Scientific Article

Laboratory-made Space Maintainers: A 7-year Retrospective Study from Private Pediatric Dental Practice

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Abstract: ***Purpose:*** *The purpose of this study was to report survival times and problems encountered with laboratory made space maintainers placed over 7 years by one pediatric dentist.* ***Methods:*** *Charts were reviewed for 235 patients with fixed space maintainers placed between January 1, 1997, and December 31, 2003, and followed to December 31, 2005. Problems encountered and appliance lifetimes were recorded and assessed. Failures were recorded as: (1) cement loss; (2) solder breakage; (3) split bands; (4) eruption interference; (5) bent wire; (6) complete loss; or (7) not specified. Appliance outcomes, transferred patients, and those lost to follow-up were recorded.* ***Results:*** *A total of 323 appliances were followed, with: (a) 93 (29%) successes; (b) 110 (34%) still in service; and (c) 104 (32%) known failures. Of the latter, most (62%) were from cement loss (60%) and 13 (12%) were totally lost. No statistically significant differences were noted between types of appliances, gender, and types of failure, except for the fact that bands and loops exhibited more cement loss (P=.045). Mean pooled survival times were between 26 and 27 months.. Of the 104 failures: (a) 34 (33%) were no longer needed (being considered clinically successful); (b) 57 (55%) were recemented; and (c) 13 (12%) were remade. Sixteen appliances were lost to follow-up or transferred.* ***Conclusion:*** *A total of 63% of all space maintainers lasted their anticipated lifetimes or were still in use. (Pediatr Dent 2007;29:500-6) Received July 18, 2006 / Revision Accepted March 22, 2007.*

KEYWORDS: SPACE MAINTAINERS, LINGUAL ARCH, NANCE, BAND AND LOOP, SURVIVAL TIMES, TOOTH MIGRATION

Premature primary tooth loss can lead to space loss, crowding; and, shifting of the midlines.[1-3] When primary second molars are lost, there is an increase in mesial drift of the adjacent permanent first molar, resulting in either a Class II or Class III posterior relationship—depending on the arch with tooth loss.[1] Crowding is significantly increased when there has been premature primary tooth loss.[2] Shifting of the dental midline occurs towards the site of early extraction of primary teeth.[3] Space maintainers are recommended to prevent these side effects.[4] Unfortunately, there is a lack of studies addressing whether space maintainers actually result in eliminating the anticipated crowding and occlusal changes which may occur after primary tooth loss.

Studies of space maintainers placed after premature loss of primary teeth demonstrate limited appliance longevity,[5-9] with median survival times of all space maintainers ranging from: (a) 7 months[7-9]; to (b) 14 months5; to (c) 18 months.8 Unilateral appliances have greater survival times than bilateral appliances.[5,7,8] Unilateral space maintainers show no statistical differences in survival times between maxillary and mandibular arches,[5] but bilateral mandibular space maintainers show reduced survival times compared to maxillary bilateral appliances.[5,6,8,10] There are no significant outcome differences when gender, age, primary vs mixed dentition, and operator are assessed.[7-9] Most of the previous studies[5-9] have not addressed whether the space maintainer appliance was in the mouth long enough to serve its purpose. Survival times of 7 to 18 months,[5,7-9] however, may be too short to serve the purpose of holding space in a 7-year-old when premolars may not erupt until age 11 or 12, some 4 to 5 years later.

Problems with space maintainers vary from a low of 13% to a high of 63%.[7,9] Space-maintaining appliances commonly experience problems with: (1) loose bands or cement loss; (2) solder failure; (3) broken or split bands; (4) soft tissue lesions; (5) loss of the appliance; and (6)interference with eruption.[5-9] Loose bands are the main reason for failure. Since bilateral space maintainers usually have permanent first molars banded, any loose band may increase decay risk in a patient whose previous dental history resulted in primary tooth loss. Given the reported survival times, it is a

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potential problem that patients who are lost to follow-up range from: (a) 20%8; to (b) 21%7; to (c) to 53%.9 If a patient is lost to follow-up and subsequently has a loose band, extensive decalcification and/or decay on a permanent first molar could occur.

Because of reported space maintainer longevity and the limited documentation of success, the Canadian Association of Public Health Dentistry questions their use.[11] An evidence-based, decision-making approach towards the use of space maintainers in children has been presented by Brothwell.[12] Other authors suggest that mandibular lingual arch appliances be avoided whenever possible because of low median survival times.[5,8] The majority of previous studies have been conducted in university settings where appliances have been placed to hold space after primary tooth loss.[5-9] One study has reported on appliance outcomes with undergraduate dental students placing appliances in an outreach clinic.[6] Results from university-based studies[5-9] may not be reflective of private practice results.[10] There have only been 2 studies on cemented space maintainers from private practice,[10,13] involving: (1) the cemented crown retained distal shoe appliance[13]; and (2) bilateral space maintainers placed in the late mixed dentition in a combined orthodontic/pediatric dental practice by orthodontists.[10]

To date, there are no reported data from private pediatric dental practice relative to space maintainer longevity or problems encountered. Without such data, third party providers of funding may choose to limit or deny space maintainer funding, as has occurred with the First Nations Non-insured Health Benefits Program in Canada.

The purpose of this study was to report the survival times and problems encountered with all primary and mixed dentition laboratory-made space maintainers placed by one private pediatric dental practitioner over a 7-year period.

Methods

This retrospective study included data from the private pediatric practice of one of the authors (MRN) in Vancouver and Delta, British Columbia, Canada. The sample included a total of 323 appliances (45 mandibular band and loop, 67 maxillary band and loop, 142 mandibular lingual arch appliances, and 69 maxillary Nance appliances) placed in 235 patients between January 1, 1997, and December 31, 2003. If an appliance was recemented or remade, it was counted as a new appliance and the survival data recorded for the new appliance[7,10] (Table 1). Appliances were followed until removal or, if they were still in use, until the end point of the study which was December 31, 2005. A total of 253 appliances were initially placed—with 57 recemented and 13 remade, accounting for a total of 323 (Table 1).

Patient acceptance into the study occurred if the appliance was made either before or after premature extraction or loss of a primary tooth. Primary tooth loss or extraction was due to decay and its consequences. The decision to place the space maintainer and its design was made by the pediatric dentist. Excluded from the study were patients in whom a bilateral space maintainer was used in conjunction with either habit correction or tooth movement. Also excluded from the study were non-laboratory constructed appliances placed. Therefore, all Denovo-type space maintainers (Denovo, Baldwin Park, Calif)—which may have been placed on sedated or anaesthetized pediatric patients—were excluded from the study. Also, no distal shoe appliances were studied. Therefore, the sample represented all passive unilateral and bilateral laboratory-made space maintainers (except distal shoe appliances) placed by one pediatric dentist over a 7-year period which were followed from January 1, 1997, until December 31, 2005.

Appliances were made in the following fashion. At the first visit, separators were placed interproximal to the teeth that were to be banded. At the second visit, after separator removal, bands were fitted and an alginate impression was made with the separators replaced. Band fitting and impression taking was done by an orthodontic module-certified dental assistant. Appliances were made by the same in-house orthodontic laboratory utilizing 0.040 inch round stainless steel wire soldered at the lingual midpoints of the molar band for bilateral appliances and at the lin-

Table 1. SAMPLE OF CHILDREN AND APPLIANCES SURVEYED IN THE PRESENT STUDY

		Gender						
Appliance	Mean age at insertion N±SD in mos	M	F	Total patients	Appliances initially placed	Recemented appliances	Remade appliances	Total
Mandibular band and loop	6 ys, 6 mos ± 13.1	15	8	23	33	11	1	45
Maxillary band and loop	6 ys, 4 mos ± 15.1	22	19	41	46	21	0	67
Lingual arch	8 ys, 0 mos ± 23.5	57	58	115	115	18	9	142
Nance	7 ys, 10 mos ± 18.8	31	25	156	59	7	3	69
Total	7 ys, 6 mos ± 21.9	125	110	235	253	57	13	323

gual and buccal midpoint of the molar bands for band and loop appliances. Prior to cementation: (1) separators were removed; (2) the teeth were polished; and (3) the appliances were trial fitted. The insides of the bands were not microetched. The appliance was cemented by one of the authors (MRN) using a glass ionomer cement (Ketac Cement-Espe, Seefeld, Germany) mixed to a stiff consistency on a regular (nonfrozen) paper slab. Patients were followed up at 6- to 9-month recall intervals in conjunction with their regular preventive dental care.

All information was retrieved from the charts by one of the authors (MF) to determine the outcome and longevity of the appliances. The following dates were recorded: (1) patient's birth; (2) appliance insertion; (3) recementation; (4) repair; and (5) removal. Also recorded was whether the appliances: (1) succeeded; (2) were still in use; (3) were removed between appointments; (4) failed; (5) were lost to follow-up; or (6) were transferred to new care. The lifetime of the appliances was assessed to December 31, 2005, if they were still in use.

Successful appliances were either still in use at the end of the or had been removed by the pediatric dentist having been deemed to have clinically succeeded. The end date for a successful appliance was the date of removal. If an appliance failed, the failure mode was recorded. Failure categories were as follows: (1) cement loss (ie, loose band); (2) solder breakage; (3) bent archwire; (4) split band; (5) soft tissue lesion; (6) eruption interference; (7) complete loss; and (8) failure with the reason not specified.[10] Appliances were considered failed for any of these reasons or if the appliance had been removed between 6- to 9-month preventive recall appointments. This occurred when the patient was seen by a general practitioner for appliance removal between regularly scheduled recall visits. The failure date was recorded as the date when the loose, broken, or distorted appliance was removed. If an appliance was lost or removed by the general practitioner, the failure rate was recorded as the last day that the appliance was observed. Appliance failures were classified as either: (1) no longer needed; (2) recemented; or (3) remade. The appliance was classified as having failed, even if the decision was made by the pediatric dentist not to remake or recement it.[10] Data collection, methodology, and statistical analysis were identical to that described by Moore and Kennedy.[10]

Data were entered into a spreadsheet using Excel (Microsoft Corp, Redmond, Wash). The DBMS/COPY data conversion package v. 7.0.3 (Conceptual Software Inc, Houston, Tex) was then used to convert the spreadsheet into an SAS data file (SAS Institute Inc, Cary, NC). Subsequent data analyses were carried out in SAS. Descriptive statistics—including frequencies of successes and failures and types of failures, means, and standard deviations of survival times—were determined using SAS procedures FREQ and MEANS. Frequencies of failures under different conditions were compared using contingency table chi-square tests. When cell frequencies were small, a Fisher's exact test was used to make comparisons between groups. Means of survival times were compared using 2 methods. The generalized linear model procedure (PROC GLM) was used to compare mean survival times, controlling for extraneous variables, such as age at insertion and gender. The log-rank test (PROC LIFETEST) was used to produce and compare survival curves. The significance level was predetermined at the probability value of 5% or less ($P<.05$).

Results

A total of 323 space maintainers were followed, with 5 being transferred to other practices and 11 being lost to follow-up. The mean age at initial appliance insertion (Table 1) was: (a) 6 years, 6 months for mandibular band and loop appliances; (b) 6 years, 4 months for maxillary band and loop appliances; (c) 8 years, 0 months for mandibular lingual arch appliances; and (d) 7 years, 10 months for maxillary Nance space maintainers.

The appliance outcomes are shown in Table 2. If space maintainers that were still in use are rated as successful,[10] then the success rates were: (a) 62% for mandibular band and loop appliances; (b) 55% for maxillary band and loop appliances; (c) 66% for mandibular lingual arch appliances; and (d) 64% for maxillary Nance appliances. Ninety-three of 323 appliances (29%) were successful and 110 (34%) were still in service. Therefore, 203 of all 323 (63%) space maintainers placed by one pediatric dentist were either still in use or had lasted their expected lifetime. There were 104 known appliance failures, representing 32% of the overall

Table 2. APPLIANCE OUTCOME EXPRESSED AS N(%)

		Success		Failure		Unknown	
Appliance	Placed	Successful	Still in use	Failed	Removed by general practitioner	Transferred	Lost to follow-up
Mandibular band and loop	45	20 (44)	8 (18)	17 (38)	0 (0)	0 (0)	0 (0)
Maxillary band and loop	67	22 (33)	15 (22)	24 (36)	1 (1)	0 (0)	5 (8)
Lingual arch	142	34 (24)	60 (42)	39 (28)	3 (2)	3 (2)	3 (2)
Nance	69	17 (25)	27 (39)	19 (28)	1 (1)	2 (3)	3 (4)
Total	323	93 (29)	110 (34)	99 (31)	5 (1)	5 (2)	11 (3)

Table 3. DEMONSTRATION OF ALL TYPES OF FAILURE IDENTIFIED IN THE SAMPLE AS N(%) AND WITH STATISTICAL SIGNIFICANCE

	Total	Cement loss	Solder breakage	Not specified	Band split	Eruption interference	Soft tissue	Bent	Complete loss	Removed by general practitioner
Mandibular band and loop	17	12 (71)	0 (0)	0 (0)	1 (6)	0 (0)	1 (1)	0 (0)	3 (18)	0 (0)
Maxillary band and loop	25	19 (76)	0 (0)	1 (4)	1 (4)	1 (4)	0 (0)	0 (0)	2 (8)	1 (4)
Lingual arch	42	22 (52)	0 (0)	1 (2)	4 (10)	3 (7)	0 (0)	5 (12)	4 (10)	3 (7)
Nance	20	9 (45)	1 (5)	3 (15)	0 (0)	1 (5)	0 (0)	1 (5)	4 (20)	1 (5)
Total	104	62 (60)	1 (1)	5 (5)	6 (6)	5 (5)	1 (1)	6 (6)	13 (12)	5 (5)
Chi-square	6.33	NS	NS	NS	NS	NS	NS	NS	NS	NS
P-value	.097									

sample. There were no statistically significant differences in suc-cess and failure rates between the 4 appliances and based upon gender.

Appliance failures are shown in Table 3, with statistical comparisons between appliance type recorded. The most common cause of failure was cement loss, representing 60% of all failures. Cement loss accounted for: (a) 71% of mandibular band and loop appliance failures; (b) 76% of maxillary band and loop appliance failures; (c) 52% of mandibular lingual arch appliance failures; and (d) 45% of maxillary Nance appliance failures. There was no statistical difference in cement loss failure between the 4 appliances. When mandibular and maxillary band and loop appliances were pooled and failures were compared to bilateral space maintainers, however, the band and loop appliances suffered statistically greater cement loss (P=.045; Table 4). Split bands and bent appliances each represented 6% of all failures. Numerically split bands and bent appliances occurred more in bilateral appliances, but there was no statistically significant difference in split bands or bent appliances between the 4 appliances. This was followed by: (1) eruption interferences (5%); (2) reason not specified (5%); and (3) removed by general practitioner (5%). Of 104 failed appliances, 13 (13%) were completely lost.

The outcomes of the failed appliances are shown in Table 5. Of the 104 failures: (a) 34 (33%) were regarded as no longer needed; (b) 57 (55%) were recemented; and (c) 13 (12%) were remade. Of the total sample of 323 space maintainers: (a) 11% were deemed clinically successful and left out; (b) 19% were recemented; and (c) 4% were remade. The mean pooled survival times for all 4 appliances (Figure 1 and Table 6) were: (a) 27 months for mandibular band and loop appliances; (b) 26 months for maxillary band and loop appliances; (c) 27 months for mandibular lingual arch appliances; and (d) 26 months for maxillary Nance appliances. There were no statistically significant differences between the 4 groups for either: (1) failed; (2) successful; or (3) pooled survival times of the appliances (Table 6).

Sixteen appliances could not be followed, since 5 transferred care to other practices and 11 appliances were lost to follow-up. The mean survival times were: (a) 23 months for recemented appliances; and (b) 19 months for remade appliances. Remade appliances were successful 62% of the time, compared to 69% for recemented appliances.

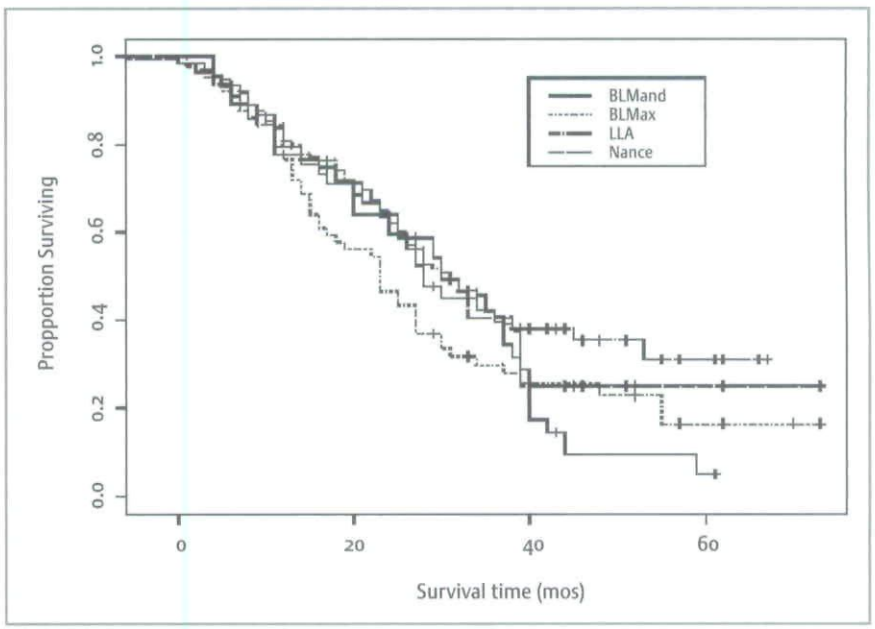

Figure 1. Comparison of survival of all appliances.

Table 4. COMPARISON OF FAILURE RATES AND CEMENT LOSS AMONG APPLIANCES TYPES

Appliance	Cement loss	Other failures	Total	% cement loss
Mandibular and Maxillary band and loop	31	11	42	74*
Lingual arch	22	20	42	52
Nance	9	11	20	45
Total	62	42	104	

* $P=.045$

Table 5. FATE OF KNOWN FAILED APPLIANCES EXPRESSED AS NUMBERS AND PERCENTAGES OF FAILURES OF THE TOTAL SAMPLE PERCENTAGES

Appliance	No longer needed or observed	Recemented	Remade	Total
Mandibular band and loop	5	11	1	17
Maxillary band and loop	4	21	0	25
Lingual arch	15	18	9	42
Nance	10	7	3	20
Total	34	57	13	104
% of total failures	33	55	12	100
% of total appliances	11	19	4	34

Discussion

Previous studies have indicated space maintainer problems ranging from 13% to 63%.[5-9] In this study, approximately 32% of the appliances failed—with 63% being successful or still in service. Unlike other studies,[6-8] the band and loop appliance exhibited a higher frequency of failure than the bilateral space maintainers, although this was not statistically significant. Since previous studies[5,8,10] had indicated that mandibular appliances may fail more frequently than maxillary appliances, the decision was made to count band and loop appliances separately by the arch in which they were placed. In fact, in this study, there was no difference in failure between maxillary and mandibular appliances, regardless of their being unilateral or bilateral.

This study was conducted in the same private practice, with the appliances made by the same laboratory and using identical methodology and statistical analysis as that reported by Moore and Kennedy.[10] Therefore, comparison between this study and Moore's and Kennedy's study may be reasonable. The success rate of 63% is slightly worse than the 72% success reported by Moore and Kennedy.[10] Table 2 indicates that the success rate was 66% for the mandibular lingual arch appliance and 64% for the Nance appliance, compared to 71% for the mandibular lingual arch appliance and 75% for the maxillary Nance appliance as reported by Moore and Kennedy[10] in older mixed dentition patients.

Similar to Moore's and Kennedy's study,[10] we considered an appliance as a failure even if the clinical decision was made not to recement or remake the appliance. We felt that an appliance presenting with problems should not be counted the same as an appliance that presented without problems because the clinical decision may be to either: (1) recement; (2) remake; or (3) discontinue the appliance. If the percentage of patients whose failed appliances were no longer needed is added to the successful group, then the success rate would rise to 77% for the lingual arch appliance and 79% for the Nance appliance. These results are similar to the comparable interpretation of 81% success for the lingual arch appliance and 82% success for the Nance appliance, as discussed by Moore and Kennedy.[10]

More failed appliances were recemented in this study (55%) than in Moore's and Kennedy's study[10] (45%). Also, there was an 11% frequency of failed appliances that were classified as no longer needed compared to the 39% frequency of "no longer needed" in Moore's and Kennedy's study.[10] This study's patients had appliances placed in the early mixed dentition which were, therefore, expected to last longer than those placed in the late mixed dentition patients reported in Moore's and Kennedy's study.[10] This explains both the higher recementation rate and the lower incidence of appliances that were no longer needed. In this study, there was a reduced number of remade appliances (13%), compared to 17% of appliances being remade in Moore's and Kennedy's study.[10] Since almost one third of the sample had appliances that were still in service, it might be that future study of these early mixed dentition patients may result in failures showing up later.

Similar to other studies,[10] the main cause of failure was cement loss, which accounted for 60% of all failures. If complete loss of appliances were also attributed to cement loss, then the frequency of failure from cement loss would rise from 60% to 73% of all failures. Cement loss in single orthodontic bands cemented with glass ionomer cement range from less than 1% to 20%.[14-17] Cement loss in this study occurred in 19% of the total sample, which is higher than the 15% reported by Moore and Kennedy.[10] This may be due to a variety of factors, including the:

1. patients' young ages, which may negatively impact on cooperation and available crown length for banding;
2. assumed higher decay experience, which resulted in premature extraction of primary teeth;
3. young children's diets, which may consist of more sweetened sticky foods that could negatively impact appliance retention;

4. anatomy of the primary second molar, which may also preclude a tight band fit;
5. bulbous gingival margin shape of the primary molar, which may require a larger band that is looser (due to is larger size), and which may explain the increased cement loss of the band and loop appliances in this study;
6. classification of bilateral appliances as failures if only 1 of the 2 bands became loose.[10]

It is disappointing that so many of the appliances failed from cement loss. This is likely due to a combination of poor band fit in the first place and indulgence in sticky foods on the patient's part. Clinicians should be advised to ensure the best fit of the band prior to cementation and give strong appliance care instructions to patients to improve their success rates. Two technique differences are noted between this study and Moore's and Kennedy's study,[10] which exhibited slightly improved band retention, and these may account for the increased cement loss:

1. The insides of the bands were microetched.
2. A different cement was mixed on a frozen slab to enhance band retention.[10]

Studies on cement loss with different types of cement in larger samples are, therefore, recommended.

Table 6. MEAN SURVIVAL TIMES OF APPLIANCES (MONTHS ± SD)

Appliance	Failed	Success	Pooled
Mandibular band and loop	20.9 ± 13.3	30.3 ± 14.1	26.7 ± 14.4
Maxillary band and loop	18.4 ± 13.4	31.1 ± 17.9	26.0 ± 17.3
Lingual arch	16.6 ± 10.8	31.3 ± 13.4	26.9 ± 14.4
Nance	16.0 ± 11.4	29.9 ± 14.1	25.5 ± 14.7
Pooled	17.6 ± 12.0	30.8 ± 14.5	26.4 ± 15.0
Statistical significance*	NS	NS	NS

* NS-nonsignificant

Successful appliances had a mean survival time of 30 to 31 months (Table 6), which is better than those reported by Moore and Kennedy[10] in private practice and better than some university-based studies.[7-9] Because of the early mixed dentition age of this sample, the appliances would be required to last a longer time than those placed in the late mixed dentition by Moore and Kennedy.[10] Therefore, the results must be appropriately interpreted. Since 110 of 323 appliances (32%) were still in use (Table 2), the apparently long survival times must be viewed with caution. The durability of those appliances still in use is unknown, and their fate should be the subject of further study. Given that primary and early mixed dentition patients may require a space maintainer to be in service for 6 or more years until eruption of the permanent dentition, survival times would require an increased study duration, which is recommended as a possible future area of investigation. Furthermore, the following variables should be studied that utilize regression models for survival analysis, rather than the survival times studied here: (1) caries experience; (2) race; (3) location of tooth loss; (4) operator; and (5) other possible variables.

Of clinical significance, the mean survival times of failed appliances ranged from 16 to 21 months—with failed appliances accounting for 32% of the sample. Therefore, clinicians should consider that, somewhere between 16 and 21 months, some appliances may need removal and recementation if they are required to serve a longer time. Parents and children should be advised of this possibility at appliance insertion. Given that children treated with space maintainers often have a caries rate that resulted in premature primary tooth loss, care must be taken to prevent further caries from occurring by way of a loose band. Both recemented and remade appliances exhibited improved longevity compared to other studies.[7,8,10] As with other private practice studies,[10] the numbers of patients lost to follow-up was smaller than in university-based samples.[7-9] Likely this reflects the patient sample and the office procedure for ensuring recall.[10]

Retrospective studies carry strengths and weaknesses that require interpretation and give direction for future research. The strengths of this study are: (1) a relatively large sample size; (2) a relatively long duration; and (3) the fact that it is the first to be reported from a private pediatric dental practitioner.

Furthermore, all appliances placed over a 7-year time period were accounted for. Poor record keeping resulted in 5 appliances (5% of all failures) not being able to be accurately classified according to type of failure. Appliance longevity results are comparable to some university-based studies[5,6,8] and improved compared to others.[7-9] Because the sample was collected from one pediatric dental practice, the results may not be transferable to other pediatric dental practices or to general dentistry practices.

This study provided useful information as to the frequency and types of failure encouraging the clinician to focus on improving those areas such as band fit and cement durability. The results, however, do not prove whether the appliance did what it was supposed to do. Lacking from the literature are data that determine how many appliances actually last their anticipated lifetime and at what point in their lifetime they fail, with the exception of Moore's and Kennedy's study.[10] This is relevant since 110 of 323 appliances in this study were still in service. Furthermore, this and other studies do not provide any information as to whether the planned space maintainer was successful in its task. Success might be measured in terms of the:

1. eruption of the underlying permanent tooth or teeth;
2. absence of the patient needing orthodontic treatment, or the space maintainer treatment resulting in an easier, faster, or a preferred orthodontic treatment plan such as a non-extraction approach.

Further research needs to be done to address these issues.

Conclusions

Based on this study's results, the following conclusions can be made:

1. In a private pediatric dental practice, the majority of all space maintainers lasted their anticipated lifetime without incident or were still in service.
2. Band and loop appliances exhibited more cement loss than bilateral space maintainers
3. Appliance type, arch, and gender do not appear to be related to appliance failure.

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