet providers or with the Survey Monkey server. Furthermore, although the use of Internet and email is common in today’s society, a responder bias may have existed since only those subjects who are computer literate and are reasonably Internet savvy could have participated. Either way, it is impossible to determine how many potential respondents were unable to submit their surveys or were disinterested in completing the survey all together due to technical difficulties.

Preference or shortage of time in the office may have also deterred some participants who may have preferred to print off the survey document to complete on the train, on a plane, or at home. Since this was not possible in the current study, such participants would have been excluded from the group, potentially biasing the results (Wyatt, 2000).

In a comparison of postal, email, and fax survey methods amongst pediatricians in Georgia, USA, McMahon et al (2003) demonstrated that fax, followed closely by postal responses, were the most popular methods by which to respond, with email responses being the least popular.
They concluded that mixed mode distribution provided a significant advantage in increasing the response rate, and further critical appraisal was required before email can be considered an ideal mode for the distribution of surveys (McMahon et al., 2003).

Other researchers have also noted the need to include mixed modalities of distribution to reach those that would only reply to one mode (Schleyer & Forrest, 2000). Williams, Burr, and Williams (2004), in describing techniques that can be used to maximize the response rates, advised “sending the questionnaires by first class mail, using short questionnaires, using coloured ink, personalizing the letters (addressed to a named person and signed personally), using follow-up reminders and then sending a second copy of the questionnaire to non-respondents, and keeping questions of a sensitive nature to a minimum”. While these additions are very costly and time consuming, had some of them been implemented in the current study, an increased response rate might have been achieved.

The response rate of a questionnaire survey is defined as the number of completed and partially completed questionnaires/surveys/interviews divided by the number of eligible sample units (Braithwaite et al., 2003; Eysenbach & Diepgen, 1998; McAvoy & Kaner, 1996). Had the present survey accepted partially complete surveys, the response rate may have also been higher. It is possible that some potential respondents may not have known the answer to a particular question or did not agree with any of the answer choices for a given question, but because the survey had to be complete prior to submission, they may have chosen not to submit the survey.

In an attempt to minimize response bias, a reminder was sent to both the pediatric dentists and orthodontists two weeks after the initial invitation was emailed. While the exact number was not calculated, the response rate did increase for both groups after the reminder was sent. It is an accepted view that multiple attempts at increasing the response rate are recommended (Parashos et al., 2005). Brathwaite et al (2003) surveyed family doctors and found that their response rate almost doubled after five reminders and achieved rates comparable with those obtained in postal surveys of a similar group of general practitioners. Sending out multiple reminders in the current study might have yielded a higher response rate. However, as per AAO policy, only one reminder was sent to the orthodontists. In order to maintain consistency between the two groups, only one reminder was sent to the pediatric dentists as well.
Sixty-one percent of the pediatric dentists and 87.0% of the orthodontists were male. Similarly, in a mail survey of pediatric dentists conducted by Seale and Kendrick (2001), the majority (75%) of the respondents were also male. Likewise, in a mail survey study conducted by Yang and Kiyak (1998), 81% of respondents were male. These are likely representative samples, as both the majority of active pediatric dentists currently registered with the AAPD (approximately 55%, according to the AAPD) and active orthodontists currently registered with AAO (approximately 75%, according to the AAO) are male. Brathwaite et al (2003) also reported that most of the respondents to their Internet survey were male.

Most of the respondents worked mainly in private practice, which is in agreement with the results of the Hilgers (2003) survey of pediatric dentists in which 79.3% of respondents worked exclusively in private practice. This is important because spms require strict follow up (AAPD Clinical Affairs Committee-Developing Dentition Subcommittee & AAPD Council on Clinical Affairs, 2008; Bijoor & Kohli, 2005; Qudeimat & Fayle, 1998). If they are placed in patients who are treated in private practice, they are more likely to be assessed at recall visits, as opposed to those placed in patients attending hospital-based or publicly funded clinics where patients may not be seen regularly. The majority of orthodontists (56.5%) in this survey believed that fixed spms should be followed up every 6 months. Forty nine percent of the pediatric dentists believed that they should be followed up every 6 months and 33.8% believed that they should be followed up at recall appointments.

The most common type of fixed spm placed by orthodontists (95.5%) was the lingual arch, followed by the Nance appliance (65.2%). Bilateral spms were used most commonly by orthodontists, possibly because they aim to achieve symmetrical space maintenance in the mixed dentition and are not compensating for teeth extracted due to caries. The least commonly placed fixed spm by the orthodontists was the distal shoe. Since this appliance is usually placed to compensate for a second primary molar lost prior to the eruption of the first permanent molar, and orthodontists rarely treat patients in the primary dentition, this result was not surprising.

The vast majority of the orthodontists (87.9%) exclusively provided custom lab fabricated spms, while only 49.3% of the pediatric dentists exclusively provided custom lab fabricated fixed spms. Since custom lab fabrication involves two appointments with the clinician (one to take an impression and the second to fit and cement the spm) in addition to the time of a laboratory
technician, it can be an expensive process (Kulkarni, Lau, & Hafezi, 2009). An alternative is chair side fabricated spms that are commercially available from companies such as DENOVO and Unitek (Kulkarni et al., 2009). Almost half of the pediatric dentists employed both methods of spm fabrication.

Cement loss (47.6%, 27.5%) and breakage (23.4%, 30.4%) were considered by pediatric dentists and orthodontists, respectively, to be the most common causes of fixed spm failure. This is in agreement with the published literature in which most studies cite cement loss as being the primary cause of failure; however, 11.1% of pediatric dentists and 14.5% of orthodontists considered an appliance that requires re-cementation due to cement loss a failure. Similarly, the majority of the pediatric dentists (85.0%) and the orthodontists (72.5%) agree with the authors of the present study that re-cementation of a fixed spm should be considered maintenance rather than a failure. These findings support the present study’s definition of failure, which does not include recementation.

**Future Directions**

Although the results of the retrospective cohort study demonstrate that fspms are successful in terms of their durability and longevity, they do not prove whether the appliances did what they were intended to do: it cannot be determined from the present results whether the spms actually maintained the appropriate amount of space and that the permanent successors erupted into their proper position. Neither was success measured in terms of whether the patient avoided needing or had a shorter duration of orthodontic treatment. Future research examining these definitions of success would be useful. Moreover, future multicenter randomized studies involving multiple operators should be performed to confirm this study’s findings.

The results of the survey demonstrate that fspms are widely used and considered important appliances in preventive orthodontic treatment, however, because the response rate of the orthodontists was low, non-responder bias cannot be ruled out. Future studies could attempt to re-survey orthodontists, perhaps at a different time of year, or using different survey modalities to confirm this study’s findings. Since only a fraction of children are treated by pediatric dental specialists, a survey of general practitioners may provide useful information regarding their use
of fspms and in ascertaining whether more training in the placement of fspms is required in undergraduate dental programs.
Summary

In summary, the results of the present retrospective cohort study suggested that, despite the poor success rates in the published literature, fixed space maintainers (fspms) are reliable and dependable appliances that should be placed whenever they are indicated.

Factors that may contribute to a high success rate with fspms may be:

1. Careful patient selection

2. Meticulously and consistently following a strict protocol for the fabrication and cementation of fspms

3. Frequent long term follow-up and maintenance.

The results of the survey study indicated that fspms were used by the vast majority of pediatric dentists and orthodontists that responded. Furthermore, fspms were considered a standard of care. Most of the survey respondents agreed that re-cementation of a fspm should be considered maintenance of the appliance rather than a failure.
Conclusions

1. The fixed space maintainers (fspms) in this study (band and loops, distal shoes, LLHAs, Nance appliances and ULHAs) demonstrated a high clinical success rate (86.6%). Only 3.3% of the appliances failed and 10% were lost to follow-up or transferred to new care.

2. There were no significant differences between the success and failure rates of the various appliances.

3. It took an average of 20 months for the appliances that failed to fail and an average of 26 months for appliances that succeeded to achieve success.

4. The vast majority of respondent pediatric dentists (99.8%) and orthodontists (97.0%) provided fspms in their practice, and 97.6% of the pediatric dentists and 89.9% of the orthodontists considered spms to be a standard of care.

5. The majority of respondent pediatric dentists (85.0%) and orthodontists (72.5%) considered re-cementation of a fspm as maintenance rather than a failure.
References


*Anesthesiology*, 24, 111.


Faculty of Dentistry, Department of Pediatric Dentistry, University of Toronto (Ed.). (2006). *Pediatric dentistry manual* (ninth edition Ed.). Toronto:


*American Journal of Orthodontics & Dentofacial Orthopedics, 113*(1), 96-103.
Appendices

Appendix A. Pretreatment consent forms

CONSENT TO DENTAL TREATMENT

I, (relationship), have been informed by Dr. Paul Andrews of the need to undergo dental treatment as presented to me for my (son or daughter) on the treatment plan dated

I have been fully informed about the details of the recommended treatment and alternative approaches including their risks, benefits and fees. I fully understand them, and agree to accept the treatment as recommended by Dr. Andrews.

I understand that individual reactions to treatment cannot be predicted, and that if any unanticipated reactions occur during or following any treatment, I agree to report them to the office as soon as possible.

I have been told that the success of the recommended treatment depends upon my cooperation in keeping scheduled appointments, following home care instruction, including oral hygiene and dietary instructions, and reporting to the office any change in my child’s health status as soon as possible.

I acknowledge that no guarantees or assurances have been given by anyone as to the results that may be obtained.

I have discussed all of the above with Dr. Andrews, and all my questions have been answered.

I hereby authorize Dr. Andrews to complete the treatment as presented to me on the treatment plan dated

Patient/Parent/Guardian Signature ___________________________ Date ___________________________

Witness Signature ___________________________ Doctor’s Signature ___________________________
to advise you of treatment options

to enable us to contact you and maintain communication with you

to offer and provide treatment, care and services in relationship to the oral and maxillofacial complex and dental care generally

to communicate with other treating health-care providers, including specialists and general dentists who are the referring dentists and/or peripheral dentists

to allow us to efficiently follow-up for treatment care, billing and collect unpaid accounts for teaching and demonstrating purposes on an anonymous basis

to complete and submit dental claims for third party adjudication and payment

to deliver your charts and records to the dentist’s insurance carrier to enable the insurance company to assess liability and quantify damages, if any

to comply with legal and regulatory requirements, including the delivery of patients’ charts and records to the Royal College of Dental Surgeons of Ontario in a timely fashion, when required, according to the provisions of the Regulated Health Professions Act

to comply with agreements/undertakings entered into voluntarily by the member with the Royal College of Dental Surgeons of Ontario, including the delivery and/or review of patients’ charts and records to the College in a timely fashion for regulatory and monitoring purposes

to prepare materials for the Health Professions Appeal and Review Board (HPARB)

to permit potential purchasers, practice brokers or advisors to evaluate the dental practice

to invoice for goods and services

to process bank card and credit card payments

to assist this office to comply with all regulatory requirements

to comply generally with the law

By signing the consent section of this Patient Consent Form, you have agreed that you have given your informed consent to the collection, use and/or disclosure of your personal information for the purposes that are listed. If a new purpose arises for the use and/or disclosure of your personal information, we will seek your approval in advance.

Your information may be accessed by regulatory authorities under the terms of the Regulated Health Professions Act (RHPA) for the purposes of the Royal College of Dental Surgeons of Ontario fulfilling its mandate under the RHPA, and for the defence of a legal issue.

Our office will not under any conditions supply your insurer with your confidential medical history. In the event this kind of a request is made, we will forward the information directly to you for review, and for your specific consent.

When unusual requests are received, we will contact you for permission to release such information. We may also advise you if such a release is inappropriate.

You may withdraw your consent for use or disclosure of your personal information, and we will explain the ramifications of that decision, and the process.
Patient Consent

For Collection Use and Disclosure of Personal Information

I have reviewed the above information that explains how your office will use my personal information, and the steps your office is taking to protect my information.

I know that your office has a Privacy Code, and I can ask to see the Code at any time.

I agree that Dr [patient’s name] can collect, use and disclose personal information about [patient’s name] as set out above in the information about the office’s privacy policies.

______________________________  ______________________________
signature                        print name

______________________________  ______________________________
date                             signature of witness
Appendix B. Letter to parents

Dear Parents,

An investigation studying the success and longevity of space maintainers is being conducted through the University of Toronto, Department of Pediatric Dentistry for a graduate qualification. This study shall include certain dental records of patients from the private dental office of Dr. Paul Andrews. These records will only be used on an anonymous basis.

Should you wish to learn more about this study or should you wish to withdraw from this study, please contact the office of Dr. Paul Andrews at (905)270-4700.

Sincerely,

Dr. Michael J. Sigal
Professor and Head, Discipline of Pediatric Dentistry
Director, Graduate Program in Pediatric Dentistry

Dr. Paul B. Andrews
Assistant Professor Department of Pediatric Dentistry

Dr. Lori Waichenberg
Masters Student
Pediatric Dentistry
## Appendix C. Pediatric dentist survey

### The use of space maintainers among pediatric dentists.

<table>
<thead>
<tr>
<th>Question</th>
<th>Options</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>1. What is your gender?</strong></td>
<td>Male, Female</td>
</tr>
<tr>
<td><strong>2. What is your age group (years)?</strong></td>
<td>20-29, 30-39, 40-49, 50-59, ≥ 60</td>
</tr>
<tr>
<td><strong>3. How many years have you been practicing pediatric dentistry?</strong></td>
<td>≤ 9, 10-19, 20-29, 30-39, ≥ 40</td>
</tr>
<tr>
<td><strong>4. In which region do you primarily practice?</strong></td>
<td>District 1 (CT, ME, MA, NH, NY, RI, VT, NL, NS, PEI, NB, QC), District 2 (DE, DC, MD, NJ, PA), District 3 (AL, FL, GA, KY, MS, NC, SC, TN, VA, WV, PR), District 4 (IL, IN, IA, ON, MB, OH, MI, MN, NE, ND, SD, WI), District 5 (AR, CO, KS, LA, MO, NM, OK, TX, MX), District 6 (AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY, SK, AB, BC, NT, NU, YT)</td>
</tr>
<tr>
<td><strong>5. Which of the following best describes the pediatric dentistry program that you graduated from?</strong></td>
<td>Hospital-based, University-based, Combined</td>
</tr>
</tbody>
</table>
The use of space maintainers among pediatric dentists.

6. Of the total time that you spend practicing pediatric dentistry, please approximate the percentage that you spend practicing in the following locations:

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private practice</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Academic</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Hospital</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Publicly funded clinic (eg public health, Medicaid, military)</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Retired from active practice</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

7. Of all the patients that you currently treat, please approximate the percentage who are in the following stages of occlusal development:

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>Mixed</td>
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<tr>
<td>Permanent</td>
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<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

8. Of the total number of patients that you currently treat, please approximate how many are in the following socio-economic status (SES) categories:

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>Middle</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
<tr>
<td>Low</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

9. What percentage of your patients have the following type of dental coverage?

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private third party dental</td>
<td>☐</td>
<td>☐</td>
<td>☐</td>
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</tr>
<tr>
<td>coverage</td>
<td></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Publicly funded dental</td>
<td>☐</td>
<td>☐</td>
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<tr>
<td>coverage</td>
<td></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>No dental insurance</td>
<td>☐</td>
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<td>☐</td>
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<td>☐</td>
<td>☐</td>
</tr>
</tbody>
</table>

1. Did your pediatric dental training program advocate and provide training for the placement of fixed space maintainers?

○ Yes
○ No

2. Do you provide/use fixed space maintainers?

○ Yes
○ No
**The use of space maintainers among pediatric dentists.**

**3. What is the greatest deterrent to your use of fixed space maintainers?**
- Failure rate
- Cost
- Patients are not compliant for follow up care.
- Most patients intend to seek orthodontic treatment, so there is no need to maintain space.
- Lack of training
- None
- Other

**4. Do you consider space maintainers to be a standard of care?**
- Yes
- No
- I don’t know

**5. Do you routinely consider space issues when a primary tooth is treatment planned for extraction or is lost prematurely?**
- Yes
- No
- I don’t know

**6. Space maintenance is an important part of interceptive and preventive dental care.**
- Agree
- Neutral
- Disagree

**7. The strategic importance of the extracted/missing tooth in the arch should be an important factor to be considered while treatment planning for a space maintainer?**
- Agree
- Neutral
- Disagree
# The use of space maintainers among pediatric dentists.

**8. What do you think is the biggest reason for failure of fixed space maintainers?**
- Cement loss
- Breakage
- Bent archwire
- Split band
- Soft tissue irritation
- Interference with eruption or occlusion
- Other

**9. I consider a space maintainer that requires re-cementation due to loss of cement a failure.**
- Agree
- Neutral
- Disagree

**10. Re-cementation of a fixed space maintainer should be considered maintenance of an appliance rather than a failure.**
- Agree
- Neutral
- Disagree

**11. In your opinion, how often should a fixed space maintainer be followed up?**
- Every 3 months
- Every 6 months
- Annually
- At recall appointments
- As needed
- Never

**1. Approximately how many fixed space maintainers do you provide per month?**
- < 10
- 10-30
- > 30
- I don't provide space maintainers.
### The use of space maintainers among pediatric dentists.

1. **What type(s) of fixed space maintainer do you place in your practice?** (Please check all that apply)
   - [ ] Band and loop
   - [ ] Distal shoe/Intra-alveolar appliance
   - [ ] Lingual arch
   - [ ] Nance appliance
   - [ ] Transpalatal Arch
   - **Other (please specify)**

2. **The fixed space maintainers that you provide are fabricated as follows:**
   - [ ] Custom lab fabricated
   - [ ] Prefabricated
   - [ ] Both
   - [ ] Other

3. **Are most of your fixed space maintainers provided to compensate for teeth extracted due to caries?**
   - [ ] Yes
   - [ ] No
   - [ ] I don't know.

4. **Does the patient’s dental insurance coverage affect your decision to provide a space maintainer (when indicated)?**
   - [ ] Yes
   - [ ] No
   - [ ] I don't know.

5. **In your opinion, if your patient does not have dental coverage for space maintainers, how often will he/she agree to pay for it?**
   - [ ] Always
   - [ ] Sometimes
   - [ ] Never
   - [ ] I don't know.
The use of space maintainers among pediatric dentists.

6. What do you use to cement fixed space maintainers? (Please check all that apply)

- Glass ionomer cement
- Resin based cement
- Compomer cement (resin-glass ionomer hybrid cement)
- Zinc phosphate cement
- I don’t know
- Other

Thank you for responding to my survey!
Appendix D. Orthodontist survey

The use of space maintainers among orthodontists.

1. What is your gender?
   - Male
   - Female

2. What is your age group (years)?
   - 20-29
   - 30-39
   - 40-49
   - 50-59
   - ≥ 60

3. How many years have you been practicing orthodontics?
   - ≤ 9
   - 10-19
   - 20-29
   - 30-39
   - ≥ 40

4. In which region do you primarily practice?
   - District 1 (CT, ME, MA, NH, NY, RI, VT, NL, NS, PEI, NB, QC)
   - District 2 (DE, DC, MD, NJ, PA)
   - District 3 (AL, FL, GA, KY, MS, NC, SC, TN, VA, WV, PR)
   - District 4 (IL, IN, IA, ON, MB, OH, MI, MN, NE, ND, SD, WI)
   - District 5 (AR, CO, KS, LA, MO, NM, OK, TX, MX)
   - District 6 (AK, AZ, CA, HI, ID, MT, NV, OR, UT, WA, WY, SK, AB, BC, NT, NU, YT)

5. Which of the following best describes the orthodontics program that you graduated from?
   - Hospital-based
   - University-based
   - Combined
The use of space maintainers among orthodontists.

*6. Of the total time that you spend practicing orthodontics, please approximate the percentage that you spend practicing in the following locations:

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
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<tbody>
<tr>
<td>Private practice</td>
<td>○</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Academic</td>
<td>○</td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hospital</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>Publicly funded clinic (e.g. public health, Medicaid, military)</td>
<td>○</td>
<td></td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Retired from active practice</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*7. Of all the patients that you currently treat, please approximate the percentage who are in the following stages of occlusal development:

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Primary</td>
<td>○</td>
<td></td>
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<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mixed</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Permanent</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*8. Of the total number of patients that you currently treat, please approximate how many are in the following socio-economic status (SES) categories?

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>High</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Middle</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Low</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*9. What percentage of your patients have the following type of dental coverage?

<table>
<thead>
<tr>
<th></th>
<th>0</th>
<th>1-19%</th>
<th>20-39%</th>
<th>40-59%</th>
<th>60-79%</th>
<th>80-100%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private third party dental coverage</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Publicly funded dental coverage</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>No dental insurance</td>
<td>○</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

1. Did your orthodontics training program advocate and provide training for the placement of fixed space maintainers?

○ Yes
○ No

2. Do you provide/use fixed space maintainers?

○ Yes
○ No
### The use of space maintainers among orthodontists.

**3. What is the greatest deterrent to your use of fixed space maintainers?**
- Failure rate
- Cost
- Patients are not compliant for follow up care.
- Most patients intend to seek advanced orthodontic treatment in the future.
- Lack of training
- None
- Other

**4. Do you consider space maintainers to be a standard of care?**
- Yes
- No
- I don't know

**5. Do you routinely consider space issues when a primary tooth is treatment planned for extraction or is lost prematurely?**
- Yes
- No
- I don't know

**6. Space maintenance is an important part of interceptive and preventive dental care.**
- Agree
- Neutral
- Disagree

**7. The strategic importance of the extracted/missing tooth in the arch should be an important factor to be considered while treatment planning for a space maintainer?**
- Agree
- Neutral
- Disagree
The use of space maintainers among orthodontists.

8. What do you think is the biggest reason for failure of fixed space maintainers?
   - Cement loss
   - Breakage
   - Bent archwire
   - Split band
   - Soft tissue irritation
   - Interference with eruption or occlusion
   - Other

9. I consider a space maintainer that requires re-cementation due to loss of cement a failure.
   - Agree
   - Neutral
   - Disagree

10. Re-cementation of a fixed space maintainer should be considered maintenance of an appliance rather than a failure.
    - Agree
    - Neutral
    - Disagree

11. In your opinion, how often should a fixed space maintainer be followed up?
    - Every 3 months
    - Every 6 months
    - Annually
    - At recall appointments
    - As needed
    - Never

1. Approximately how many fixed space maintainers do you provide per month?
   - < 10
   - 10-30
   - > 30
   - I don’t provide space maintainers.
The use of space maintainers among orthodontists.

1. What type(s) of fixed space maintainer do you place in your practice? (Please check all that apply)
   - Band and loop
   - Distal shoe/ Intra-alveolar appliance
   - Lingual arch
   - Nance appliance
   - Transpalatal Arch
   - Other (please specify)

2. The fixed space maintainers that you provide are fabricated as follows:
   - Custom lab fabricated
   - Prefabricated
   - Both
   - Other

3. Are most of your fixed space maintainers provided to compensate for teeth extracted due to caries?
   - Yes
   - No
   - I don't know.

4. Does the patient's dental insurance coverage affect your decision to provide a space maintainer (when indicated)?
   - Yes
   - No
   - I don't know.

5. In your opinion, if your patient does not have dental coverage for space maintainers, how often will he/she agree to pay for it?
   - Always
   - Sometimes
   - Never
   - I don't know.
The use of space maintainers among orthodontists.

6. What do you use to cement fixed space maintainers? (Please check all that apply)

- Glass ionomer cement
- Resin based cement
- Compomer cement (resin-glass ionomer hybrid cement)
- Zinc phosphate cement
- I don't know
- Other

Thank you for responding to my survey!
Appendix E. Sample letter of introduction

Dear Doctor,

My name is Lori Waichenberg, and I am a pediatric dentistry graduate student at the University of Toronto. I am conducting a survey of pediatric dentists across North America regarding the use of, attitudes toward and perceived difficulties with fixed space maintainers. Your participation in this research will increase our understanding of how prevalent space maintainer use is and how successful they are perceived to be by North American pediatric dentists. The survey is available online at www.surveymonkey.com.

You are assured of complete confidentiality and anonymity in completing this survey, as the ID number will only be used to log respondents and for follow-up reminders. Your responses will not be linked to your name in any way.

This research has been approved by the Research Ethics Board at The University of Toronto. If you have any questions about your rights as a participant, you may contact the ethics office at ethics.review@utoronto.ca or (416) 946-3273; or in regards to the survey itself, myself, Lori Waichenberg at lori.waichenberg@utoronto.ca.

Please ensure that your responses be received no later than July 28, 2011. Your participation in this would be greatly appreciated.

Sincerely,

Dr. Lori Waichenberg

MSc. Candidate

Pediatric Dentistry, University of Toronto