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Bitewing Radiographic Evaluation of Interproximal Carious Lesions on Permanent First Molars in 6 and 12 year-olds in the Public Health System of Chile

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Bitewing Radiographic Evaluation of Interproximal Carious Lesions
on Permanent First Molars in 6 and 12 year-olds in the Public
Health System of Chile

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Master in Dental Science Thesis

Bitewing Radiographic Evaluation of Interproximal Carious Lesions
on Permanent First Molars in 6 and 12 year-olds in the Public
Health System of Chile

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2010

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ABSTRACT

The national dental public health system in Chile provides comprehensive dental care for children ages 6 and 12, as well as for women during their first pregnancy and adults over 60 years old. Diagnosis and treatment planning are based solely on a clinical examination. Dentistry at all other ages is solely for urgent issues. Our hypothesis is that bitewing radiographs on the 6 and 12 years old children will reveal additional carious lesions which, if detected and treated surgically or pharmacologically, will significantly improve the oral health of the children throughout Chile. We performed 2-bitewing radiographic examinations on 120 children, ages 6 and 12, in the Boca Sur Community Health Center in San Pedro de La Paz, Chile, who had already received an oral examination and treatment based solely on a clinical examination. Interproximal carious lesions, as well as missing and restored teeth, were scored for the permanent first molars following de-identification of the data set. All positive findings on these images were communicated to the Community Health Center staff so the children could be treated. The Study Coordinator (Dr. Haristoy), an experienced OMF Radiologist, scored the first molars for interproximal carious lesions using a 7-point scale, and also scored missing and restored teeth and any other significant findings. Data were analyzed for interproximal carious lesion detection on bitewing images versus the oral examination. Oral examination findings were taken from the patient's dental record in the Community Health Center. Bitewing radiographs showed significantly more interproximal carious

lesions than clinical examination alone, especially in the 12-yr-old age group where the first molars had been present in the mouth for several years. The strongly positive outcome from this study could have a profound impact in the dental public health system in Chile.

Introduction

Oral Public Health Policy and Problems in Chile

Oral health problems are highly prevalent in all Chilean age groups with dental caries being the most prevalent oral disease in Chilean children and adolescents.

In Chile the epidemiological profile of dental caries and other oral diseases is limited. The available studies were conducted at different times, on different age groups and with different methodologies making comparisons difficult^{1,2,1,2,3,2,4}. However, we can obtain some general conclusions such as: 90% of the population has tooth decay, 67% periodontal disease, and about 72% have a malocclusion (population between 2 to 18 years)¹.

The national study (Urbina et al.)^{2,1} conducted by the Ministry of Health between 1996 and 1999 in children ages 6 to 8 and 12 years yielded the following results (Table I):

Table I

Study	Age	Caries Prevalence	dmft	d	m	f	DMFT	D	M	F
Urbina	6-8	84.7%	4.15	2.25	0.8	1.1	0.93			
	12	84,4%					4,19	2.25	0.84	1.1

Gamonal (1996)³ studied adults aged 35 to 44 and 65 to 74 years, of middle to low socioeconomic level, from 8 Santiago neighborhoods. The random sample for this study was 929 adults and the data revealed all the subjects have caries experience with a high number of missing teeth (Table II).

Table II

Study	Age	Caries Prevalence	DMFT	D	M	F
Gamonal	35-44	100%	25.96	9.47	10.34	6.15
	65-74	100%	26.02	8.16	14.28	3.58

The Chilean National Health Survey of 2003^{2,2}, measured the oral health of the adult population over 17-years-old. They found that only 27.8% had a complete dentition, with significant differences between the younger age group (17 to 24-years-old) in which 61.8% had a complete dentition and the older adults (over 24 years) in which only 0.7% had a complete dentition. In the older adults 5.5% were completely edentulous, a condition not found in any person between 17 to 24 years old; however 33.4% of those older than 65 years old were completely edentulous. The mean DMFT score was 2.5 with a range of 0 to 21.

The conclusions of these national surveys are that caries is a disease of early onset and has a strong relationship with age, causing an increase in intensity and impact over the years in the Chilean population.

These studies and their results are the basis and the foundation of the strategic guidelines in dental care of the Chilean Ministry of Health^{2.5,2.6}. These data allow the estimation of the current and future oral health needs of the population, and provide data for the planning and development of current dental care guidelines^{2.7,2.8}.

The current national dental public health model was designed to give priority to prevention and oral health promotion activities, opting for care with the greatest impact and the best cost/benefit; however, today restorative care is also provided. It is critical to focus the dental care resources to children, adolescents and specific adult groups with greatest need due to the limited resources^{2.9}.

Thus, the present oral health policy prioritizes care of populations under 20 years old and first time pregnant women, placing emphasis on prevention and promotion. This model aims to achieve healthy future generations with greater responsibility for their own health. The target populations under 20-years-old are 2-, 4-, 6- and 12-year-olds^{2.5,2.6,2.7,2.8}.

The model has the following targets for dental health in 2010 (year of the bicentennial)^{2.5}:

- Reduce the caries incidence in the population under 20 years-old. This impact will be measured in 12 year-olds, with a rate of 2.0 (DMFT).

- Minimal basic dental coverage for adults will ensure emergency care to the entire population (reinforcement of care with the Network of Emergency Care).

According to the WHO, DMFT and dmft rates with values between 2.7 and 4.4 are considered moderate severity and with values between 4.5 to 6.5 are considered high. With these strategies and policies, the country hopes to achieve a value less than 2.0, which is considered optimal for developed countries⁴.

In 2007, a national study conducted by the Chilean Ministry of Health (Soto et al.)^{2,3, 2.4} evaluated the impact and efficacy of the new policy. This study was focused in children ages 6 and 12 years. The study yielded the following results (Table III):

Table III

Study	Age	Caries Prevalence	dmft	d	m	f	DMFT	D	M	F
Soto	6	70.4%	3.71	1.95	1.52	0.24	0.16	0,08	0,001	0,07
	12	62.5%					1,9	0,75	0,112	1,039

These values in general show that the new policy is being effective, which is evident when we compare the results with the results of Urbina's study, did before to introduce the new policy. However the study still shows consistently high prevalence of caries^{2,3, 2.4} with over 70% of children aged 6 and over 60% of children aged 12.

Although the methodology and populations of both studies were similar and can be comparable, it is important to mind that both studies were based only in of clinical diagnoses, without support additional exams, such as radiology.

Caries Diagnosis:

Clinical Examination versus Bitewing Radiographs

The term diagnosis has been defined as the art or act of identifying the disease from its signs and symptoms⁵; this definition is different from the detection of signs and symptoms. Usually in the case of caries, there are virtually no symptoms until disease late stages. Some authors have stated that this is not a diagnostic step and hence there is no caries diagnosis⁶, as the first exam starts with the detection.

At the level of public health care in Chile, the diagnosis that determines the treatment in dental care is generally made solely by clinical examination, which has very poor sensitivity in detecting interproximal carious lesions that are treated pharmacologically or surgically^{2,7,2.8}.

Radiology has been used for years to detect the presence and extent of carious lesions in teeth, which are not visible to clinical inspection, and also to complement the clinical examination of caries of occlusal surfaces. Even in countries with low caries prevalence rates, radiology has been justified by numerous studies^{7,8}. Although the positive predictive value of bitewing radiographs is low and can give high false positive values, in countries with high caries prevalence such as countries from South America, the predictive value of bitewing radiographs is likely to be high, leading to a high value of true positives.

The radiographic image is intimately related to the development of the carious lesion; the caries process produces a decrease in the mineral content of the enamel and dentin, which results in a decrease in the attenuation of X-ray beam that passes through the tooth. This is seen on the image as a decrease in the radiographic density (radiolucent image), considered the true positive. A loss of 30 to 40% of the mineral content of the affected area is necessary in order to render it visible on the radiograph⁹.

Dove did a systematic review of the literature over a period of 33 years studying the efficacy of 6 different methods for detection of carious lesions in permanent and deciduous teeth, including clinical and radiographic examinations¹⁰. This review suggests that the radiographic exam has higher sensitivity than specificity, showing that the radiograph exam has a greater capacity to detect a person with a carious lesion than a person without. This review also suggests that the sensitivity of radiography is greater than that of clinical examination in caries detection on interproximal surfaces of the teeth where lesions are not cavitated. Therefore, a clinical examination alone results in interproximal carious lesions not being detected, increasing the likelihood of major future carious extension and sequelae. It is clear that more carious lesions are detected with the combination of clinical and radiographic examination than by the clinical examination alone^{7,11}. Some studies have concluded that clinical examination alone detected less than 50% of the total interproximal carious lesions, while bitewing radiographs alone yield up to

90% efficacy in detecting proximal carious lesions¹²⁻¹⁷. In children with complete deciduous dentitions, 12.4% of interproximal carious lesions are not detected by the clinical exam alone¹⁸. Other studies have shown that in high risk caries patient only half of the radiolucent areas identified in dentin by clinical exam alone are cavitated^{19,20}, which further weakens the clinical detection. Numerous studies have shown that, combined clinical and radiographic exams are essential for accurate diagnosis prior to treatment^{12,21-23}.

Currently the most common management for carious lesions is surgical treatment, i.e., removal of the lesion and restoration of the tooth. Unfortunately surgical treatment is most appropriate when cavitation is present. However, radiographs cannot distinguish cavitation from demineralization. In many developed countries, non-surgical interventions are gaining popularity. Such preventive treatments are only effective if the lesion is detected in early stages with no cavitation^{24,25}. Since lesion detection must occur in early stages of caries progression, a diagnostic method with a high sensitivity is essential. However radiographs have a low sensitivity leading to an increase in false positives. This is not a problem because the treatment for early or incipient lesions (potential false positives) is "non-surgical", often purely pharmacologic (topical fluoride), so the damage to these false positives would be of little or no consequence.

Most evidence suggests that even in high caries risk children actual caries progression from radiographic detection to passage into dentin is actually quite slow²⁶⁻²⁹. In determining the appropriate choice of lesion management it is therefore important to be able to determine whether a demineralized lesion is cavitated and whether it is stable or progressing. Radiological follow up is important to determine disease progression and future treatment options.

In Chile there are no studies on the behavior of caries progression. There are numerous studies examining caries progression in populations with low caries risk (Scandinavian countries)²⁶⁻²⁹. The transition from enamel caries to dentinal caries takes an average of 1.5 to 2 years in 35% of the population²⁶⁻²⁹.

The key questions now arise in defining the studies that will clarify the following issues in the Chilean population:

- What percentage of carious lesions is missed if bitewing radiographs are not used, and the diagnosis is based solely on clinical examination?
- What is the implication of missing interproximal carious lesions?
- What is the relationship between diagnostic methods and decisions on surgical and non-surgical (pharmacotherapeutic) care?

Despite the extensive literature which clearly supports the use of radiology as critical and complementary in the detection of caries, the Chilean public health system guidelines for the dental care in children 6 and 12 years old recommends radiographs only in the clinically doubtful cases and/or in cases with high caries risk. In practice, this translates into near zero use of radiology in the public health system.

The lack of adequate detection and subsequent diagnosis of caries, may result in patients without adequate treatment causing a failure in the programs of dental care and in the goals of the public health system, putting at risk the entire planning Oral Health Program of the Ministry^{2,5,2.6}.

It is essential in meeting the national dental public health objectives to evaluate the quality of the programs of dental care, particularly those of children under 20 years old since they are the basis of the proposed goals by the Ministry of Health for the bicentennial^{2,5}. It is vital to conduct research that will evaluate the impact of public policies, assessing their planning and provision of dental services, and analyzing current knowledge to make the best clinical decisions and management.

Digital Radiology and Caries Detection

Digital technology has many advantages over conventional radiologic techniques, including increased speed of image acquisition and reduced radiation dose^{15,16,30-33}. Other advantages are reduced environmental impact as there are no processing chemicals, ease of use, image postprocessing and lower operating costs. Diagnostic efficacy has been shown to be comparable to conventional film-based radiology^{30,31,34-39}. *In vitro* studies comparing several diagnostic methods have shown results very similar in sensitivity and specificity between conventional and digital radiographs. However, in recent years, studies with newer digital systems have shown increased sensitivity, without reduced specificity, which, coupled with postprocessing, results in superior efficacy in the detection of caries^{40,41}.

Hypothesis

Using only clinical examinations in the Dental Program offered by the public health system in Chile results in a significant percentage of 6 and 12 year-old children with undiagnosed interproximal carious lesions in permanent first molars.

Objective

The objective is to demonstrate that bitewing radiographs result in diagnosis of significant numbers of interproximal carious lesions of permanent first molars in 6 and 12 year-olds children that were not diagnosed by clinical examination alone in a Community Health Center as part of the Dental Program offered by the public health system in Chile.

Aims

Aim 1

Measure the prevalence of untreated interproximal carious lesions in the permanent first molars of 6 and 12 year-old children after completion of the comprehensive dental treatment based solely on a clinical examination.

Aim 2

Measure the distribution, based on radiographic criteria, of the enamel vs dentinal interproximal carious lesions in permanent first molars of 6 and 12 year-old children after completion of the comprehensive dental treatment based solely on a clinical examination.

Methods and Materials

The Study Population

We examined a representative population of Chilean children who received dental care according to the “Standard of Care” of the National Public Health System². This population was located in the community of San Pedro de la Paz, Greater Concepción, Bio Bio region, Chile. The eligible subjects for the study were children, ages 6 and 12 years old, who received dental care through the public system in Boca Sur Community Health Center of San Pedro during 2009.

According to the publication of the Ministry of Health^{2,1}, "Diagnosis of Oral Health Status", which describes the rates for DMFT (decayed, missing, and filled permanent teeth) and dmft (decayed, missing and filled primary teeth) during years 1996, 1997 and 1999 by region in children between 6 to 8 and 12 years, respectively, the national averages were:

- 12 years old: DMFT of 3.42, dmft of 0.2.
- 6 to 8 years old: DMFT of 0.93, dmft of 4.19.

In the Bío-Bío region the figures are worse than the national average:

- 12 years old: DMFT of 4.52, dmft of 0.3.
- 6 to 8 years old: DMFT of 1.11, dmft of 4.80.

San Pedro de la Paz

San Pedro de la Paz is a Chilean city, located in the Concepción Province, Bio Bio Region. The population was 80,447 people in the 2002 census, which was estimated in 2006 at 90,827 people, and is projected to be 132,000 by 2012. Almost all of the population is urban (98.98%).

The Municipal Health Direction is responsible for administering three CESFAM (Centers for Family Health); Candelaria, Boca Sur and Lomas Colorada. All of these establishments provide "Primary" Health Care to beneficiaries of Law No. 18,469 that are enrolled in the establishments. The dental health programs are provided by the primary health care facility of each municipality.

The average numbers of children receiving dental care per year in the Boca Sur Community Health Center (CESFAM) of San Pedro de la Paz are; 297 6-yr-olds (24.75 per month) and 316 12-yr-olds (26.33 per month).

Evaluation

To evaluate the public health dental care programs provided to the target groups ages 6 and 12 years, the study used digital bitewing radiographs as the method of evaluation.

Eligible Subjects

Children had to meet the following requirements to be eligible:

1. be enrolled in Boca Sur Community Health Center in the Commune San Pedro de la Paz, and
2. have received comprehensive dental treatment under the official dental program of the Chilean Public Health System during 2009 in Boca Sur Community Health center (CESFAM) of San Pedro de la Paz.

Recruitment Strategy

The recruitment was done in the last week of July 2010. Based on the appointment list for 2009 of Boca Sur Community Health Center, the study coordinator reviewed the records to identify individuals who met the eligibility criteria. The only information that was extracted from the records was if they received dental treatment at the center in 2009 and their phone contact information. For each group of 6- and 12-yr-olds 50% more children were offered appointments than was required, thus insuring adequate size of the final study population. The families of children who fulfilled the eligibility requirements were contacted by phone, the study was explained, and they were invited to participate. Parents and their children who agreed to participate were given an appointment at the Dental Clinic of Boca Sur Community Health Center (CESFAM) located in San Pedro de la Paz, which served as the base for the radiologic examinations during the study (Fig. I).

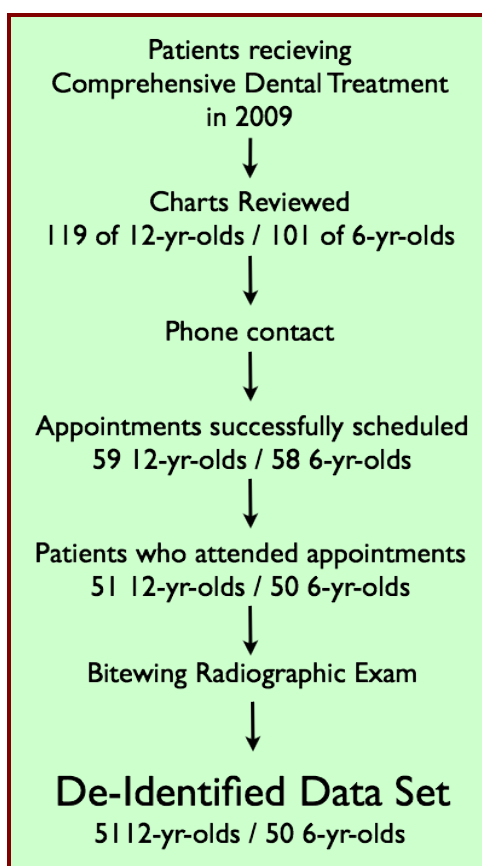


Figure 1

Summary: Selection and Recruitment of Subjects and Preparation of Data Set

Description of sample sizes

Sample sizes of 50 6-yr-olds plus 51 12-yr-olds were obtained based on 101 phone contacts for the 6-yr-olds and 119 for the 12-yr-olds. Charts were randomly selected and reviewed until 50 subjects were successfully radiographically examined for each age group. These sample sizes provided up to 200 first molars and 400 interproximal surfaces for caries detection per group (Fig. 2-3).

Chart Reviewed in 6-yr-olds (101)

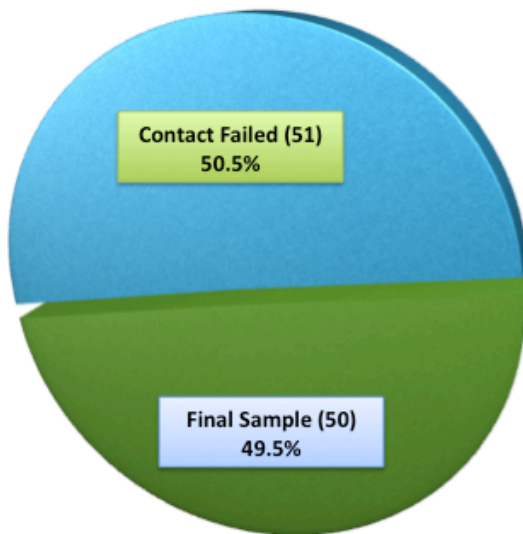
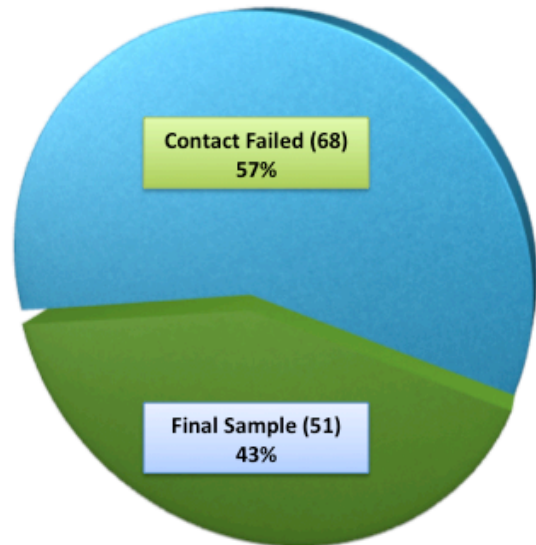
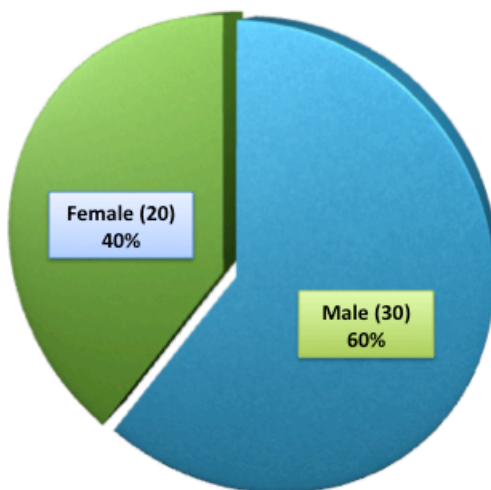


Chart Reviewed in 12-yr-olds (119)



Final Samples from Charts Reviewed

6-yr-olds



12-yr-olds

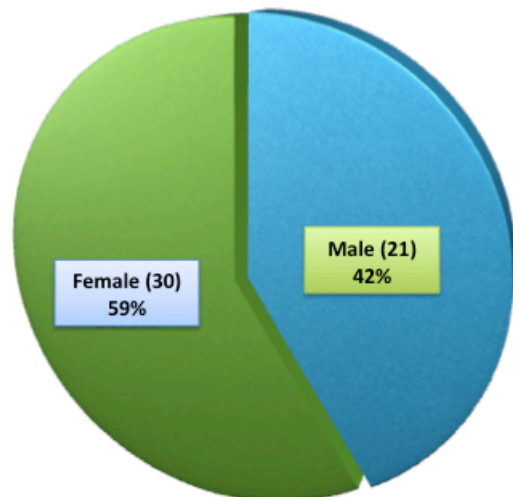


Figure 3
Gender Distributions of Subjects
Sampling

The bitewing radiograph examinations for the study were carried out over 20 work days during August 2010.

At the appointment, the children were accompanied by at least one parent, or failing that an adult person responsible for the child. The adult, who was responsible for the child, was informed of the details of the exam procedure and provided consent for the child to participate. The children's assent was also obtained.

Prior to obtaining X-ray images, the demographic information was confirmed (Complete name, age, address, phone number). The bitewing radiographs were acquired by the person in charge of the research (project coordinator). Two bitewing radiographs (1 per side) were acquired using standard techniques for image quality and radiation dose reduction. A maximum of two retakes (total) was permitted for each patient. After the acquisitions, the images were evaluated by the operator (Project coordinator), who assured that the images met the following benchmarks: (Fig. 4)

- a) visualized all of the crowns of the upper and lower first molars,
- b) visualized the mesial and distal surfaces of the first molars with minimal overlapping.



Figure 4
Bitewing Radiograph Exam

Techniques and Equipment

The image acquisition used standard technique to obtain the bitewing radiographs. Bitewing radiographs is a technique used worldwide as a complement to the clinical exam for detection of caries on interproximal surfaces of posterior teeth.^{5,13,14,17}. The equipment used was a conventional X-ray machine (KODAK Trophy, model 2100, Rochester USA) high frequency (300kHz), at fixed settings of 60 kVp and 10mA with a focal spot dimension of 0.7 mm. The exposure time was appropriate for the age and size of the child.

The receptor used was a photostimulable storage phosphor (PSP) digital technology, which uses a receiver or phosphorus sensor plate (PSP) as the image receptor. The PSP digital system is considered indirect digital technology because when the PSP is exposed, the image is not immediately displayed on the plate, instead being stored as a latent image. The image is displayed only after the PSP plate is exposed to a laser scanner and the latent image is converted to an analogue display for diagnosis.

The PSP system used was a Soredex OpTime, (PaloDEx Group Oy, Tuusula, Finland). This equipment has receptors that have three size formats; 0, 1 and 2. In this study we used size 1 for taking radiographs in children aged 6 and size 2 for children aged 12. The use of a positioner for the digital receiver served to maximize the quality of the image geometry in each patient. Infection control was accomplished by disposable plastic sleeves covering the receptor for each patient. In addition, the receptor was disinfected between each patient using cotton rolls and hydrogen peroxide (2%).

Images (JPG format) were stored on a laptop PC (Gateway Inc., Irvine, California, USA) belonging to the Project Coordinator with appropriate password and firewall protection.

Diagnosis and Informing the Community Health Center Dentist of the Findings

Two days after the image acquisitions, the radiographs were viewed using the Soredex proprietary software “ClinicView” (Fig.4), and the project coordinator generated a diagnosis for each patient. This diagnosis was part of the official patient record and was different than the record that was used for the research project. The image and diagnostic information were delivered to the dentist (Chief of the Dental Program of Boca Community Health Center) no more than two days after the patients were examined.

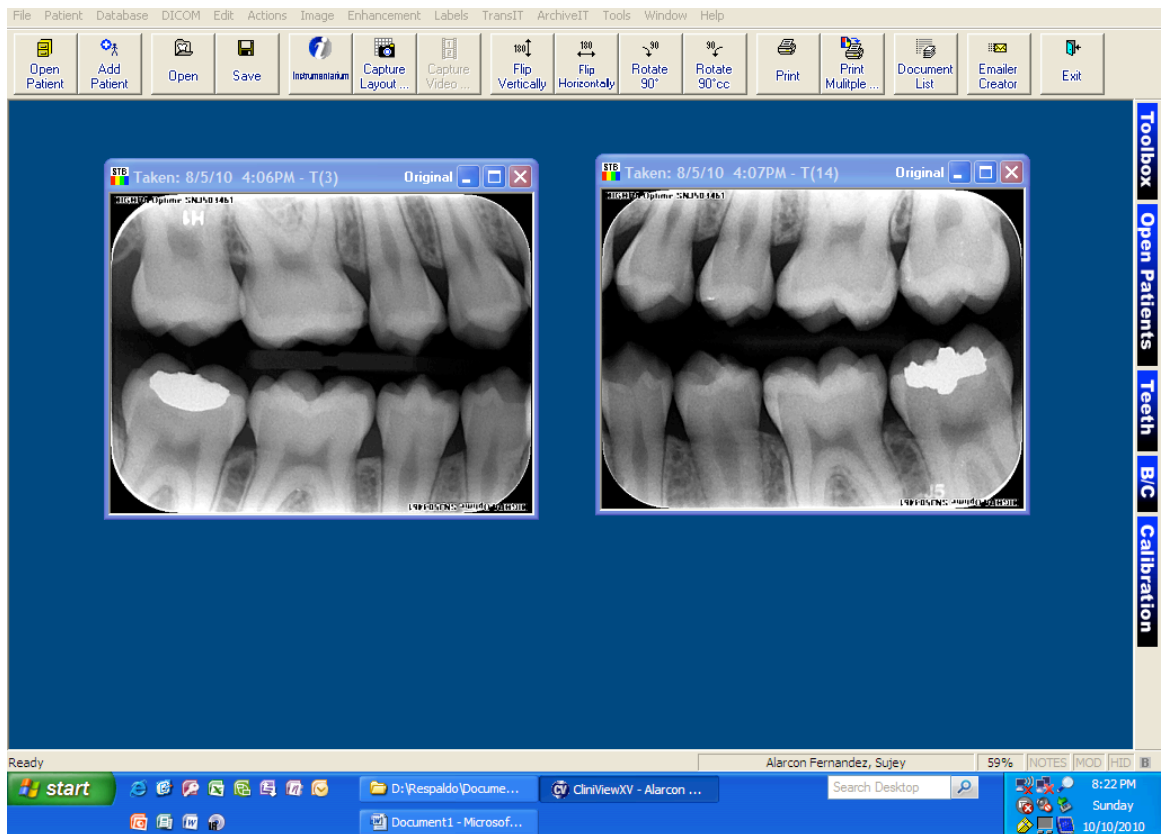


Figure 4
ClinicView Software

Evaluation of the images

Image interpretation was carried out under optimal conditions in a dark room with dim backlighting. The images were displayed on a 27-inch monitor (Apple, Macintosh, California, USA) that was set at 2,560x1,440 pixel-resolution. The analog brightness and contrast controls of the monitor were constant during interpretation. For the image analysis the study used the “ClinicView” software (PaloDEx Group Oy, Tuusula, Finland) (Fig. 4). During this analysis the operator used software tools, including magnification, brightness and contrast enhancement.

Each mesial and distal first permanent molar surface (Fig. 5) was scored on a 0-7 scale, widely used in studies of radiographic appearance of caries around the world^{28,29}, where: (Fig. 6)

0= no radiolucent area on the surface of enamel.

1= radiolucent area in enamel

2= radiolucent area reaching the dentino-enamel junction.

3= radiolucent area in dentin

4= radiolucent area projected at or superimposed over the pulp chamber

5= proximal multisurface restoration

6= occlusal restoration (Not applicable for this project)

7= missing tooth

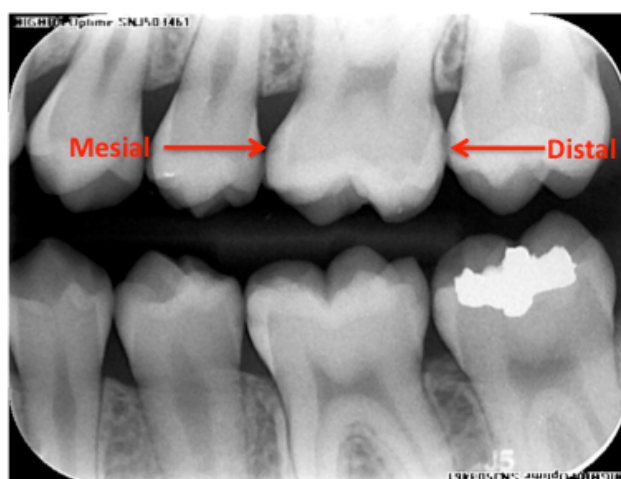


Figure 5
Mesial and Distal Surfaces of Permanent 1st Molar

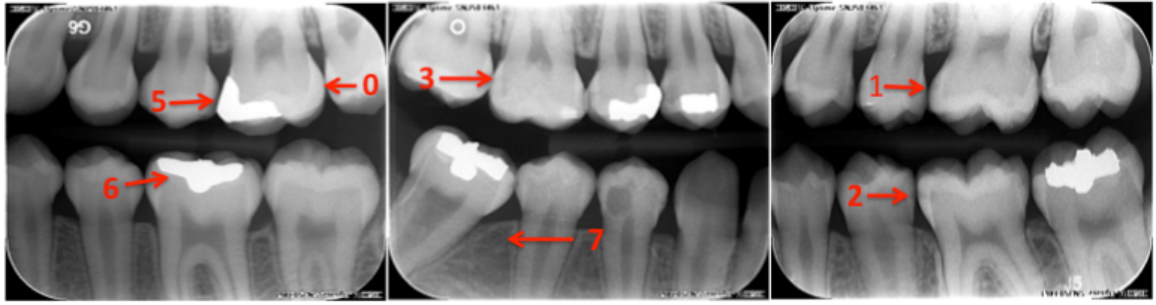


Figure 6
Scoring Scale of Radiographic Findings¹

¹Examples of typical radiographic findings and how they were scored using the criteria described in Methods and Materials. 0= no carious lesion; 1= carious lesion in enamel; 2= DEJ carious; 3= carious lesion in dentin; 4= carious lesion projected at or superimposed over the pulp chamber; 5-6= restorations and 7= missing tooth.

In the 6-yr-old group, the unerupted or partially erupted permanent 1st molars were classified by radiographic criteria (Fig. 7) as fully erupted if they had (Fig. 8):

- a) mesial contact and/or,
- b) occlusal contact.

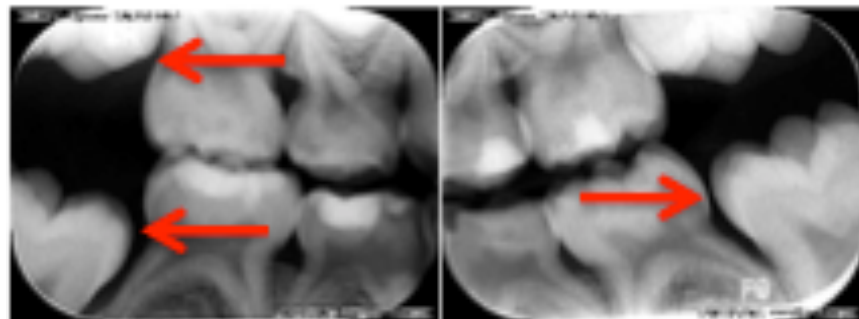


Figure 7
Unerupted or Partially Erupted Permanent 1st Molars in 6-yr-old Subject

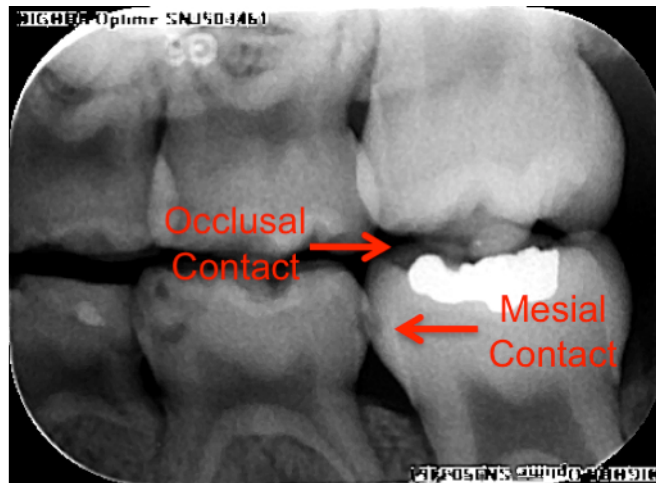


Figure 8
Fully Erupted Permanent 1st Molar in 6-yr-old Subject

Data Management

All the data were entered and stored on an excel spread sheet (version 2003, Microsoft Office, Washington, USA). Clinical and image data were analyzed by age, tooth and patient. Differences were so dramatic and unequivocal that it was decided that statistical analysis was unnecessary

Institutional Review Board

This project was reviewed and approved by the University of Connecticut Institutional Review Board. In Chile the project was review and approved by the Director and the Chief Dentist of Boca Sur Community Health Center.

Results

Clinical Examination

The clinical examination information was obtained from the clinical record sheet completed by the clinic dentist prior to any restorative treatment and prior to the radiographic exam. Using this clinical examination information the prevalence of 12-yr-olds with missing permanent 1st molars (either one or more) was 4%. In the 6-yr-olds, clinically, high numbers of permanent 1st molar were either partially erupted or unerupted. However, we assumed (confirmed by radiographic diagnosis) that there were no missing permanent 1st molars due to extraction or congenital absence (Table IV).

Table IV

Prevalence of Children with Missing Permanent 1st Molars Based Solely on Clinical Exam Prior to Treatment.

Group	All Permanent 1st Molars Present²	One or More Missing Permanent 1st Molars²
12-yr-olds	49 (96%)	2 (4%)
6-yr-olds ¹	50 (100%)	0

¹ Clinically there were some 1st molars partially erupted or unerupted (considered present)

² Number of children (percentage)

Clinically, the prevalence of children with caries experience in permanent 1st molars (decayed and/or restored) was 92% in 12-yr-olds and 4% in 6-yr-olds (Table V). Among 12-yr-olds less than half of those with caries (45%) had received any restorative care and among 6-yr-olds with caries, none had received any restorative care (0%).

Table V

Prevalence of Children with Decay and/or Fill permanent 1st Molars Based Solely on Clinical Exam Prior to Treatment.

Group	With Fill Permanent 1st Molar¹	With Decay Permanent 1st Molar¹	With Fill and Decay Permanent 1st Molar¹	Caries Free
12-yr-olds	3 (6%)	23 (45%)	21 (41%)	4 (8%)
6-yr-olds	0 (0%)	2 (4%)	0 (0%)	48 (96%)

¹ Number of children (percentage)

The majority of the decay in 6- and 12-yr-olds was recorded as occlusal carious lesions in the clinical exam sheet. However, the clinical charting was not precise about the lesion location so it was not possible to exactly determine if the lesions involved one or more surfaces.

Excluding caries free or restored teeth, the prevalence of children with clinically decayed permanent 1st molars (either one or more) was 85% in 12-yr-olds and 4% in 6-yr-olds (Table VI).

Table VI

Prevalence of Children with Decay Permanent 1st Molars Based Solely on Clinical Exam Prior to Treatment.

Group	Children with Decay Permanent 1 st Molars ¹	Children without Decay Permanent 1 st Molars ¹
12-yr-olds	44 (86%)	7 (14%)
6-yr-olds	2 (4%)	48 (96%)

¹ Number of children (percentage)

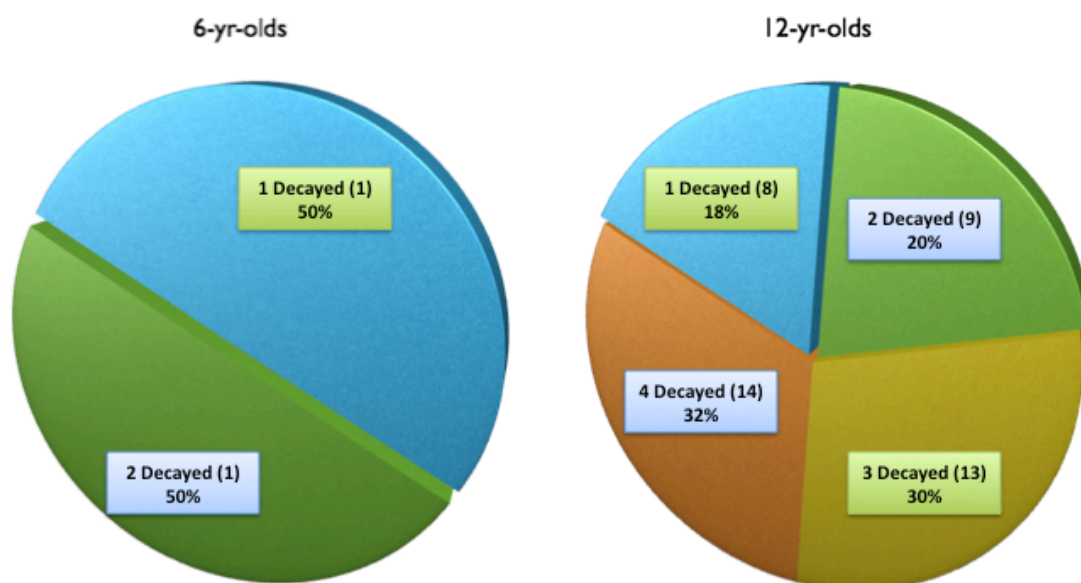


Figure 9

Distribution of Children by Number of Decayed Permanent 1st Molars

Among 12-yr-olds over half of the children had 3 or 4 teeth decayed while among 6-yr-olds no children had 3 or 4 teeth decayed (Fig. 9).

A total of 202 teeth were present in 12-yr-olds and a total of 200 teeth were present in 6-yr-olds. Of these teeth, 60% were decayed and unrestored in the 12-yr-olds and 4% were decayed and unrestored in the 6-yr-olds (Table VII). However the information for the 6-yr-olds is misleading as we considered all the teeth to be present and as described many teeth were partially erupted or unerupted.

Table VII

Prevalence of Decay in Permanent 1st Molars Based Solely on Clinical Exam.

Group	Teeth with Decay¹	Teeth with No Decay¹	Teeth Present
12-yr-olds	121 (60%)	81 (40%)	202/204 ²
6-yr-olds	3 (4%)	197 (96%)	200/200 ²

¹ Number of Teeth (percentage)

² Number of teeth present/Maximum number of teeth possible

Radiographic Examination

When 6- and 12-yr-olds were examined radiographically, the prevalence of children with missing permanent 1st molars (either one or more) in 12-yr-olds was 6%, indicating that one child lost one or more teeth between the clinical and radiographic exam, a period of between 12 to 20 months. Among the 6-yr-olds the prevalence of fully erupted teeth was 78.5%; there were neither extracted teeth nor congenitally missing teeth (Table VIII).

Table VIII

Erupted vs Unerupted or Partially Erupted Permanent 1st Molars in 6-yr-olds Based Solely on Bitewing Radiographic Exam

Group	Fully Erupted ¹	Unerupted or Partially Erupted ¹	Total Teeth Present ²
6-yr-olds	157 (78.5%)	43(21.5%)	200

¹ Number of Teeth (percentage)

² Radiographically all 1st molars were present

Radiographically, the prevalence of children with unrestored interproximal carious lesions (proximal surface decay) in permanent 1st molar was 76% in 12-yr-olds and 14% in 6-yr-olds (Table IX).

Table IX

Prevalence of Children with interproximal Carious Lesions on Permanent 1st Molars Based Solely on Bitewing Radiographic Exam

Group	Children with interproximal Carious Lesion ¹	Children with No interproximal Carious Lesion ¹
12-yr-olds	39 (76%)	12 (24%)
6-yr-olds	7 (14%)	43 (86%)

¹ Number of children (percentage)

Among the teeth present, 40% of the teeth in the 12-yr-olds and 8% of the fully erupted teeth in the 6-yr-olds had unrestored carious lesions (Table X).

Table X

Prevalence of Teeth with interproximal Carious Lesions on Permanent 1st Molars Based Solely on Bitewing Radiographic Exam

Group	Teeth with interproximal Carious Lesion ¹	Teeth with No interproximal Carious Lesion ¹	Teeth Present
12-yr-olds	74 (40%)	127 (60%)	201 ²
6-yr-olds	12 (8%)	145 (92%)	157 ³

¹ Number of Teeth (percentage)

² Radiographic finding of 3 missing teeth.

³ Analysis based on fully erupted teeth as seen on radiograph.

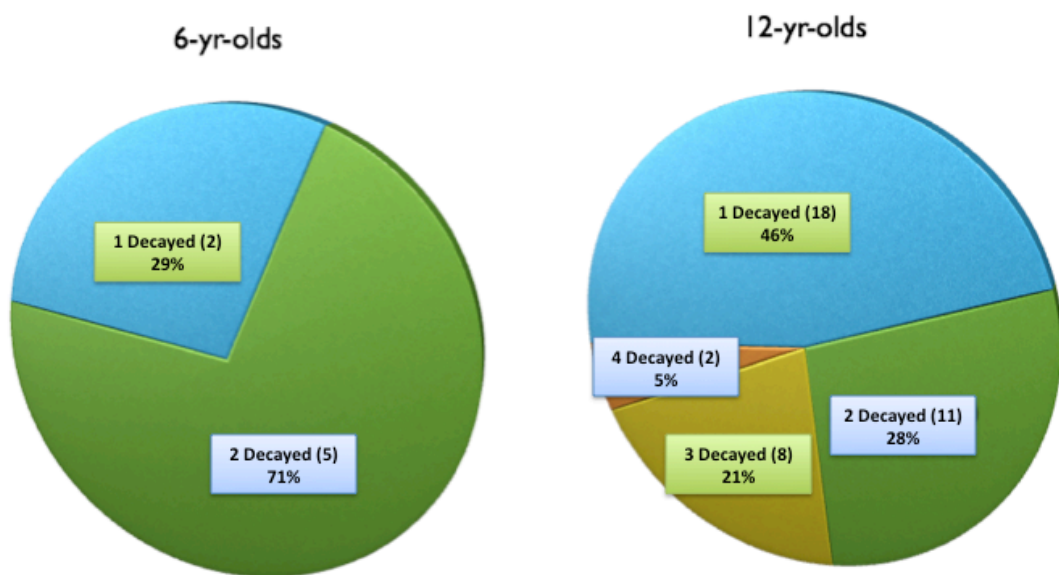


Figure 10

Distribution of Children by Number of Permanent 1st Molar Teeth with Interproximal Carious Lesions

Among 12-yr-olds with 1st permanent molar interproximal carious lesions nearly 75% had 1 or 2 teeth with interproximal carious lesions while among the 6-yr-olds with 1st permanent molar interproximal carious lesions 100% had 1 or 2 teeth with proximal surface decay. Among 12-yr-olds over 25% of the children had 3 or 4 teeth with proximal surface decay (Fig. 10).

The majority of 1st permanent molar proximal surfaces decayed were mesial, with 100% of the surfaces in the 6-yr-olds and 65% of the surfaces in the 12-yr-olds being mesial (Table XI).

Table XI

Surface Distribution of Interproximal Carious Lesions on permanent 1st Molars

Group	Mesial ¹	Distal ¹	Total Interproximal Lesions
12-yr-olds	56 (65%)	30(35%)	86 ²
6-yr-olds	12 (100%)	—	12

¹ Number of Teeth (percentage)

² Based on 74 teeth with interproximal carious lesions, 12 of which had lesions on two surfaces (Mesial and Distal)

Among the 86 proximal carious lesions in the 12-yr-olds the majority were in enamel (65%), and only one child had a lesion superimposed over the pulp. Among the 12 lesions in the 6-yr-olds, all were restricted to the enamel (Table XII).

Table XII

Depth of Proximal Carious Lesions Based Solely on Bitewing Radiographic Exam¹

Group	Enamel ²	DEJ ²	Dentin ²	Pulp ²	Total Interproximal Lesions
12-yr-olds	56 (65%)	14 (16%)	15 (17%)	1 (2%)	86 ³
6-yr-olds	12 (100%)	—	—	—	12

¹ Detailed description of the mechanism for scoring the depth of the lesions is in the text under "Methods"

² Number of Teeth (percentage)

³ Based on 74 teeth with interproximal carious lesions, 12 of which had lesions on two surfaces (Mesial and Distal)

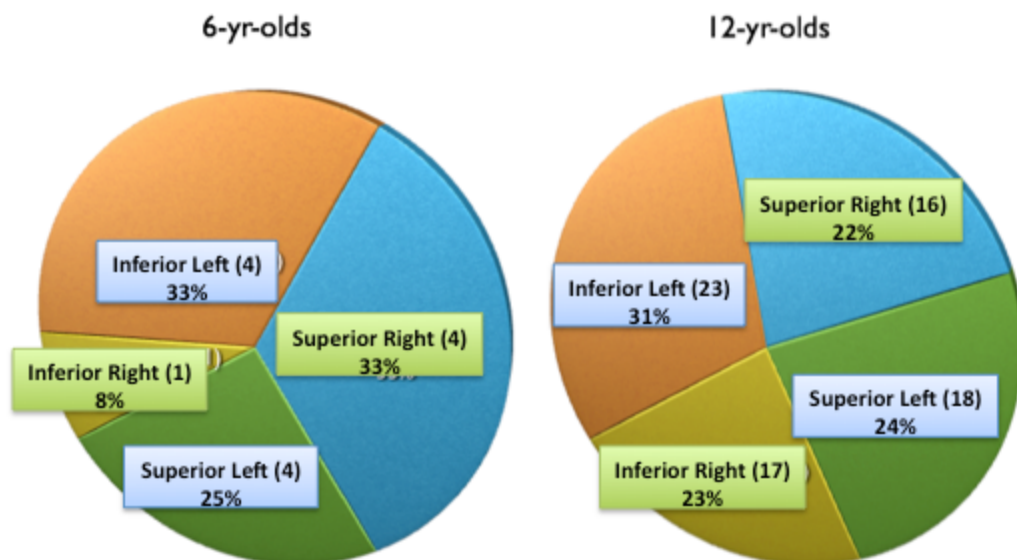


Figure 11
Distribution of Proximal Tooth Decay in Permanent 1st Molars by Quadrant

The distribution of the unrestored interproximal carious lesions in permanent 1st molars in the 12-yr-olds in the different quadrants was very even, with 46% of 74 teeth with interproximal carious lesions distributed in maxillary quadrants. In 6-yr-old children the distribution of the 12 permanent 1st molars with interproximal carious lesions (either 1 or 2 surfaces) among the quadrants was more varied (Fig. 11).

In summary, of the patients that were charted “caries free” on the basis of a clinical examination, 57% (n=4) of the 12-yr-olds and 15% (n=7) of the 6-yr-olds had radiographic diagnosis of unrestored interproximal carious lesions (one or more). Among the patients that had received completed restorative care based on the clinical examination findings alone, 80% (n=35) of the 12-yr-olds and none (n=0) of the 6-yr-olds had radiographic diagnosis of unrestored interproximal carious lesions (Figure 12 and 13 / Table XIII and XIV).

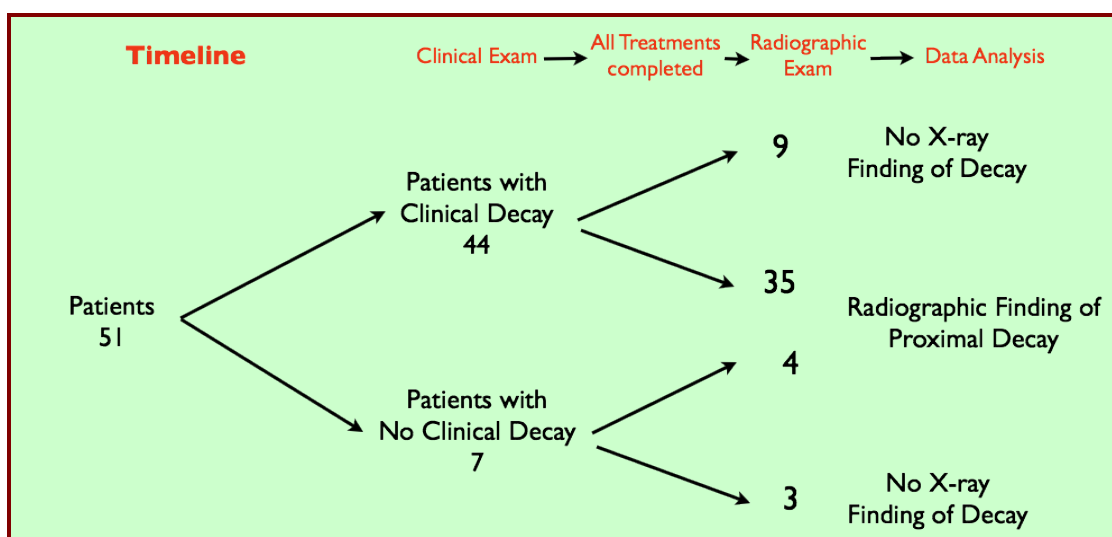


Figure 12
Summary of the Results in 12-yr-olds

Table XIII

Summary of interproximal Carious Lesion Findings in 12-yr-olds.

+/- Carious Lesion	Carious Lesion on Radiograph¹	No Carious Lesion on Radiograph¹
Clinical Carious Lesion	80% (35)	20% (9)
No Clinical Carious Lesion	57% (4)	43% (3)

¹ Percentage (Number of Teeth)

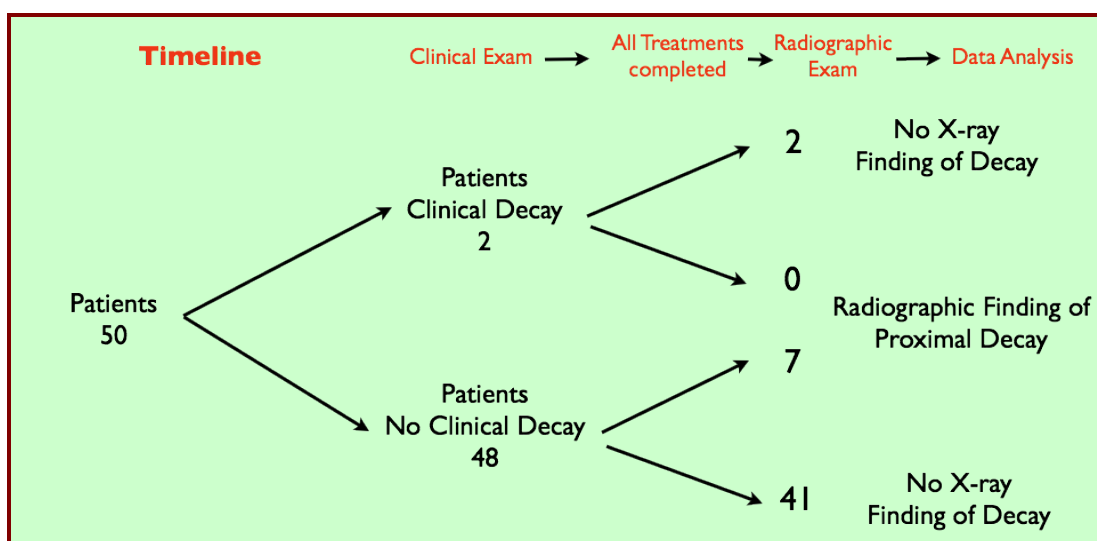


Figure 13
Summary of the Results in 6-yr-olds

Table XIV

Summary of Decay findings in 6 year olds

+/- Carious Lesion	Carious Lesion on Radiograph¹	No Carious Lesion on Radiograph¹
Clinical Carious Lesion	0 (0)	100% (2)
No Clinical Carious Lesion	15% (7)	85% (41)

¹ Percentage (Number of Teeth)

Discussion

The clinical information obtained from the clinical records of the local dentist suggests that the children examined are representative of Chilean children examined in other studies^{1,2.1,2.2}. Therefore, the results obtained in our study can be extrapolated for the rest of the children in Chile. It is important to note that comparable studies in Chile were done on only urban-type populations; thus, these results are representative of the Chilean children from urban populations.

The eruption status of these children appeared comparable to international norms, where the published range of age for the eruption of the permanent 1st molar is 6-7 years⁴²⁻⁴⁴. At the age of 6, the prevalence of fully erupted teeth was 78.5% in the present study.

The audit of the clinical exam performed in the dental public health facility showed that at age 12, 92% of the children had decayed, filled or missing permanent 1st molars. The majority of the children had received no treatment of their first molars. These results are high compared with the caries prevalence of 84.4% found by Urbina et al^{2.1} and the 62.5% found by Soto et al^{2.4} given that in our study we only examined the four first permanent molars whereas the Urbina and Soto's studies examined the complete dentition^{2.1,2.4}.

The aim of the present study was to demonstrate that clinical examination alone results in an incomplete diagnosis of carious lesions in the permanent first molars of 6- and 12-year-old children who were treated as a part of the comprehensive dental plan in the public health system of Chile. The results of the present radiological study convincingly confirm this hypothesis and show that lack of bitewing imaging of 6- and 12-yr-old children results in incomplete treatment in the public health system of Chile. These results are in agreement with conclusions reached in numerous studies that support the use of radiographic exams (bitewing) as a complementary diagnosis for the detection of caries^{7,10,12-14,17-19,21-24,45-48}.

In our study, the use of radiographs showed that 76% of 12-yr-old children and 15% of the 6-year-old children had unrestored interproximal carious lesions in permanent 1st molars that went undiagnosed based solely on the clinical examination. Unfortunately it is impossible to compare these results with other Chilean studies^{1,2,1,2,3,2,4}, because no other Chilean study has used radiology as a complementary exam for the evaluation of the oral health status of the population. This conclusion is based on data from Chilean studies cited in the Chilean Ministry of Health².

In the international literature, there are no studies that have radiographically examined the status of the permanent 1st molar shortly after treatment, probably because in almost all of these countries bitewing radiographs is a standard of care for caries diagnosis prior to treatment.

Diagnosis of interproximal carious lesions on bitewing radiographs has been overwhelmingly justified by numerous studies over the past decades^{7,10,12-14,17-19,21-24,45-48}. Typically these studies have lower levels of proximal surface decay than in our study. Machiulskiene et al. compared clinical and radiographic caries diagnosis in posterior teeth of 12-yr-old Lithuanian children, and found that when the lesion was at dentin level (cavitated), 44% of the lesions were found only through radiographic examination¹². Clark et al. and Popoola et al. found that using bitewing radiographs alone resulted in significantly better diagnosis of proximal caries than when using clinical examination alone⁴⁶. In a recent and powerful study, Hopcraft et al. showed that in a young adult population in Australia, 67-77% of proximal caries lesions were detected by radiographs alone²³. This result increased the number of decayed surfaces detected by 45-46% compared to that found by the clinical examination alone. Similar conclusions were reached by Richardson et al. in his study on Royal Air Force recruits¹⁴. The overwhelming world literature is in agreement with our study, that bitewing radiographs are essential in the diagnosis of proximal caries.

In our analysis of the mesial and distal distributions of proximal carious lesions in the permanent 1st molar, we found that in both age groups the majority of lesions were located on the mesial surfaces. These results can be explained on the basis of the contacting surfaces of these teeth. To produce a proximal carious lesion it is necessary to have contact with the adjacent tooth, which creates an area that is no longer self-cleaning. Thus, all carious

lesions in 6-yr-olds were on mesial surfaces as they universally have no distal contact. The preponderance of mesial carious lesions in 12-yr-olds are similarly explained; their mesial surfaces are in contact almost from the time of eruption, while their distal surfaces are not in contact until the completed eruption of the second (12-year) molars.

The depth of proximal carious lesions is critical in deciding whether to treat the lesion surgically (restoration) versus pharmacologically (fluoride, sealants). In our study, in 12-yr-olds the majority of lesions detected on bitewing radiographs were restricted to enamel (65%) and in 6-yr-olds 100% of them were restricted to enamel. This distribution (majority of the lesions located in enamel surfaces) is comparable with results from other studies worldwide^{14,22,23}, and can be explained from the period of time that caries takes to develop and penetrate into the tooth surface. The result in 12-yr-olds is comparable with Machiulskiene et al. study in which 76% of the lesions were restricted to the enamel¹².

While radiology identifies significantly more interproximal carious lesions than does clinical exam alone, as a diagnostic test it has two weaknesses. The first weakness of bitewing imaging is its low sensitivity in the identification of an incipient carious lesion; in other word, the ability of the radiographic image to correctly identify small interproximal lesions is low, and leads to either not identifying a true incipient lesion (false negative) or identifying a non-existent incipient lesion (false positive). However, as most false positives

occur around incipient lesions, this is not much of a problem because these lesions are typically managed through "non-surgical" or pharmacologic (topical fluoride) means. Therefore, the damage to teeth with a false positive diagnosis would be of little or no consequence. Conversely, false negative diagnoses would be in patients who would receive topical fluoride treatment as part of the dental public health system; this would be the appropriate treatment.

The second weakness of bitewing radiographs is that it cannot determine with precision if a radiolucent lesion is a demineralized, non-cavitated lesion or a truly cavitated lesion. Determining if a lesion is cavitated or not is crucial to determine the type of management. Demineralized, non-cavitated lesions can be managed using non-surgical or pharmacological techniques such as topical fluoride; as where cavitated lesions require surgical or restorative treatment. The literature suggests that the majority of lesions confined to enamel are non-cavitated¹². In the Machiulskiene et al. study, 76% of the lesions diagnosed either by clinical and/or radiographic exams were confined to enamel and classified as non cavitated lesions¹². Given that 65% of the proximal lesions in the present study are confined to enamel, and as the literature suggests that the majority of these lesions are non-cavitated, it would be reasonable to advocate non-surgical or pharmacological management of these lesions. In contrast, the literature shows that 24% of carious lesions in to dentin or at the dentino-enamel junction are cavitated¹², therefore these are more likely to need surgical treatment. Moreover,

cavitated lesions, if left untreated, generally progress to pulpal involvement, infection in the peri-radicular bone, and possibly more serious sequelae with attendant urgent care and possible hospitalization^{49,50,51}. However, in the research setting it is possible to determine clinically if proximal caries lesions are cavitated or non-cavitated by using tooth separation techniques. This approach is not practical or possible in the public health setting. Further research would be required to determine the most appropriate and successful strategies for managing these different stages of lesions for Chilean children.

The results of this study are relevant in both age groups, especially in regard to oral health policies. The Chilean public health system provides comprehensive dental care only for children ages 6 and 12. After the treatment offered at these ages, the children/adolescents can receive dental care only for urgent problems, resulting in a lack of comprehensive dental care after these ages. However, our data show that 14% of these 6-yr-olds and 76% of these 12-yr-olds have untreated caries remaining after their comprehensive treatments. As mentioned earlier, such lesions are likely to progress to much more serious problems.

These results suggest that there are three changes in the pediatric oral health policies of Chile which would significantly improve the care and oral health of the population at minimal additional expense and which may ultimately save money and effort by avoiding subsequent urgent oral health problems and related systemic health problems:

- Introduce a 2-bitewing radiographic exam as a mandatory step in the diagnosis and subsequent dental care of the recipient pediatric populations. Our results, and those of numerous studies worldwide, show that the bitewing radiographic examination, coupled with the clinical examination, is significantly more powerful in the detection of proximal caries lesions than clinical examination alone, and that this exam is useful to help determine the radiological depth of the proximal caries lesions. This information, in addition to identifying interproximal carious lesions, would be useful in identifying whether pharmacological or surgical treatment of such lesions should be chosen.
- Increase the age range in which comprehensive dental treatment is offered to the younger children such that both 6-yr-old and 7-yr-old children are included. This suggestion is based on our results showing that more than 20% of the permanent 1st molars are not yet fully erupted at age of 6 and therefore cannot receive preventive sealants.
- Introduce appropriate policies of caries management that promote non-surgical or pharmacological techniques along with appropriate follow-up after the comprehensive dental treatment for both ages, but especially at age 12. This suggestion is based on the finding of the high number of enamel lesions that may potentially be managed by non-surgical or pharmacological techniques. Follow-up will need to be

based on the pattern of disease development and characteristics of the population. While these policies may lead to an increase in the use of resources by the government, these interventions are preventive and can be provided by hygienists, which may be a more cost-effective solution than offering restorative care. Through preventing more serious oral health outcomes, the overall health care cost to the government might actually be reduced⁵².

In conclusion, the present policies of oral health care provided by the public health system of Chile, today result in 76% of the 12 year-olds who have received treatment still needing additional treatments, either pharmacological or restorative. Because only urgent care is provided after the individual reaches 12 years the carious lesions will continue unchecked. At some point in the future these children will end up requiring urgent and more complex dental care. This results in wasted resources as effort has been put into restoring the teeth yet the miss diagnosis of disease results in disease progression and likely loss of these teeth at older ages.

For future studies is important to consider some limitations that we found in our study. In the clinical analysis, the clinical sheet did not reflect the exact locations of the carious lesions or restorations on the individual teeth. Therefore it was often not clear if a carious lesion involved one or more surfaces. It would have been desirable to perform an initial simple clinical examination prior to radiological examination to better understand the clinical

condition of the children and the teeth under study. The range of time between when the comprehensive dental treatment was received and the radiological analysis was different for each patient, ranging between 8 to 22 months. This issue likely affected the results found in the radiological analysis. In Europe where caries progression has been extensively studied, caries progression has been shown to be slow. However in the Chilean population, based on the high rates of caries prevalence and risk factors such as diet and home oral health care, the progress of the disease may be faster. Thus, caries lesions may have significantly progressed between the clinical examination and the radiographic examination.

Further studies are needed to evaluate the behavior of caries and oral health in the Chilean population, especially concerning the progression of their dental health after age 12 and the effectiveness of various preventive measures on proximal caries progression. Finally, It is critical to examine the socioeconomic effects of the present untreated dental disease outcomes, and project the effects of the suggested changes in the Chilean oral public health policies and systems.

Conclusions

The study and its results provided information that has:

- Assessed the quality of dental care in oral health programs offered by the Ministry of Health to the children population and indicated that bitewing radiographs would significantly increase the detection of interproximal carious lesions in children;
- Assessed the importance of bitewing imaging in the diagnosis of caries in populations at high risk of caries;
- Assessed possible beneficial changes in the protocols of care programs for 6- and 12-year-olds, not only by adding bitewing radiographs, but by extending the initial period of dental coverage from 6 years old to 6-7 years old; and,
- Provided a clear starting point for future clinical studies to assess the progression of caries in children in rural versus urban Chile and to measure the health and public health expense benefits of adding bitewing imaging to the dental care of children.

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