Comparative Effectiveness Study to Assess Two Examination Modalities Used to Detect Dental Caries in Preschool Urban Children

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Abstract

Background: Dental caries affecting the primary dentition of U.S. children continues to be the most prevalent chronic childhood disease. Preventive screening for dental caries in toddlers by dental professionals is labor-intensive and costly. Studies are warranted to examine innovative screening modalities that reduce cost, are less labor-intensive, and have the potential to identify caries in high-risk children. **Subjects and Methods:** Two hundred ninety-one children were randomized into two groups: Group 1 received a traditional, visual tactile examination initially and follow up-examinations at 6 and 12 months, and Group 2 received a teledentistry examination initially and follow-up examinations at 6 and 12 months. The mean primary tooth decayed and filled surfaces (dfs) scores were calculated for all children at baseline and 6 and 12 months. **Results:** At baseline, the mean dfs score for children examined by means of teledentistry was 2.19, and for the children examined by means of the traditional method, the mean was 1.27; the means were not significantly different. At the 12-month examination, the mean dfs score for the children examined by means of teledentistry was 3.02, and for the children examined by means of the clinical method, the mean dfs was 1.70; the means were not significantly different. At 12 months the mean fillings score for the children examined by means of teledentistry was 1.43 and for the children examined by means of the clinical method was 0.51; the means were statistically significantly different ($p < 0.001$). **Conclusions:** These results suggest that the teledentistry examinations were comparable to clinical examinations when screening for early childhood caries in preschool children. The data further showed that color printouts of teeth with cavities provided to parents of children who received teledentistry screenings promoted oral healthcare utilization, as children from the teledentistry study group received more dental care than children from the clinical study group.

Key words: telehealth, e-health, telemedicine

Introduction

Dental caries affecting the primary dentition of U.S. children continues to be the most prevalent and preventable chronic childhood disease. The latest data from the National Health and Nutritional Examination Survey re-

leased in 2007 by the Centers for the Disease Control and Prevention reported that the prevalence of caries in the primary dentition of U.S. children increased significantly in the last decade, with almost 28% of 2–5-year-old U.S. children having caries experience in the primary dentition.¹ Despite progress in reducing dental caries, children living below the federal poverty level experience more dental disease than those who are economically more affluent. Furthermore, dental caries seen in poor children is more likely to be untreated than dental caries present in children living above the poverty level; more than one-third (36.8%) of poor children 2–9 years of age have one or more untreated decayed primary teeth, compared with 17.3% of more affluent children.²

Studies are warranted to examine innovative modalities that have the potential to access and to identify children at high risk of early childhood caries (ECC) at an early age. Such methods would decrease the dependency on dental public health professionals to provide hands-on oral screening examinations, which are labor-intensive, costly, and time-consuming. One such measure is teledentistry.^{3,4} We hypothesize that teledentistry screening by lay health aides may be a cost-effective way to help reduce or eliminate barriers to optimal oral health, decrease the cost of dental care, and improve oral healthcare access and utilization by U.S. underserved populations, in particular, low-income preschool children with the highest risk of ECC. For instance, a cost-effectiveness analysis of outpatient pulmonary subspecialty consultations via telemedicine has shown that telemedicine is a cost-effective alternative for the delivery of outpatient pulmonary care for rural populations with limited access to subspecialty services.⁵

The purpose of this study was to conduct a comparative effectiveness study of teledentistry screening performed by lay health-aides versus the traditional clinical examination screening method performed by dental health professionals for detecting ECC or identifying children at high risk of developing ECC. The sampling frame for this study comprised low-income preschool children, 12–60 months of age, enrolled in selected urban childcare programs in Rochester, NY.

Subjects and Methods

STUDY POPULATION

A study sample of 291 preschool children, 12–60 months of age, was drawn from a cohort of nearly 600 children who were available in 2008–2009 and attended urban childcare centers located in the northeast quadrant of the city of Rochester, NY. Our sample was limited to the children whose parents agreed to participate in the study and provided informed consent. The majority of study

participants were African American and Hispanic children; only a few children were white or children of mixed race/ethnicity. Children enrolled in our study lived in the most impoverished areas of the city of Rochester. The consented children were randomized in two groups: Group 1 received a traditional, visual tactile examination initially and follow-up examinations at 6 and 12 months, and Group 2 received a teledentistry examination initially and follow-up examinations at 6 and 12 months. The sample size calculation was based on a two-tailed Pearson's chi-squared test for proportion of children who had any utilization of dental services from baseline to the 12th month of follow-up. It indicated that a sample size of 98 in each group had 80% power to detect a 20% difference (significance level of $\alpha=0.05$). After taking into account an estimated 30% attrition rate, 128 children were needed per group.

INFORMED CONSENT

The University of Rochester Medical Center Research Subject Review Board approved the study prior to its initiation. Informed consent was obtained from parents of participating children prior to the study. Children 12–60 months of age, regardless of gender, ethnic origin, or race, were eligible to participate in the study. There were no other exclusionary criteria.

RANDOMIZATION PROCEDURES

After the parent or guardian signed the consent form, each child was randomly assigned to the control (clinical) or the experimental (teledentistry) arm. A computerized uniform random number generator was used to allocate children to the clinical or teledentistry arm.

EXAMINATION PROCEDURES

Children who were enrolled in the study were examined at baseline and at 6 and 12 months thereafter. The clinical oral examinations were performed at the six childcare facilities selected for the study by a pediatric dentist with the assistance of a trained and experienced data recorder. The pediatric dentist was trained by an experienced

Fig. 2. Anterior view of the healthy primary dentition.

dental examiner with special training in performing this type of oral examination. Fiber optic lights, plane mirrors, and number 23 piano-wire explorers were used to conduct the clinical examinations. The explorer was used only to clean the tooth surface as necessary and was not used to probe the tooth or tooth surfaces. Radiographs were not used.

Teledentistry exams were performed at the six childcare facilities selected for the study. A trained telehealth assistant (TA) conducted these examinations in the telemedicine examination room. The Dr. Camscope intraoral camera (Sometech Inc., Seoul, Republic of Korea) was used to image the oral hard tissues. *Figure 1* depicts the intraoral camera used in this study. Six images of the labial/buccal and occlusal surfaces of each child's teeth were recorded, including two anterior and four posterior views. *Figure 2* is an anterior view of the primary dentition without dental caries. *Figure 3* is an anterior view of the primary dentition with ECC. The teledentistry dental examiner at the Eastman Dental Center had password-secure access to the images stored in the Web database. A general dentist, who was calibrated in the same manner as the clinical caries examiner (i.e., by a gold standard caries examiner), scored the teledentistry images. To assess reliability of the clinical exams and teledentistry exams, the kappa statistic was calculated. The intra-observer agreement was

Fig. 1. Picture of the intraoral camera.

Fig. 3. Anterior view of the carious primary dentition.

Fig. 4. Teledentistry study flow chart.

assessed based on clinically re-examining a selected subsample (5%) of children and a blinded re-reading of a randomly selected subsample (5%) of the stored images. Both examiners' reliability scores were excellent (kappa statistic of 93% and 87%, respectively). The imaging protocol, the TA training, and the intraoral camera specifications have been described elsewhere.³ The TAs provided educational counseling to the parents of children in both the experimental and control arm along with providing referrals to parents of all participating children. Referrals were generated immediately in both arms of the study (i.e., in the control group after completion of the examination and the experimental group after completion of the teledentistry examination). The TAs were also responsible for providing color printouts of teeth with untreated caries to parents in the experimental arm.

CARIES MEASUREMENT

Decayed and filled surfaces (dfs) values were recorded on individualized prelabeled caries exam forms. The most recent definition of ECC was used for this study.⁶ Accordingly, ECC was defined as the presence of one or more decayed (noncavitated or cavitated tooth surfaces), missing (due to caries), or filled tooth surfaces in any primary tooth in a child 71 months of age or younger. Severe ECC is defined as the presence of any sign of smooth-surface caries in children younger than 3 years of age, one or more cavitated, missing (due to caries), or filled smooth surfaces in primary maxillary anterior teeth from 3 to 5 years of age, or maxillary dfs scores of ≥ 4 (3 years of age), ≥ 5 (4 years of age), or ≥ 6 (5 years of age).⁶

QUESTIONNAIRES

The purpose of the questionnaires used in this study was to gather information from the parents of the participating children and the TAs regarding their satisfaction with the teledentistry examinations. Five TAs completed the satisfaction questionnaire with teledentistry examinations at the end of the study. We received 17 satisfaction question-

naires from parents of the children who completed the study and were enrolled in the teledentistry examination group. From the available data, we gathered information about parental perspective on the teledentistry process. These questionnaires are shown in the Appendix.

STUDY FLOW

The study team received 343 signed consent forms. A computerized uniform random number generator was used to allocate consented children to the clinical or teledentistry arm. One hundred seventy-five children were allocated to the clinical study arm (control), and 167 were allocated to the teledentistry arm (experimental).

Four children were excluded from the clinical arm and five children from the teledentistry arm, as they were either too old or too young to participate in the study. Before we commenced baseline examination procedures, 9 children were lost from the clinical arm, and 38 children were lost from the teledentistry arm; these children left the childcare programs. According to the TAs, the most common reason for the children to leave the childcare center program was related to the family losing the childcare subsidy or moving away from the area.

At baseline, 162 children were examined in the clinical arm and 129 children in the teledentistry arm. At the 6-month follow-up examination, 111 children were examined in the clinical arm (51 children were lost to follow-up), and 88 children were examined in the teledentistry arm (41 children were lost to follow-up). At the 12-month follow-up examination, 70 children were examined in the clinical arm, and 46 children were examined in the teledentistry arm. The study flow chart is presented in *Figure 4*.

DATA ANALYSIS

Prevalence of ECC was calculated at baseline and 6- and 12-month follow-up examinations. The mean primary tooth dfs score was calculated for all children by method of examination (i.e., teledentistry or traditional clinical exam) at baseline and 6- and 12-month follow-up examinations. The Wilcoxon Mann-Whitney test was used to compare groups.

Results

At baseline, of 291 children were examined, approximately 27% had caries experience in the primary dentition. The mean dfs score for all of the children was 1.68 (standard deviation [SD]=4.58) with a range of 0 to 37 carious surfaces.

The mean dfs score for the children examined by means of teledentistry ($n=129$) was 2.19 (SD=5.41), and for the children examined by means of the clinical method ($n=162$), the mean dfs

Table 1. Mean Decayed and Filled Surfaces, Decayed Surfaces, and Fillings Scores by Screening Modality at Baseline

	TELEDENTISTRY GROUP (N= 129)	CLINICAL GROUP (N= 162)	P VALUE ^a
dfs	2.19 (5.41)	1.27 (3.76)	NS
ds	1.13 (4.02)	0.91 (3.25)	NS
fs	1.06 (3.73)	0.35 (1.72)	NS

Data are mean (standard deviation) values.

^aBy Wilcoxon Mann-Whitney test.

dfs, decayed and filled surfaces; ds, decayed surfaces; fs, fillings score; NS, not significant.

score was 1.27 (SD=3.76); the means between the two groups were not significantly different (by Wilcoxon Mann-Whitney test, $p>0.05$). The mean fillings (f) score is an indicator of a child having received dental care. For the children examined by means of teledentistry, the f score was 1.06 (SD=3.73), and for the children examined by means of the clinical method, it was 0.35 (SD=1.72); the means between the two groups were not statistically different (by Wilcoxon Mann-Whitney test, $p>0.05$). These baseline data are presented in *Table 1*.

At the 6-month follow-up examination, of 199 children examined, approximately 33% had caries experience in the primary dentition. The mean dfs score for all of the children was 1.81 (SD=4.43) with a range of 0 to 40 carious surfaces. The mean dfs score for the children examined by means of teledentistry ($n=88$) was 1.89 (SD=4.04), and for the children examined by means of the clinical method ($n=111$), the mean dfs was 1.75 (SD=4.74); the means between the two groups were not significantly different (by Wilcoxon Mann-Whitney test, $p>0.05$). The mean f score for the children examined by means of teledentistry was 1.01 (SD=3.40), and for the children examined by means of the clinical method it

Table 3. Mean Decayed and Filled Surfaces, Decayed Surfaces, and Fillings Scores by Screening Modality at the 12-Month Follow-Up Visit

	TELEDENTISTRY GROUP (N= 46)	CLINICAL GROUP (N= 70)	P VALUE ^a
dfs	3.02 (6.01)	1.70 (3.37)	NS
ds	1.59 (4.69)	1.19 (2.74)	NS
fs	1.43 (4.28)	0.51 (2.14)	<0.001

Data are mean (standard deviation) values.

^aBy Wilcoxon Mann-Whitney test.

dfs, decayed and filled surfaces; ds, decayed surfaces; fs, fillings score; NS, not significant.

was 0.86 (SD=4.16); the means between the two groups were not statistically different (by Wilcoxon Mann-Whitney test, $p>0.05$). These data are presented in *Table 2*.

At the 12-month follow-up examination, of the 116 children examined, approximately 35% had caries experience in the primary dentition. The mean dfs score for all of the children was 2.22 (SD=4.62) with a range of 0 to 26 carious surfaces. The mean dfs score for the children examined by means of teledentistry ($n=46$) was 3.02 (SD=6.01), and for the children examined by means of the clinical method ($n=70$), the mean dfs score was 1.70 (SD=3.37); the means between the two groups were not significantly different (by Wilcoxon Mann-Whitney test, $p>0.05$). The mean f score for the children examined by means of teledentistry was 1.43 (SD=4.28), and for the children examined by means of the clinical method, it was 0.51 (SD=2.14); the means between the two groups were statistically significantly different (by Wilcoxon Mann-Whitney test, $p<0.001$), suggesting that children enrolled in the teledentistry arm received significantly more dental fillings than children from the clinical arm. These data are presented in *Table 3*.

RESULTS FROM THE TAS AND PARENTAL SATISFACTION QUESTIONNAIRES

The TAs had either a very good ($n=3$) or a good ($n=2$) experience with the teledentistry examinations. Their average time to master the oral camera was within 1–2 weeks. The TAs were also asked to compare teledentistry examinations with telehealth examinations; three of the TAs stated that the teledentistry examinations were less difficult to perform than the telehealth examinations, and two of the TAs stated that they were comparable with the telehealth examinations. About 63% of the parents who completed the questionnaires had a very good experience with the teledentistry examinations, and 37% had either a good or fair experience with the teledentistry examinations. About 50% of the parents liked the idea of receiving color printouts of their children's carious teeth as motivating them to make an appointment with a dentist. About 50% of the parents who accessed dental care for their children shared the pictures with their child's dentist.

Table 2. Mean Decayed and Filled Surfaces, Decayed Surfaces, and Fillings Scores by Screening Modality at the 6-Month Follow-Up Visit

	TELEDENTISTRY GROUP (N= 88)	CLINICAL GROUP (N= 111)	P VALUE ^a
dfs	1.9 (4.04)	1.75 (4.74)	NS
ds	0.87 (2.40)	0.89 (2.42)	NS
fs	1.01 (3.40)	0.86 (4.16)	NS

Data are mean (standard deviation) values.

^aBy Wilcoxon Mann-Whitney test.

dfs, decayed and filled surfaces; ds, decayed surfaces; fs, fillings score; NS, not significant.

Discussion

In 2009, the U.S. Congress made a financial commitment to provide strong federal support of comparative effectiveness research to evaluate the relative effectiveness of different healthcare services and treatment options and to encourage the development and use of clinical registries, clinical data networks, and other forms of electronic data to generate outcome data. The Institute of Medicine formed a consensus committee to prepare a list of priorities for comparative effectiveness research studies. One hundred national priority topics were introduced in various areas of medicine. The “oral” category listed in the priority topics was related to comparing the effectiveness of various delivery models in preventing dental caries in children.⁷

Data from our comparative effectiveness study suggest that teledentistry examinations were comparable to clinical examinations when screening for ECC in preschool children. In a previous report,⁴ we presented data on the sensitivity and specificity of teledentistry examinations compared with the existing gold standard clinical examinations. Sensitivity of the teledentistry examinations was 100%, and specificity was 81%, compared with traditional oral clinical exams. The kappa statistic between traditional oral clinical examinations and teledentistry examinations was .61, suggesting good agreement between the two examination modalities. The mean dfs scores for the teledentistry images and the visual examinations were not statistically different, indicating that teledentistry could be a useful tool for dental screening of young children in childcare centers for detecting early signs of caries risk or caries activity, especially ECC.⁴

In the current, comparative effectiveness, longitudinal study, children from the teledentistry study group received more dental care than children in the clinical study group, suggesting that teledentistry screenings promoted oral healthcare utilization. As in the prior studies, preschool children who were examined by TAs for dental caries by means of teledentistry were receptive and cooperative during the intraoral screenings.^{3,4} A majority of the parents who returned satisfaction questionnaires were pleased with the process and found the idea of providing color pictures of teeth with cavities informative and helpful in seeking oral healthcare for their child. However, the data collected from the parental questionnaires should be interpreted with caution, as only 37% of satisfaction questionnaires with the teledentistry screenings were completed and returned at the end of the study. Our rationale for including the composite results from the satisfaction questionnaires is that, to our knowledge, no data exist that relate to the satisfaction of teledentistry screenings in small children.

A recently completed study in California evaluated virtual dental examinations versus in-person dental examinations performed on adult patients with a variety of dental, developmental, medical, and psychosocial conditions; the study concluded that a virtual dental examination was considered a strong substitute for an in-person examination. Sensitivity and specificity scores measured in the study exceeded the standard test accuracy threshold of 160 for all study dentists, both individually and combined.⁸

Screening children for dental caries by means of a teledentistry examination can be particularly useful in urban and rural areas

where individuals do not have adequate access to dental care or do not have adequate access to dental specialists. Virtual oral screenings of preschool children performed by trained childcare employees offer potential cost and time savings for dentists and patients. After the dentist assesses the intraoral images, patients can be referred for appropriate dental care as indicated by the virtual examination. As suggested by the results of this study, teledentistry screenings may increase the likelihood of oral healthcare for children whose primary caregivers do not access routine dental care. Consultation with dental specialists by means of teledentistry also has the potential to increase access to specialty dental care for children who live in urban and rural areas where specialty care is not easily available. Recently, oral medicine specialists in Northern Ireland tested a teledentistry oral medicine model to process oral medicine referrals from rural areas of Ireland to oral medicine specialists in Belfast.⁹ Remote diagnosis of pediatric dental problems, mainly dental caries, yielded excellent sensitivity and specificity that were similar to the results obtained in one of our studies.^{4,10} Orthodontists in the United States have tested teledentistry to provide interceptive orthodontic services to disadvantaged children with good success.¹¹

We did not observe any adverse events as a consequence of intraoral imaging of small children. Indeed, the risk of an adverse event should be minimal and certainly less than risks associated with visual/tactile oral examinations that use dental instruments.

Our data strongly suggest that oral screenings of preschool children conducted by means of teledentistry are comparable to traditional, visual oral examinations conducted in-person by a dentist and that they promote oral healthcare utilization of preschool, urban children. The future of teledentistry as a public health service for screening preschool children for oral disease, its value to parents in improving access to care, its acceptance by dental health practitioners, and the availability of resources to support teledentistry depend on its embrace by both public and private dental insurers as a viable, cost-effective method of screening children for oral disease and thus enhancing the potential to prevent or reduce dental caries, especially ECC, in children.

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Disclosure Statement

No competing financial interests exist.

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Appendix

Study ID _____

Telehealth Assistants Satisfaction Survey Questionnaire
Eastman Dental Center, University of Rochester School of Medicine and Dentistry
Tell us about your experience with teledentistry.

Please read each question carefully. Fill in the blank or place a check mark (✓) in the BOX next to the answer that best describes you.

1. What was your experience with the teledentistry exams?
 - ☐₁ Very good
 - ☐₂ Good
 - ☐₃ Fair
 - ☐₄ Not good
 - ☐₅ Bad
2. How long did it take you to master the oral camera attachment?
 - ☐₁ 0–1 week
 - ☐₂ 2–3 weeks
 - ☐₃ 4–6 weeks
 - ☐₄ 7 weeks or more
 - ☐₅ I am still learning it
3. Please compare teledentistry exams to telehealth exams:
 - ☐₁ The teledentistry exam is more difficult than the telehealth exam.
 - ☐₂ The teledentistry exam is less difficult than the telehealth exam.
 - ☐₃ The teledentistry exam is comparable to the telehealth exam.
4. If you have any additional comments, please write them below:

THANK YOU FOR TAKING THE QUESTIONNAIRE AND ANSWERING QUESTIONS.
Please return the completed questionnaire to the Study Coordinator.

Study ID _____

Parents Questionnaire
Eastman Dental Center, University of Rochester School of Medicine and Dentistry
Tell us about YOUR CHILD'S dental visits during the study.

Please read each question carefully. Fill in the blank or place a check mark (✓) in the BOX next to the answer that best describes you.

1. Did your child receive a referral for dental care while enrolled in the study?
☐₁ Yes
☐₂ No (If No, end of questionnaire)
2. If your child received a referral for dental care, what type of care was your child referred for?
☐₁ My child received a referral for tooth decay or for a tooth extraction.
☐₂ My child received a referral for dental cleaning and fluoride treatment.
☐₃ My child received a referral for a routine check-up.
3. Did you speak with the dentist who referred your child for care?
☐₁ Yes
☐₂ No
4. Did your child receive the recommended dental treatment?
☐₁ Yes
☐₂ No
5. If you answered yes to the previous question, please identify the dental office your child went to: _____
6. How soon did your child visit the dentist after the referral was received?
Within
☐₁ less than 1–2 weeks
☐₂ 1–2 weeks
☐₃ 2–4 weeks
☐₄ 1–2 months
☐₅ 3–4 months
☐₆ 5–6 months
☐₇ more than 6 months
☐₈ My child did not visit the dentist
7. What was your experience with teledentistry?
☐₁ Very good
☐₂ Good
☐₃ Fair
☐₄ Not good
☐₅ Bad
8. Did the telehealth assistant explain your child's dental problem in a way that you could understand?
☐₁ Yes
☐₂ No
9. Did the pictures of your child's teeth motivate you in making an appointment with a dentist?
☐₁ Yes
☐₂ No
10. Did the telehealth assistant motivate you in making an appointment with a dentist?
☐₁ Yes
☐₂ No
11. Did you share the pictures with your child's dentist?
☐₁ Yes
☐₂ No

THANK YOU FOR TAKING THE QUESTIONNAIRE AND ANSWERING QUESTIONS.

Please return the completed questionnaire to the teledentistry assistant.