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## Removable Appliance Therapy for Interceptive Orthodontic Treatment

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REMOVABLE APPLIANCE THERAPY FOR INTERCEPTIVE ORTHODONTIC  
TREATMENT

by

Vikas Gupta

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## Removable Appliance Therapy for Interceptive Orthodontic Treatment

### ABSTRACT

**Introduction:** Socioeconomically disadvantaged children have limited access to orthodontic services not only because of their families' competing needs for limited resources, but also because of the limited availability of orthodontists in their communities and a shortage of orthodontists who are willing to treat patients enrolled in Medicaid. We will systematically explore the hypothesis that an early interceptive treatment protocol using removable appliances provides the same treatment outcome but better cost-effectiveness than a traditional fixed-appliance protocol.

**Methods:** Interim data on a prospective study with patients being treated either in private practice with rational fixed Phase I orthodontic treatment (n=11) or in a community clinic with removable interceptive orthodontic treatment (n=10). Initial and post treatment study models were acquired along with pretreatment PAR and clinical photos. PAR and ICON scores were assessed on all initial and final casts. Cost effective analyses were performed comparing the two treatment groups as well as comparing the removable group to no treatment. Sensitivity analyses were performed to assess the robustness of our data while manipulating certain treatment outcome variables.

**Results:** For the fixed group the average PAR score at T2 was 7.6 with a 68% reduction from T1 to T2, while the ICON average score was 16.2 with a 67% reduction. In the removable group the average PAR score at T2 was 13.4 with a lesser reduction from T1 to T2 than the fixed group at 48% ( $p=0.20$ ), while the ICON average score was 25.3 with a significantly lower reduction of 39% when compare to the fixed group ( $p=0.037$ ). Cost effectiveness analyses showed that the removable appliance treatment protocol was cost effective when compared to no treatment but not cost effective when compared to

the traditional fixed Phase I treatment using the studies measured probabilities of success.

**Conclusion:** The removable appliance protocol used at the Fruitvale community clinic can effectively reduce the severity of malocclusions. However, in order for this treatment to be cost effective when compared to a traditional fixed Phase I protocol it needs to demonstrate consistent clinical results and minimize the probability of “No Improvement”.

## **INTRODUCTION:**

Orthodontic treatment has become increasingly popular and commonplace in the United States with most seeking an esthetic, functional, and/or psychosocial benefit. A major epidemiological study found that about 60% of the population under the age of 18 has an orthodontic need due to various malocclusions [1]. This burden of care, however, is still largely unaddressed with the same study finding that only 30% of Caucasian people, 11% of Hispanic/Latino, and 8% of African American people actually received treatment [1].

Although some studies refute a long-term psychological benefit from orthodontic treatment [2], others have shown that adolescents who have completed orthodontic treatment were less likely to have a physical, psychological and social impact on their daily performances associated with their malocclusion [3]. In addition, one study reported an improvement in the majority of Oral Health Related Quality of Life (OHRQoL) domains when assessed using the Child Perception Questionnaire on 11- to 14-year olds [4]. Moreover, another study focused on bullying and malocclusion found that interceptive orthodontic treatment initiated in adolescents who are being bullied due to the presence of a malocclusion may have a positive impact on their OHRQoL and may experience less bullying related to their malocclusion [5]. Clearly there are far reaching implications for untreated malocclusions, particularly in severely compromised situations.

On the surface it may seem that the large economic disparities within and between groups is a major reason for untreated malocclusions. A closer look reveals a more complex answer. Socioeconomically disadvantaged children have limited access to orthodontic services not only because of their families' competing needs for limited

resources, but also because of the limited availability of orthodontists in their communities and a shortage of orthodontists who are willing to treat patients enrolled in Medicaid [6]. In Washington State, under a quarter of orthodontists have treated Medicaid patients with 81% of the state's orthodontic treatment being done by 10 clinicians. The reasons orthodontists have cited for not treating the Medicaid population include low reimbursement rates, poor patient compliance, and excessive bureaucracy [7]. In addition, Government funding is only for those children who present with a "medically necessary" malocclusion. This translates into coverage for <1% children who are eligible for state-funded dental treatment [8]. Unfortunately, many children do not fall under the "medically necessary" category but have a malocclusion that requires orthodontic treatment. This means that a majority of children who have malocclusions will not receive government-funded orthodontic treatment, and leaves the burden of paying for orthodontic treatment solely on the family or caregiver(s).

A possible solution to the dilemma of cost and clinical efficiency is interceptive orthodontics with removable appliances. Interceptive orthodontics can be defined simply as any procedure that eliminates or reduces the severity of malocclusion in the developing dentition. Its efficacy in reducing the burden of malocclusions has been demonstrated in several studies including one randomized control trial showing that interceptive orthodontics during the mixed-dentition stage moved the majority (80%) of patients from a "medically necessary" treatment status to an "elective" treatment status as defined by peer assessment rating (PAR) scores [7]. The limited nature of interceptive orthodontics means lower cost, both financially and in terms of total time, to patients and orthodontists. If certain treatment goals can be consistently achieved with interceptive orthodontics then it provides an excellent opportunity to improving OHRQoL for adolescents currently experiencing barriers to receiving orthodontic care. Removable

appliance therapy in particular, carries its own set of possible advantages as it relates to treating underserved populations. It has already been demonstrated through clinical trials that removable appliances can be as effective as fixed appliances in early interceptive orthodontics such as resolution of an anterior cross-bite [9]. It has also been demonstrated in recent years that removable appliances such as clear aligners can provide better periodontal health and greater satisfaction to patients when compared to fixed appliances [10]. With the difficulties in treating a population with limited resources, a more limited option with lower costs, less monitoring, and greater oral hygiene may be of extreme benefit.

A community clinic in Fruitvale, California (with the help of faculty members from UCSF) has developed a specific treatment protocol using only removable orthodontic appliances to treat socially disadvantaged children in a community dental clinic setting. This treatment protocol is geared specifically to reduce treatment costs and limit the number of emergency visits, while improving the orthodontic health of children ages 8-10 years old. Since its implementation, the program has been successful in providing access to care to hundreds of children.

We will systematically explore the hypothesis that an early interceptive treatment protocol using removable appliances provides the same treatment outcome but better cost-effectiveness than a traditional fixed-appliance protocol. The specific aims of our study are two-fold. First, is to compare the treatment outcome of a removable-appliance protocol to that of a fixed-appliance protocol and to determine the cost-effectiveness of a removable appliance treatment protocol compared to that of a fixed-appliance protocol.



## **MATERIALS AND METHODS:**

### *Study Design:*

This study was conducted under the approval of IRB committee, IRB2020-53. For this study, two groups of children ages 8 – 10 were prospectively followed—one undergoing phase I orthodontic treatment using traditional fixed appliance therapy and the other undergoing phase I orthodontic treatment using removable appliance therapy only. Patients for the fixed appliance group were recruited from a Private Practice setting. The removable appliance group was recruited from the community clinic in Fruitvale, California, which was referenced in the introduction. Comparable patient populations were selected into each group based on age, sex, and severity of malocclusion.

### *Data Collection:*

Interim data collection of Initial and Final records was obtained for 11 patients in the fixed group and 10 for the removable group. For initial records the following was collected: Pretreatment models, pretreatment photos, pretreatment panoramic radiograph, pretreatment questionnaire, and demographic data. For final records we obtained post treatment models.

### *Questionnaires:*

A standard demographic questionnaire was given to each patient prior to initiating treatment. A copy of these questionnaires can be found in the Appendix A.

### *Scoring:*

In order to assess treatment effectiveness pre and post treatment Peer Assessment Rating (PAR) scores were measured. This was done using the American weighted

system by examining the models. The PAR index, which was developed in 1987, is a valid and reliable measure of orthodontic outcome and is the most widely accepted index [11]. The PAR scoring also gives us a metric for assessing improvement: designation of “Great Improvement” given for a PAR score reduction  $\geq 70\%$ , “Improvement” for a score reduction of 50% to 69%, “Little Improvement” for a score reduction 30% to 49%, and “No Improvement” for a score reduction  $< 30\%$ .

In addition, the Index of Complexity, Outcome, and Need (ICON) score was measured on pre and post treatment models. This internationally developed index has been noted as a bridge between previously used measures and is considered the “easiest and most intuitive” orthodontic assessment [12]. This index gives a metric for assessing the severity of the malocclusion through the ICON Complexity Grade: “Easy” for ICON score  $< 29$ , “Mild” for a score in the range of 29-50, “Moderate” for a score of 51-63, “Difficult” for a score of 64-77, and “Very Difficult” for a score  $> 77$ . In addition, this index gives us another tool for assessing improvement through the ICON Improvement Grade. This scale categorizes improvement as “Greatly Improved”, “Substantially Improved”, “Moderately Improved”, “Minimally Improved”, “Not Improved or Worse”. The table describing the exact calculation and raw values for this grading scale can be found in Appendix

#### *Statistical Analyses:*

All data was first deidentified using a random number generator in Excel (Washington), and then the data was cleaned along with all the analysis using STATA (Texas). We conducted the following statistical analysis to evaluate the cost effectiveness of treatment. A simple t-test comparing the changes in PAR and ICON scores from T1 to

T2 in the two treatment groups. This was done to see if there were differences in treatment effectiveness between the removable and fixed treatment groups.

A logistical regression was used to look at improvement categories for the two groups and calculated Odds Ratios. This was done to see if there was a higher likelihood of having a certain improvement grade depending on the treatment type.

#### *Cost Effective Analyses:*

For cost effectiveness, an Incremental Cost Effectiveness Ratio (ICER) was calculated using our experiment probabilities of treatment success and cost of treatment. It is determined by dividing difference in cost between the two treatment groups by the difference in Quality Adjusted Life Years (QALY's) between the two groups. We determined the QALY's to be 27.89 for both no malocclusion and mild malocclusion, and 26.05 for Moderate/Severe Malocclusion. QALY's were determined using known utility values of 0.91 for no malocclusion/mild malocclusion and 0.85 for Moderate/Severe Malocclusion [13]. Moreover, we estimated the life span to be 80 more years after completion of treatment, and we applied a discount of 3% per year. Using a one-way sensitivity analysis we varied the probability of no malocclusion and some malocclusion for the removable appliance group. All results are expressed in US Dollars and were rounded to the nearest \$1. The decision tree outlining this cost effective analyses can be found in Appendix E.

## **RESULTS:**

### *Demographics:*

In Table 1 we can see a summary of the demographic information for our study population. There was approximately an even split between male and female patients in the two groups. The removable group had a large majority of Hispanic patients (27 of 29). In contrast, the fixed group had a larger proportion of Asian patients (10 of 18). This was of the total enrolled population, and our interim analysis focused on 21 of these participants.

### *PAR & ICON Scores:*

At the initial time point, T1, PAR and ICON scores were recorded for each patient by grading the models. The removable appliance protocol group recorded lower average PAR and ICON scores at 24.9 and 37.6 respectively compared to the fixed group with scores of 30.3 and 48.6. Consequently, the initial ICON Complexity Grade for the fixed group showed more patients in the mild and moderate category compared to more patients categorized as easy and mild in the removable group. A summary of all T1 measurements can be seen in Table 2.

For the fixed group, the average PAR score at T2 was 7.6 with a 68% reduction from T1 to T2, while the ICON average score was 16.2 with a 67% reduction (Table 3). All patients in this group ended with malocclusions categorized as “Easy” by ICON Complexity Grade (Table 3).

For the removable group, the average PAR score at T2 was 13.4 with a 48% reduction from T1 to T2, while the ICON average score was 25.3 with a 39% reduction (Table 4).

Of the 10 patients in this group, 6 ended with malocclusions categorized by the ICON Complexity Grade as “Easy”, 3 as “Mild”, and 1 as “Moderate” (Table 4).

The removable group had a lesser decrease in index scores from T1 to T2. The difference between the two groups in change in PAR scores was not found to be statistically significant ( $p=0.201$ ) while the fixed group showed a statistically significant greater ICON score decrease than the removable group ( $p=0.037$ ) (Table 5).

Looking at PAR Improvement Grade, in the fixed group we found 7 of the 11 patients showing “Great Improvement”, 3 displaying “Improvement”, and 1 categorized as “No Improvement”. In contrast, for the removable group we found 3 of the 10 patients showing “Great Improvement”, 2 displaying “Improvement”, and 1 categorized as “Little Improvement”, and 4 as “No Improvement”. The average PAR Improvement Grade was “Great Improvement” for the fixed group and “Little Improvement” in the removable group. Logistic Regression analysis comparing improvement categories for the fixed vs. removable groups found a PAR Odds Ratio of 7.8;  $p=0.035$ . (95% CI 1.15 - 52.92). This means that a patient in the fixed group had a 7.8 times higher odds of a better PAR Improvement Grade than a patient in the removable group. The large confidence interval shows the limitation of having a small sample size.

For ICON Improvement Grade, in the fixed group we saw 3 of 11 patients indicating “Greatly Improved”, 4 patients with “Substantially Improved”, 3 patients with “Moderately Improved”, and 1 patient showing “Minimally Improved”. In contrast, for the removable group we saw 1 of 10 patients indicating “Greatly Improved”, 3 patients with “Moderately Improved”, 4 patients showing “Minimally Improved”, and 2 patients with a “Not Improved” designation. The average ICON Improvement Grade was “Substantially

Improved” for the fixed group and “Minimally Improved” in the removable group. Logistic Regression analysis comparing improvement categories for the fixed vs. removable groups found an ICON Odds Ratio 7.04;  $p = 0.037$  (95% CI 1.12 - 43.89). This means that a patient in the fixed group had a 7.04 times odds of a better ICON Improvement Grade than a patient in the removable group. The large confidence interval shows the limitation of having a small sample size.

#### *Cost Effectiveness:*

With adjusted probabilities of successful treatment entered into our calculations for cost effectiveness for both fixed and removable we were able to determine an incremental cost effectiveness ratio (ICER) for our removable treatment protocol. For the fixed group we had a 60% chance of “Greatly Improved”, 20% chance of “Improved”, and a 20% chance of “No Improvement”. For the removable group we had a 23% chance of “Greatly Improved”, 33% chance of “Improved”, and a 44% chance of “No Improvement”. These measured values gave us an ICER value of 10,034 which is well below our threshold value of 100,000 for cost effectiveness. This means that based on our measured sample’s probabilities of “success”, we were unable to conclude that the removable treatment protocol is cost effective when compared to a fixed protocol.

Due to the small sample size of our collected T2 data, it was prudent to test the robustness of our data by performing a sensitivity analysis. Sensitivity analysis was performed using the measured fixed group data of 60% chance of “Greatly Improved”, 20% chance of “Improved”, and a 20% chance of “No Improvement”. We varied the % of “Improved” and “Greatly Improved” and fixed the % of “No Improvement” at 10%, 20%, or 25% for the removable group (Table 6). Any combination at 10% “No Improvement” was cost-effective relative to fixed because you have a negative ICER

number. This means that if a removable appliance protocol was able to achieve a 10% no improvement probability then it will be cost effective compared to fixed. When you use the same % of “No Improvement” for removable as fixed (20%), the cutoff point is 50% “Improved” and 30% “Greatly Improved” to approach cost effectiveness. This is the worst-case scenario where a removable interceptive protocol can be cost effective compared to fixed. If you fixate “No Improvement” probability to 25%, no scenario is cost-effective, only 10% “Improved” and 65% “Greatly Improved” gets close.

In addition, the cost effectiveness of the removable treatment protocol was assessed when compared to no treatment. For this analysis we used data from Keruso *et al* [14]. showing how teeth progress from mixed dentition to permanent with no treatment. This gave us 10% chance for “Greatly Improved”, 40% for “Improved”, and 50% for “No Improvement”. For the removable group calculation we used the measured probabilities stated above. This analysis gave us an ICER value of -53,182, which meets the threshold for cost effectiveness, as it is a negative number. This means the removable treatment protocol in our investigation was cost effective when compared to no treatment.

We further evaluated our data using another sensitivity analysis for cost effectiveness for the removable treatment protocol when compared to no treatment. Specifically, we explored what the worst-case scenario would be for the removable group to still be cost effective when compared to no treatment. For this analysis, the probability of “No Improvement” for the removable group was fixed at 55% while varying the probability of “Improved” and “Greatly Improved”. Sensitivity analysis shows that the worst-case scenario for the removable group to still be cost-effective compared to no treatment is 55% “No Improvement”, 30% “Improved” and 15% “Greatly Improved” (Table 7).

## **DISCUSSION:**

This study provides a framework for exploring the cost effectiveness of new and existing orthodontic treatment protocols. With the currently available data we found this removable treatment protocol to be cost effective when compared to no treatment but not cost effective when compared to the traditional fixed appliance protocol. This study confirms findings from Jolley *et al* demonstrating the effectiveness of an interceptive treatment protocol [15]. Our average PAR reduction of 48% aligns closely with the 50% PAR reduction found by Bernas *et al* in 2007 looking at early Phase I orthodontic treatment [16]. This suggests that the 68% reduction found in our fixed group may be higher than the PAR reduction found in most orthodontic settings. This finding may be attributed to greater than average clinical skills or selection bias. In addition, our finding that changes in ICON scores were statistically significant ( $p=.037$ ) but changes in PAR score were not ( $p=.20$ ) confirms findings from Deans *et al* which concluded that ICON is a reliable orthodontic index that is useful in cost effectiveness analyses [17].

Our cost effective analysis demonstrated that the probability and type of clinical success is the more important factor in achieving cost effectiveness rather than lower costs. Specifically, minimizing the probability of a patient receiving “No Improvement” is critical when trying to achieve cost effectiveness. This is demonstrated clearly in the sensitivity analyses we presented comparing removable treatment to fixed treatment. No previous studies have compared the cost effectiveness of a removable interceptive treatment protocol to a traditional fixed Phase I protocol.

After a thorough review of all cases treated it was determined that the best way to minimize the probability of “No Improvement” was stringent protocols on case selection. We discovered that certain cases, those with mild to moderate malocclusions with no



major skeletal discrepancies, were much more amenable to successful removable interceptive orthodontic treatment. An example of an initial malocclusion that showed favorable changes in the removable treatment group can be seen in Figure 1. This patient showed moderate upper crowding and misalignment with mild crowding and misalignment on the lower arch. No major skeletal discrepancies apparent with an initial PAR score of 21 and initial ICON score of 43.

In Figure 2 we can see the final occlusion after interceptive removable appliance therapy. We can see upper arch expansion, resolution of upper and lower crowding, and improvement in incisor alignment. The PAR score was reduced to 7 and the ICON score reduced to 18. Another example of a successfully treated case in the removable appliance group can be found in Figure 3 (Initial Models) and Figure 4 (Final Models). Initial photos for another successfully treated case can be found at Figure 5. This patient also showed mild to moderate crowding with misalignment and no major skeletal discrepancies.

On the other hand, those cases with severe initial malocclusions and major skeletal discrepancies had a much higher probability of undergoing “No Improvement”. These patients may be beyond the scope of being treated with removable interceptive orthodontics in a community clinic setting. Patients at the Fruitvale clinic are from a lower socioeconomic status with these patients possibly having a higher probability of missed appointments, poor oral hygiene, poor compliance, and broken appliances. These obstacles make successful treatment of this patient population more difficult and may require closer monitoring and more resources than what are available at a community clinic. An example of the initial malocclusion of a patient who had unsuccessful interceptive orthodontic treatment in the removable group can be seen in Figure 6

(models) and Figure 7 (photos). This patient had a full anterior crossbite with moderate to severe upper and lower crowding. The patient shows signs of a severe skeletal discrepancy. The patient had an initial PAR score of 64 and an initial ICON score of 73.

In Figure 8 we can see the final occlusion for this patient after undergoing two years of treatment with removable interceptive appliances. At this time the patient remains in full anterior cross bite with crowding and alignment issues in both arches. The final PAR score was 39 and final ICON score of 67. Reasons for unsuccessful treatment may include missed appointments, broken appliance, and severe initial malocclusion. This helps demonstrate the types of cases that may not be amenable to successful removable interceptive orthodontic treatment.

If prudent case selection of which patients should be treated with removable interceptive treatment is done, then perhaps patients who will have unsuccessful treatment can be minimized and cost effectiveness can be achieved.

#### **LIMITATIONS:**

The limitations of our study include small sample size and the lack of an untreated control group. The small sample size precluded us from being able to make final conclusions regarding the cost effectiveness of this removable treatment protocol. Future efforts are aimed at collecting final data on the remainder of our study patients. The lack of an untreated control group was addressed by utilizing data from past studies looking at the natural progression of malocclusion severity in the developing dentition. In addition, most of the patients treated in the removable group were Hispanic while the fixed group had mostly Asian patients. This could potentially skew the results of the data.

## **CONCLUSIONS:**

In conclusion, we have demonstrated that the removable appliance protocol used at the Fruitvale community clinic can effectively reduce the severity of malocclusions. However, in order for this treatment to be cost effective it needs to demonstrate consistent clinical results. Specifically, the number of patients who see “No Improvement” based on PAR standards needs to be minimized. Utilizing the probabilities of success in our treatment groups we were unable to demonstrate that the interceptive removable appliance protocol is more cost effective than a traditional fixed Phase I treatment protocol. However, sensitivity analysis showed that if the probability of “No Improvement” in the removable group is under approximately 25% then this treatment protocol could approach cost effectiveness. In order to accomplish this success rate, case selection is critical. Only treating those patients that need orthodontic intervention but have malocclusions that are amenable to removable treatment (i.e. no major skeletal discrepancies) can help achieve this goal in the future. Future efforts will be focused on collecting a larger sample size and investigating patients treated with Clear Aligner Therapy.

1. Removable Interceptive Orthodontic Treatment can effectively reduce the severity of malocclusions.
2. Early Interceptive Orthodontic Treatment with removable appliances is cost effective when compared to no treatment.
3. Case selection is critical when attempting an interceptive treatment protocol and considering its cost effectiveness vs. a fixed protocol.
4. Compared to fixed appliance phase I treatment, in order for the alternative treatment method to be cost-effective the treatment outcome must be, at most, no worse than the percent difference in costs.

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## TABLES

Table 1

	Removable	Fixed
Male	13	10
Female	16	8
Ethnicity		
Caucasian	0	3
African American	1	2
Asian	1	10
Hispanic	27	3

Demographic Information

Table 2

Removable Average T1 PAR			Removable Average T1 ICON	
24.9 ± 13.4			37.6 ± 14.0	
Fixed Average T1 PAR			Fixed Average T1 ICON	
30.3 ± 14.7			48.6 ± 16.8	
FIXED ICON COMPLEXITY GRADE at T1				
EASY	MILD	MODERATE	DIFFICULT	VERY DIFFICULT
1	5	5	3	0
REMOVABLE ICON COMPLEXITY GRADE at T1				
EASY	MILD	MODERATE	DIFFICULT	VERY DIFFICULT
7	16	2	2	0

T1 PAR/ICON Scoring and Complexity Summary

Table 3

Average T2 PAR			Average T2 ICON	
7.6			16.2	
ICON Complexity Grade at T2				
EASY	MILD	MODERATE	DIFFICULT	VERY DIFFICULT
11	0	0	0	0
Average T1-T2 PAR Reduction %			Average T1-T2 ICON Reduction %	
68%			67%	

Fixed Scoring Summary at T2 (N=11)

Table 4

Average T2 PAR			Average T2 ICON	
13.4			25.3	
ICON COMPLEXITY GRADE at T2				
EASY	MILD	MODERATE	DIFFICULT	VERY DIFFICULT
6	3	1	0	0
Average T1-T2 PAR Reduction %			Average T1-T2 ICON Reduction %	
48%			39%	

Removable Scoring Summary at T2 (N=10)

Table 5

	Initial PAR	Initial ICON	Final PAR	Final ICON	PAR Decrease % (p=0.201)	ICON Decrease % * (p=0.037)
FIXED (N=11)	26.6	47.2	7.6	16.2	68%	67%
REMOVABLE (N=10)	27.9	41.7	13.4	25.3	48%	39%

Scoring Summary T1 – T2

Table 6

Sensitivity Analysis Comparing Cost Effectiveness of Removable Treatment to 60/20/20  
(Greatly Improved/ Improved/ No Improvement) Fixed Treatment Group

<b>.1 No Improvement</b>		
Improved	Greatly Improved	
0.1	0.8	-33713.5
0.2	0.7	-37096.94
0.3	0.6	-41326.23
0.4	0.5	-46763.89
0.5	0.4	-54014.11
0.6	0.3	-64164.41
0.7	0.2	-79389.87
0.8	0.1	-104765.62
<b>.2 No Improvement</b>		
0.1	0.7	-307771.67
0.2	0.6	N/A
0.3	0.5	301246.48
0.4	0.4	148991.94
0.5	0.3	98240.43
0.6	0.2	72864.67
0.7	0.1	57639.22
<b>.25 No Improvement</b>		
0.1	0.65	-83740
0.15	0.6	72864.67
0.25	0.5	57639.22
0.35	0.4	47488.92
0.45	0.3	40238.7
0.55	0.2	34801.04
0.65	0.1	30571.74
0.75	0.1	30571.74



Table 7

<b>.55 No Improvement</b>		
Improved	Greatly Improved	ICER
0.1	0.35	199743.45
0.2	0.25	118541.03
0.3	0.15	83740
0.4	0.05	64406.09

Sensitivity Analysis to Determine Worst Outcome of Removable that is still Cost Effective Compared to No Treatment

**FIGURES:**

Figure 1



Initial Models for Ideal Removable Treatment Patient #1

Figure 2



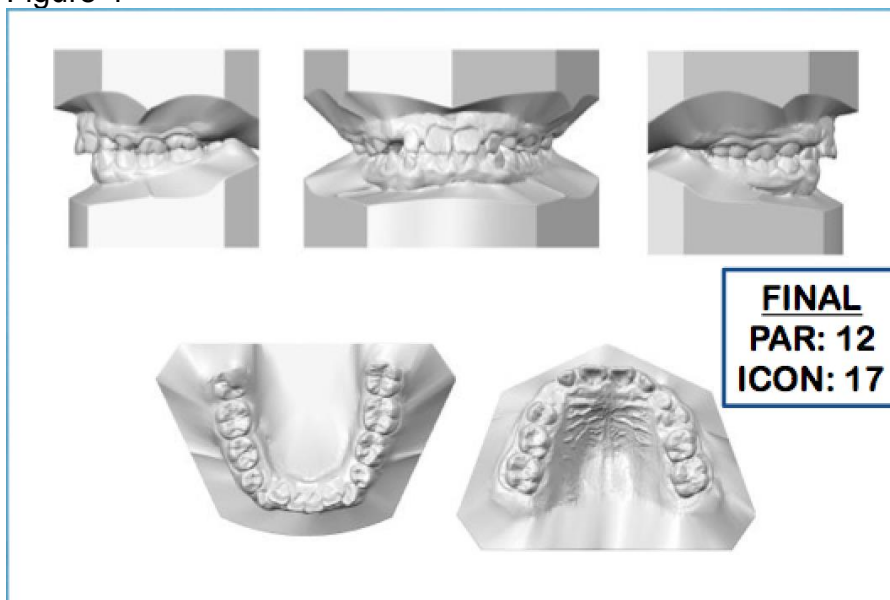
Final Models for Ideal Removable Treatment Patient #1

Figure 3



Initial Models for Ideal Removable Treatment Patient #2

Figure 4



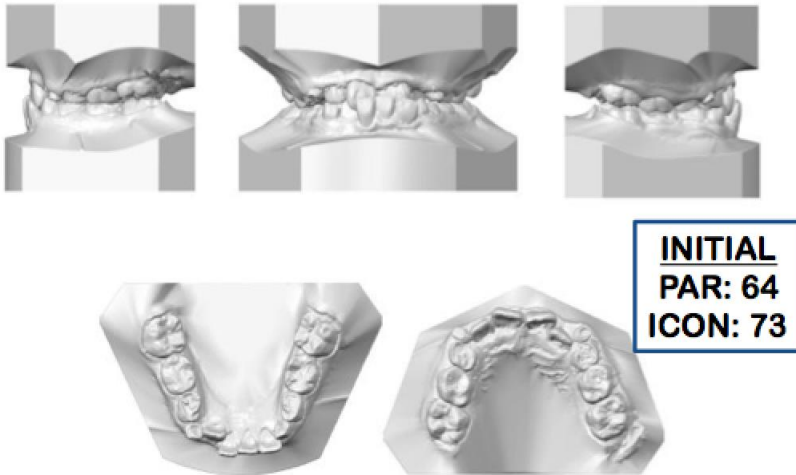
Final Models for Ideal Removable Treatment Patient #2

Figure 5



Initial Photos for Ideal Removable Treatment Patient #3

Figure 6



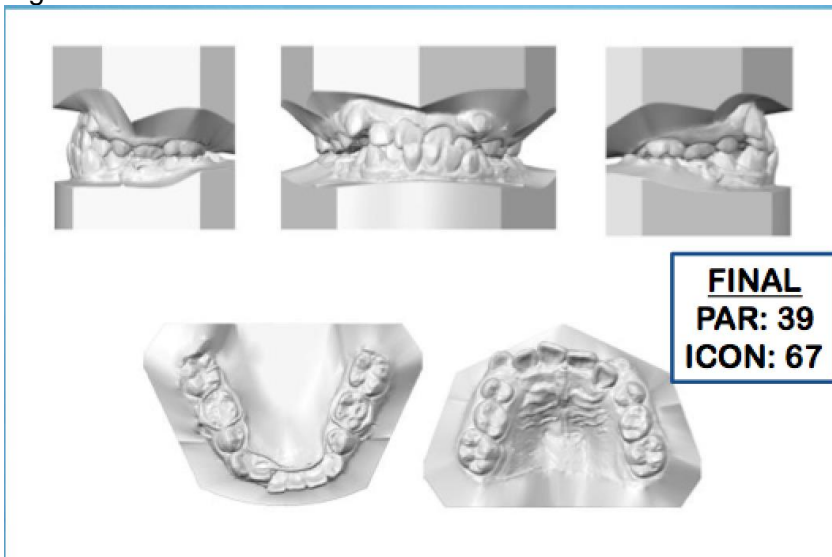
Initial Models for Difficult Removable Treatment Patient #4

Figure 7



Initial Photos for Difficult Removable Treatment Patient #4

Figure 8



Final Models for Difficult Removable Treatment Patient #4

**APPENDIX:**

**APPENDIX A: Demographic Questionnaire**

**Thank you for taking the time to fill out this short patient information survey. Your involvement in this study will greatly help support the need for government funded orthodontic treatment in California.**

*PATIENT* \_\_\_\_\_ *NAME*

*AGE* \_\_\_\_\_

*DOB* \_\_\_\_\_

*ETHNICITY* (Mark X where it applies)

Caucasian \_\_\_\_\_  
African American \_\_\_\_\_  
Asian \_\_\_\_\_  
Hispanic \_\_\_\_\_  
Pacific Islander \_\_\_\_\_  
Native American \_\_\_\_\_  
Other \_\_\_\_\_

*GENDER* (Mark X) MALE \_\_\_\_\_ FEMALE \_\_\_\_\_

*YOUR CURRENT ADDRESS*

\_\_\_\_\_  
\_\_\_\_\_

*INSURANCE*      yes      no  
IF YES, what type of insurance Medical/CCS      Private

*COMBINED HOUSEHOLD INCOME* (Mark X)

\$0-10,000 \_\_\_\_\_  
\$10,000-20,000 \_\_\_\_\_  
\$20,000-30,000 \_\_\_\_\_  
\$30,000-40,000 \_\_\_\_\_  
\$40,000-50,000 \_\_\_\_\_  
\$50,000-60,000 \_\_\_\_\_  
\$60,000-70,000 \_\_\_\_\_  
>\$70,000 \_\_\_\_\_

Name of your General Dentist

\_\_\_\_\_  
\_\_\_\_\_  
\_\_\_\_\_

## APPENDIX B: CPQ 8-10 year old

### Questionnaire on Teeth and Well Being

Today's Date: \_\_\_\_/\_\_\_\_/\_\_\_\_  
Day Month Year

1. Are you a boy or a girl

- ☐ Male
- ☐ Female

2. When were you born? \_\_\_\_/\_\_\_\_/\_\_\_\_ Age \_\_\_\_  
Day Month Year

3. When you think about your teeth or your mouth would you say they are:

- ☐ Very good
- ☐ Good
- ☐ Acceptable
- ☐ Poor

4. How much do your teeth or your mouth bother you on a daily basis?

- ☐ Not at all
- ☐ Just a little
- ☐ Somewhat
- ☐ A great deal

**Now a few questions about your teeth and your mouth**

5. How often had pain in your teeth or mouth during the last 4 weeks?
- ☐ Never
  - ☐ Once or twice
  - ☐ Occasionally
  - ☐ Often
  - ☐ Often and almost every day
6. How often during the last 4 weeks have you had ulcers in your mouth?
- ☐ Never
  - ☐ Once or twice
  - ☐ Occasionally
  - ☐ Often
  - ☐ Every day or almost every day
7. How often during the last 4 weeks have you had painful teeth when you drink cold drinks?
- ☐ Never
  - ☐ Once or twice
  - ☐ Occasionally
  - ☐ Often
  - ☐ Every day to almost every day
8. How often during the last 4 weeks has food got stuck between your teeth?
- ☐ Never
  - ☐ Once or twice
  - ☐ Occasionally
  - ☐ Often
  - ☐ Every day or almost every day
9. How often during the last 4 weeks have you had bad breath?
- ☐ Never
  - ☐ Once or twice
  - ☐ Occasionally
  - ☐ Often
  - ☐ Every day or almost every day



**10.** How often during the last 4 weeks did you need more time to eat your meals?

- † Never
- † Once or twice
- † Occasionally
- † Often
- † Every day or almost every day

**11.** How often during the last 4 weeks have had difficulty chew or bite off an apple, corn on the cob or meat?

- † Never
- † Once or twice
- † Occasionally
- † Often
- † Every day or almost every day

**12.** How often during the last 4 weeks have you not been able to eat things you like because of your teeth or mouth?

- † Never
- † Once or twice
- † Occasionally
- † Often
- † Every day or almost every day

**13.** How often during the last 4 weeks have you had difficulty in saying certain words because of your teeth and mouth?

- † Never
- † Once or twice
- † Occasionally
- † Often
- † Every day or almost every day

**14.** How often during the last 4 weeks have you had difficulty sleeping at night because of your teeth or mouth?

- † Never
- † Once or twice
- † Occasionally
- † Often
- † Every day or almost every day

### **A few questions about your feelings**

**15.** How often during the last 4 weeks have you been sad or irritated because of your teeth or mouth?

- ☐ Never
- ☐ Once or twice
- ☐ Occasionally
- ☐ Often
- ☐ Every day or almost every day

**16.** How often during the last 4 weeks have you felt disappointed or unhappy because of your teeth or mouth?

- ☐ Never
- ☐ Once or twice
- ☐ Occasionally
- ☐ Often
- ☐ Every day or almost every day

**17.** How often during the last 4 weeks have you been shy because of your teeth or mouth?

- ☐ Never
- ☐ Once or twice
- ☐ Occasionally
- ☐ Often
- ☐ Every day or almost every day

**18.** How often during the last 4 weeks have been concerned about what other people think of your teeth or mouth

- ☐ Never
- ☐ Once or twice
- ☐ Occasionally
- ☐ Often
- ☐ Every day or almost every day

**19.** How often during the last 4 weeks have you been concerned about looking just as good as other people?

- ☐ Never
- ☐ Once or twice
- ☐ Occasionally
- ☐ Often
- ☐ Every day or almost every day

**20.** How often during the last 4 weeks have you been absent from school because of your teeth or your mouth

- † Never
- † Once or twice
- † Occasionally
- † Often
- † Every day or almost every day

**21.** How often during the last 4 weeks have you had difficulty doing your homework because of your teeth or mouth?

- † Never
- † Once or twice
- † Occasionally
- † Often
- † Every day or almost every day

**22.** How often during the last 4 weeks have you had difficulty paying attention in school because of your teeth or mouth?

- † Never
- † Once or twice
- † Occasionally
- † Often
- † Every day or almost every day

**23.** How often during the last 4 weeks have you not wanted to speak or read aloud in class because of your teeth or mouth?

- † Never
- † Once or twice
- † Occasionally
- † Often
- † Every day or almost every day

## Questions about your relationship to other people

**24.** How often during the last 4 weeks have you avoided smiling or laughing when you were together with other children?

- ☐ Never
- ☐ Once or twice
- ☐ Occasionally
- ☐ Often
- ☐ Every day or almost every day

**25.** How often during the last 4 weeks have you not wanted to talk with other children because of your teeth or mouth?

- ☐ Never
- ☐ Once or twice
- ☐ Occasionally
- ☐ Often
- ☐ Every day or almost every day

**26.** How often during the last 4 weeks have you not felt like being with other children because of your teeth or mouth?

- ☐ Never
- ☐ Once or twice
- ☐ Occasionally
- ☐ Often
- ☐ Every day or almost every day

**27.** How often during the last 4 weeks have you stayed away from activities like sports or clubs because of your teeth or mouth?

- ☐ Never
- ☐ Once or twice
- ☐ Occasionally
- ☐ Often
- ☐ Every day or almost every day

**28.** How often during the last 4 weeks have other children teased you or called you names because of your teeth or mouth?

- ☐ Never
- ☐ Once or twice
- ☐ Occasionally
- ☐ Often
- ☐ Every day or almost every day

**29.** How often during the last 4 weeks have other children asked you questions about your teeth or mouth?

- ↑ Never
- ↑ Once or twice
- ↑ Occasionally
- ↑ Often
- ↑ Every day or almost every day

**Thank you for your help!**

## APPENDIX C: CHU9D

### Questionnaire on Well Being

#### Instructions

These questions ask about how you are **today**. For each question, read all the choices and decide which one is most like you **today**.

Then put a tick in the box next to it like this ☐. Only tick **one** box for each question.

#### Example

Today I feel quite upset so I will tick this box.

#### Upset

- I don't feel upset today
- I feel a little bit upset today
- I feel a bit upset today
- I feel quite upset today
- I feel very upset today

Now think about and answer the rest of the questions below

#### 1. WORRIED

- I don't feel worried today
- I feel a little bit worried today
- I feel a bite worried today
- I feel quite worried today
- I feel very worried today

#### 2. SAD

- I don't feel sad today
- I feel a little bit sad today
- I feel a bit sad today
- I feel quite sad today
- I feel very sad today

**3. PAIN**

- I don't have any pain today
- I have a little bit of pain today
- I have a bit of pain today
- I have quite a lot of pain today
- I have a lot of pain today

**4. TIRED**

- I don't feel tired today
- I feel a little bit tired today
- I feel a bit tired today
- I feel quite tired today
- I feel very tired today

**5. ANNOYED**

- I don't feel annoyed today
- I feel a little bit annoyed today
- I feel a bite annoyed today
- I feel quite annoyed today
- I feel very annoyed today

**6. SCHOOL WORK/ HOMEWORK (SUCH AS READING, WRITING, DOING LESSONS)**

- I have no problems with my schoolwork/homework today
- I have a few problems with my schoolwork/homework today
- I have some problems with my schoolwork/homework today
- I have many problems with my schoolwork/homework today
- I can't do my schoolwork/homework today

**7. SLEEP**

- Last night I had no problems sleeping
- Last night I had a few problems sleeping
- Last night I had some problems sleeping
- Last night I had many problems sleeping
- Last night I couldn't sleep at all

**8. DAILY ROUTINE (THINGS LIKE EATING, HAVING A BATH/SHOWER, GETTING DRESSED)**

- I have no problems with my daily routine
- I have a few problems with my daily routine
- I have some problems with my daily routine
- I have many problems with my daily routine
- I can't do my daily routine today

**9. ABLE TO JOIN IN ACTIVITIES (THINGS LIKE PLAYING OUT WITH YOUR FRIENDS, DOING SPORTS, JOINING IN THINGS)**

- I can join in with any activities today
- I can join in with most activities today
- I can join in with some activities today

- I can join in with a few activities today
- I can join in with no activities today

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## APPENDIX D: CPQ11-14

### Questionnaire on Teeth and Well Being

Today's Date: \_\_\_\_\_/\_\_\_\_\_/\_\_\_\_\_  
Day Month Year

1. Are you a boy or a girl

- a. ☐ Male
- b. ☐ Female

2. When were you born? \_\_\_\_\_/\_\_\_\_\_/\_\_\_\_\_ Age \_\_\_\_\_  
a. Day Month Year

3. What would you say about the health of your teeth, mouth, lips and jaws

- a. ☐ Excellent
- b. ☐ Very good
- c. ☐ Good
- d. ☐ Reasonable
- e. ☐ Poor

f. How much do your teeth, mouth, lips and jaws affect your life in general?

- g. ☐ Not at all
- h. ☐ Somewhat
- i. ☐ Some
- j. ☐ A lot
- k. ☐ A great deal

## **I. Questions relating to your mouth**

4. How often have you had pain in your teeth, mouth, lips or jaw during the last 3 months?
- a. ☐ Never
  - b. ☐ Once or twice
  - c. ☐ Occasionally
  - d. ☐ Often
  - e. ☐ Often and almost every day
5. How often do you have bleeding of your gums during the last 3 months?
- a. ☐ Never
  - b. ☐ Once or twice
  - c. ☐ Occasionally
  - d. ☐ Often
  - e. ☐ Often and almost every day
6. How often do you have ulcers in your mouth?
- a. ☐ Never
  - b. ☐ Once or twice
  - c. ☐ Occasionally
  - d. ☐ Often
  - e. ☐ Every day or almost every day
7. How often have you had bad breath during the last 3 months?
- a. ☐ Never
  - b. ☐ Once or twice
  - c. ☐ Occasionally
  - d. ☐ Often
  - e. ☐ Every day or almost every day
8. How often did food get stuck between your teeth during the last 3 months?
- a. ☐ Never
  - b. ☐ Once or twice
  - c. ☐ Occasionally
  - d. ☐ Often
  - e. ☐ Often and almost every day

9. How often did food get stuck in the roof of your mouth during the last 3 months?
- a. † Never
  - b. † Once or twice
  - c. † Occasionally
  - d. † Often
  - e. † Often and almost every day
10. How often during the last three months have you felt that you couldn't breathe through your mouth because of your teeth, lips or jaw?
- a. † Never
  - b. † Once or twice
  - c. † Occasionally
  - d. † Often
  - e. † Often and almost every day
11. How often during the last 3 months have you spent more time eating your meal than others because of your teeth, lips and jaw?
- a. † Never
  - b. † Once or twice
  - c. † Occasionally
  - d. † Often
  - e. † Often and almost every day
12. How often during the last 3 months have you had problems sleeping because of your teeth, lips or jaw?
- a. † Never
  - b. † Once or twice
  - c. † Occasionally
  - d. † Often
  - e. † Often and almost every day
13. How often during the last three months have you had difficulty biting or chewing foods such as apples, corn of the cob or meat because of your teeth, lips or jaw?
- a. † Never
  - b. † Once or twice
  - c. † Occasionally
  - d. † Often
  - e. † Often and almost every day
14. How often during the last 3 months have you had difficulty opening wide because of your teeth, lips or jaw?
- a. † Never
  - b. † Once or twice
  - c. † Occasionally
  - d. † Often
  - e. † Often and almost every day

15. How often during the last 3 months have you had difficulty pronouncing certain words because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Occasionally
- d. ☐ Often
- e. ☐ Often and almost every day

16. How often during the last 3 months has it been difficult to eat the food you really like?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Occasionally
- d. ☐ Often
- e. ☐ Often and almost every day

17. How often during the last 3 months has it been difficult to drink through a straw because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Occasionally
- d. ☐ Often
- e. ☐ Often and almost every day

18. How often during the last 3 months has it been difficult to drink/eat something cold or hot because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Occasionally
- d. ☐ Often
- e. ☐ Often and almost every day

### **Questions about feelings and emotions**

19. How often during the last 3 months have you felt irritable or disappointed because of your teeth, lips and jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Occasionally
- d. ☐ Often
- e. ☐ Often and almost every day

20. How often during the last 3 months have you felt insecure because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes

- d. † Often
- e. † Often and almost every day

21. How often during the last 3 months have you felt shy or embarrassed because of your teeth, lips and jaw?

- a. † Never
- b. † Once or twice
- c. † Sometimes
- d. † Often
- e. † Often and almost every day

22. How often during the last 3 months have you felt worried about what other people think about your teeth, lips or jaw?

- a. † Never
- b. † Once or twice
- c. † Sometimes
- d. † Often
- e. † Often and almost every day

23. How often during the last 3 months have you been worried about looking just as good as other people because of your teeth, lips or jaw?

- a. † Never
- b. † Once or twice
- c. † Sometimes
- d. † Often
- e. † Often and almost every day

24. How often during the last 3 months have you been annoyed (or irritated) because of your teeth, lips or jaw?

- a. † Never
- b. † Once or twice
- c. † Sometimes
- d. † Often
- e. † Often and almost every day

25. How often during the last 3 months have you felt nervous or afraid because of your teeth, lips and jaw?

- a. † Never
- b. † Once or twice
- c. † Sometimes
- d. † Often
- e. † Often and almost every day

26. How often during the last 3 months have you been worried that you are not as healthy as other people because of your teeth, lips or jaw?

- a. † Never
- b. † Once or twice
- c. † Sometimes
- d. † Often
- e. † Often and almost every day

27. How often during the last 3 months have you been worried about being different from other people because of your teeth, lips or jaw

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

**A few questions about your ability to work and function**

28. How often during the last 3 months have you been absent from school because of pain or because you had to go to the dentist because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

29. How often during the last 3 months have you had difficulty paying attention because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

30. How often during the last 3 months have you had difficulty doing your homework because of teeth lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

31. How often during the last 3 months have you not wanted to speak or reading aloud in class because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

### A few questions about your feelings

32. How often during the last 3 months have you avoided participating in activities like clubs, drama, music or school outings because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

33. How often during the last 3 months have you not wanted to talk to other children because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

34. How often during the last 3 months have you avoided smiling and laughing when you were together with other children because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

35. How often during the last 3 months have you had difficulty playing musical instruments like the flute, clarinet or trumpet because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

36. How often during the last 3 months have you not wanted to be with other children because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

37. How often during the last 3 months have you argued with other children or your family because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

38. How often during the last 3 months have you experienced that other children have teased you and called you names because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Sometimes
- d. ☐ Often
- e. ☐ Often and almost every day

39. How often during the last 3 months have you experienced that other children have made you feel as an outsider because of your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Occasionally
- d. ☐ Often
- e. ☐ Often and almost every day

40. How often during the last 3 months have you experienced that other children have asked you questions about your teeth, lips or jaw?

- a. ☐ Never
- b. ☐ Once or twice
- c. ☐ Occasionally
- d. ☐ Often
- e. ☐ Often and almost every day



**Appendix E: ICON Improvement Grade**

TABLE 5 *Pretreatment – 4 (post-treatment) ICON index score ranges, for ratings of treatment improvement*

Improvement grade	Score range
Greatly improved	$> -1$
Substantially improved	$-25$ to $-1$
Moderately improved	$-53$ to $-26$
Minimally improved	$-85$ to $-54$
Not improved or worse	$< -85$

## Appendix F: Decision Tree for Early Treatment Protocols

