Title

Assessment of the validity of the index of complexity, outcome and need (ICON) and the handicapping labio-lingual deviation index with California modification (HLD(CalMod))

Author
Cooke, Mary Concepta

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Assessment of the Validity of the Index of Complexity, Outcome and Need (ICON) and the Handicapping Labio-lingual Deviation Index with California Modification (HLD(CalMod))

by

Mary Concepta Cooke, DDS

THESIS

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DEDICATION

I would like to dedicate this thesis to my mother, Lilly Cooke. She did not get a chance to see me graduate, but she was with me each step of the way.

And to my friends and family: your utter confidence and belief in me was inspirational.

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ABSTRACT

PURPOSE: To determine the validity of the Index of Complexity, Outcome and Need (ICON) and the Handicapping Labio-lingual Deviation Index with California Modification (HLD(CalMod)) in identifying orthodontic treatment need and handicapping malocclusions respectively.

METHODS: 13 experienced orthodontists individually evaluated 153 sets of models and gave each a score on a 12 point scale. The models were also evaluated and scored by an ICON calibrated examiner and scored according the HLD(CalMod) Index Worksheet. The mean score of the panel on the need for treatment was used as the Gold Standard score for evaluating the validity of the indexes.

RESULTS: There was a moderately high correlation between the ICON and the Gold Standard scores. The published cut-off points for ICON did not reflect the Gold Standard cut-off points as determined by classification and regression tree modeling. The Gold Standard threshold for orthodontic treatment need was dramatically lower than the threshold developed by ICON authors. When the ICON cut-off point is modified, the sensitivity improved from 58.7% to 80.8% and the specificity stayed the same at 93.9%. There was a moderately high correlation between HLD(CalMod) and the Gold Standard scores. The policy dictated cut-off point for HLD(CalMod) did not reflect the Gold Standard cut-off point as determined by the classification and regression tree modeling. The Gold Standard threshold for handicapping malocclusions was dramatically lower than the threshold set by HLD(CalMod) Index policy makers. When the HLD(CalMod)

Index cut-off point was modified, the sensitivity improved from 25.9% to 55.6% and the specificity was reduced from 96.8% to 92.9%.

CONCLUSION: ICON would be a valid measure of orthodontic treatment need with a modified cut-off point. HLD(CalMod) index would not be a valid measure of handicapping malocclusion even if the cut-off point was modified due to the poor sensitivity of the index.

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Introduction

This study was designed to create a collection of models that were evaluated by a panel of orthodontic specialists to establish a gold standard. Secondly, this model collection was graded by a calibrated Index of Complexity, Outcome and Need (ICON) examiner. Lastly, the model collection was evaluated with the Handicapping Labio-lingual Deviation California Modification (HLD(CalMod)) index according to the instructions given on the Handicapping Labio-lingual Deviation (HLD) Index Worksheet.

Purpose

The purpose of my research is to determine the validity of the Index of Complexity, Outcome and Need and the Handicapping Labio-lingual Deviation California Modification index in identifying orthodontic treatment need and handicapping malocclusions respectively.

Specific Aims

The specific aims are to:

- determine if there is adequate agreement between an expert orthodontic panel and the Index of Complexity, Outcome and Need (ICON), in order to determine if the ICON can accurately distinguish between orthodontic treatment need and no treatment need.
- determine if there is an agreement between an expert orthodontic panel and the Handicapping Labio-Lingual Deviation Index California Modification (HLD(CalMod)), in order to determine if patients with medically necessary

handicapping malocclusions would be eligible through Medi-cal to receive orthodontic treatment.

Indications of Orthodontic Treatment Need

The justification for orthodontic treatment comes on many grounds including psychosocial implications, oral health, temporomandibular joint (TMJ) health and others. A review of the literature for different malocclusions shows the following issues.

Psychosocial

Facial aesthetics has been found to be a significant determinant of self and social perceptions and attributions.[1,2] Perceptions of facial aesthetics influence psychological development from early childhood to adulthood. The infant's visual preference for human faces has been confirmed in psychological studies.[3] This behavior is adaptive; recognition of familiar faces is critical for an infant's survival. By the age of 6 months, children can discriminate between familiar and unfamiliar faces.[4] By the age of 6 years, children have internalized cultural values of physical attractiveness. By age 8, their criteria for attractiveness are the same as those of adults.[5] A teacher's perceptions of a child's attractiveness can influence the teacher's expectations and evaluation of the child.[6] Children perceived as more attractive are not only more socially accepted by their peers, they are also believed to be more intelligent and to possess better social skills.[3,7] In addition, people perceived as attractive by their peers are considered more desirable as friends than are unattractive people.[3] Employees perceived as more attractive by their supervisors are given better job-performance ratings than less attractive employees.[8] Thus, individuals who are perceived by their parents, peers, and employers to be attractive are more likely to experience positive social interactions and evaluations. Studies of laypersons' responses to attractive and unattractive faces of strangers have shown that attractive persons are described as more competent in interpersonal relationships and friendlier than people with unattractive faces, even when the test subjects had no additional knowledge about the faces being examined.[9]

The appearance of the teeth and smile plays an important role in judgments of facial attractiveness.[10] This finding is consistent with the results of two previous national surveys that showed most Americans believe dental appearance is "very important" in social interactions, particularly in young people's selection of dating partners.[11,12] Children of normal dental appearance are judged to be better-looking, more desirable as friends, and more intelligent.[13] Children have reported that the appearance of their teeth is a common target of teasing.[14] In particular, malocclusions in the anterior region are the most conspicuous and, when present, are of greatest concern to the child.[15,16] Helm et al., have found that overjet, extreme deep bite, and crowding are associated with the most unfavorable self-perceptions of teeth.[15] Shaw[13,14] has found that an overjet of 7 mm or more, anterior crowding and deep bite are associated with a child's report of being teased. Overjet has also been found to be the most significant predictor of the decision to seek orthodontic correction, especially in children referred for treatment by their parents.[16]

Functional

McNamara[17] reviewed existing literature on occlusion, orthodontic treatment, and temporomandibular disorders (TMD), reporting an association between TMD and anterior open bite, overjet greater than 6 mm, centric relation-centric occlusion slides greater than 4mm, unilateral lingual crossbites, and five or more missing posterior teeth. It was found that those individuals with malocclusions had a wider range of lateral movement and they also complained of greater discomfort in the temporomandibular joint when compared to individuals with normal occlusion.[18]

Posterior crossbite

Tooth surface loss has been found to be correlated with posterior crossbites with a concomitant slide to maximal intercuspation.[19] The degree of dental attrition increases with the depth of the overbite.[19] Additionally, unilateral lingual crossbites have been associated with an increase in TMD symptoms.[17] Bernhardt et al.,[20] found an increased odds ratio of displaying occlusal wear in patients who had an unilateral buccolingual cusp-to-cusp relation.

Increased overjet

Numerous studies have noted negative social stereotyping attributed to individuals with larger overjets.[15,16,21,22] Increased overjet may contribute to traumatic injury. Factors that significantly increase susceptibility to traumatic dental injury were a class II molar relationship, an overjet exceeding 4 mm, a short upper lip, incompetent lips, and mouth breathing.[23]

Reverse overjet

Mohlin and Thilander[24] found that class III malocclusions were correlated to TMD symptoms in males.

Impacted teeth

Shafer et al.,[25] suggested the following sequelae for canine impaction: (a) labial or lingual malpositioning of the impacted tooth; (b) migration of the neighboring teeth and loss of arch length; (c) internal resorption; (d) dentigerous cyst formation; (e) external root resorption of the impacted tooth, as well as the neighboring teeth; (f) infection particularly with partial eruption; (g) referred pain and (h) combinations of the above sequelae. It is estimated that in 0.7% of children in the 10- to 13-year age group. Permanent incisors have resorbed because of the ectopic eruption of the maxillary canines.[26]

Anterior open bite

Anterior open bites are most often implicated in mis-articulations. Researchers have consistently noted the relationship between an anterior open bite and sibilant (hissing) disorders across languages.[27] In fact, if the anterior open bite occurred in a combination with a class II molar relationship, subjects were more likely to have more severe mis-articulations.[28]

Deep overbite

In a study by Bjornaas et al., [29] the overbite group had a significantly lower alveolar bone level than controls. The difference between the mean values was 0.7mm. It was also observed that the lower incisors had a significant loss of attachment expressed by lower bone level in both deep overbite and increased overjet malocclusions. The lower incisors showed more periodontal loss in the deep overbite cases. Local differences in occlusal and functional relations influence the reactions of the tooth supporting tissue. Deep impinging overbites can also lead to tissue destruction of the palate when the lower incisors occlude with the soft tissue.

Hypodontia

Orthodontics is indicated in patients with missing teeth. In order to restore the patient to normal occlusion, orthodontics is used to place the remaining teeth in an appropriate position to either substitute for the missing tooth or allow for a more ideal relationship for implants and/or restorations.

Crowding

A study by Staufer[30] found differences in disease severity could be attributed to the degree of anterior crowding. 60% of the patients with crowding > 5mm had shallow periodontal pockets. Differences in the degree of crowding were determined as related to tooth infractions, tooth fractures, gingival bleeding, shallow periodontal pockets, and gingival recessions > 3.5mm. The degree of crowding was found to correlate in the younger patients with tooth infractions and tooth fractures, and in the older patients with shallow periodontal pockets and gingival recessions > 3.5 mm.

Researchers have associated anterior crowding with gingival recession. The special morphological characteristics of crowded roots are important for the periodontal prognosis: narrow papillae with a reduced connective tissue matrix in the interdental gingival region and thin, poorly vascularized interradicular septa have a poor prognosis.[31] At some sites, the interradicular bone may be missing, leading to the merging of the periodontal ligaments of adjacent roots and poor esthetic papillas.[32]

Spacing

While increased dental spacing is associated with a lower incidence of caries,[33] the psychosocial implications are not clear and have not been studied.

Estimates of Orthodontic Treatment Need

In Danish school children aged 13-17, it was estimated that 45-61% had orthodontic treatment need.[34] The study included a panel of four orthodontists evaluating the records of 293 patients and all four had agreement in only 69% of the cases. When Holmes evaluated close to 1000 British 12-year old children, she found that 36% had moderate to very great orthodontic treatment need.[35] Although the estimates of orthodontic treatment need may vary from study to study, we can assume that at least 1/3 of adolescents have significant need for orthodontic treatment.

History of Indices

When a third party is responsible for paying for orthodontic treatment there are usually limited funds. Eligibility for treatment may only be as encompassing as funds will allow. Therefore, in certain instances, an index may be needed to identify those patients who are in most need of orthodontic treatment. This will ensure the patients with the most severe malocclusion are treated. There needs to be rationing care to the most deserving (needing) in a society with limited resources.

The problem with using a universal index lies in the fact that orthodontists can not agree among themselves on a definition of a malocclusion. To expect indices to accomplish what a panel of orthodontists would find difficult is not only impractical, but has been impossible.

A discussion of popular indices will follow. These indices have been developed to yield a tool that would help classify malocclusions in a way that would be useful for public health purposes. Jamison and McMillan,[36] along with Draker,[37] and Shaw[38] summarized it best when they listed requirements for such an index:

1. The index should be accurate, valid, reliable, and reproducible.
2. It should be easy to learn.
3. It should be objective in nature and yield quantitative data which may be analyzed by current statistical methods.
4. It must be designed to differentiate between handicapping and nonhandicapping malocclusions.
5. The examination required must be one that can be performed quickly, even by examiners, without special instruction in orthodontic diagnosis.
6. The index should lend itself to modification for the collection of epidemiological data regarding malocclusion other than prevalence, incidence, severity (e.g., frequency of malpositioning of individual teeth).
7. It should be usable on either patients or study models.
8. It should measure the degree of handicap, if any, and avoid classifying the term "malocclusion."

McGorray et al.,[39] further clarified the issues of indices by stating that there were five types of indices, with some indices covering more than one area:

1. Diagnostic clarification: Angle's classification
2. Epidemiological indices: The Occlusal Index
3. Treatment need indices: Handicapping Labio-lingual deviation (HLD), Treatment Priority Index (TPI), Index of Orthodontic Treatment Need (IOTN), Index of Complexity, Outcome and Need (ICON), Dental Aesthetic Index (DAI)
4. Treatment outcome: Peer Assessment Rating (PAR), ICON
5. Treatment complexity: ICON

Reliability of Clinical Measures of Malocclusion

When intra-examiner reliability of epidemiologic registrations of malocclusions was evaluated, a high level of consistency was obtained for most malocclusion traits.[40] Dental examiners can be trained to use the IOTN (described below) for epidemiological surveys by using a pre-calibration exercise; agreement on the dental health component improves after the index has been used for some months.[41]

Among seven orthodontists judging dental and facial aspects of malocclusion reliability of maxillary and mandibular anteroposterior positions, incisor exposure, interlabial gap, and maxillary crowding was poor. Acceptable reliability existed for mandibular anterior crowding, facial convexity, overbite, overjet, and molar classification. Excellent reliability existed only for evaluating the presence of a posterior crossbite.[42]

For five orthodontic residents rated casts on six dimensions, it was found that inter-rater reliability was highest for dental-facial attractiveness.[43] The data indicated that clinical evaluations of the severity of malocclusions are comparable objective measures in terms of inter-rater reliability. Clinical evaluations are also relatively stable over time.[43]

When developing the ICON, Richmond found that professional opinion on the need for treatment appeared divided in 24% (one quarter) of the cases, and varied as much as 48% among individual practitioners. He brings up the important point that professional disagreement raises questions about the justification for orthodontic treatment, as well as being a fertile ground for legal dispute.[44] Another study by Richmond found that a panel of dentists was divided as what constituted a need for orthodontic treatment on dental health grounds.[45] In the same study, orthodontists had a more uniform perception of orthodontic treatment need on dental health grounds than the general dentists. It is suggested this may be due to orthodontists' greater exposure to both individuals requiring orthodontic treatment and the literature concerned with the assessment of orthodontic treatment need.[45]

Handicapping labio-lingual deviation index [HLD(CalMod) and HLD(Md)]

The Handicapping Labio-Lingual Deviation index (HLD) was developed in 1960 to "obtain a method which will complement and perhaps substitute for clinical judgment which, although useful to a degree, is vulnerable to poor agreement because it is entirely subjective."[37] There are two major modifications: the HLD(CalMod) used in California and the HLD(Md) used in Maryland. The HLD(CalMod) was found to be a valid and reliable instrument with which to determine treatment need, and its overall accuracy to distinguish between patients for which treatment is indicated, from those for whom it is not, is very high.[46] The use of the HLD(CalMOD) directs more public funding toward patients with severe class II malocclusions than does the HLD(Md) index.[47] More than a quarter of the approvals came from the exception "overjet greater than 9 mm".[48] The addition of variables present in the HLD(CalMOD) index accounts for the increase in the number of patients included in the orthodonticaly handicapped group.[47] Of the patients who were considered orthodonticaly handicapped by the HLD(CalMOD) index, 70% possessed an automatically qualifying trait.[47] Another study completed by Parker[48] found that only 44% of the cases submitted to the state were approved as one of the exceptions in the index. Among the patients with no qualifying exception, the greatest contributing factor to a score of 15 or more points was crowding of anterior teeth in the group, approved by the HLD(Md) index., while overjet was the greatest contributing factor in the group approved by the HLD(CalMOD) index.[47]

Dental Aesthetic Index (DAI)

The Dental Aesthetic Index (DAI) was described in a monograph by Cons, Jenny and Kohout.[21] It has both a clinical component and an esthetic component. The scores from both parts are added together to a single score. The esthetic portion is based on public perceptions of the dental aesthetics of 200 photographs of occlusal configurations.[49] DAI scores can be rank ordered on a continuous scale, and can differentiate cases within severity levels.[49] The DAI scores are significantly associated with perception of need for treatment by students and parents.[50,51] Scores are also good predictors of the receipt of future fixed-orthodontic treatment[52]

The DAI was found to be a valid and reliable instrument with which to determine treatment need, and its overall accuracy to distinguish patients for which treatment is indicated from those for whom it is not, is very high.[46] Freer and Freer[53] found that the DAI under-estimated treatment need in cases with displaced canine teeth, incisor crowding or rotations, and increased overbite. It also over-estimated treatment need in cases with increased overjet in otherwise well-aligned arches.

Index of Orthodontic Treatment Need (IOTN)

The Index of Orthodontic Treatment Need (IOTN) ranks malocclusion in terms of the significance of various occlusal traits for an individual's dental health and for perceived esthetic impairment.[39] IOTN was found to be a valid and reliable instrument with which to determine treatment need, and its overall accuracy to distinguish patients who deserve treatment is very high.[46] With a 95% confidence limit, weighted kappa values were IOTN DHC of 0.93 (lower-upper confidence boundary, 0.88-0.98) and IOTN DAC 0.93 (lower-upper confidence boundary, 0.89-0.97). Holmes[35] found that when IOTN was used in her study to evaluate over a thousand subjects, she concluded that IOTN is quick and simple to use, and demonstrated very good levels of intra-examiner agreement. When a group of dentists were given an IOTN learning package, they made fewer errors when assessing aesthetic need, and fewer errors when assessing dental health need.[54]

The Dental Aesthetic Component (DAC) portion of the IOTN was found to overestimate treatment need in cases with increased overjet and contact point displacements greater than 2 mm.[53] The DAC portion under-estimated treatment need in cases with excessive overjet and buccally-displaced canines, and over-estimated treatment need in cases with spaced-arches and deep overbite.[53]

Interestingly, when IOTN was applied clinically to a group of patients, and then later to photos and models taken at the initial visit, there was substantial agreement between the Dental Health Component (DHC) and Aesthetic Component (DAC) gradings recorded for a group of patients from their study casts, and when compared directly to the clinical records. Agreement between DAC scores obtained from photographs, and clinical and study cast scores, was much lower. The DA Component of IOTN can be applied with confidence, both clinically and to study casts, but this would not appear to apply to photographic records.[55]

When evaluating the same occlusion over an 8-year period, IOTN was found to be a reliable index over time when taking into account occlusal changes that are occurring during the 11 to 19-year age range. The study by Cooper et al.,[56] provides some reassurance to clinicians that an IOTN grading at age 11 years is unlikely to change by the time the patient is 19 years old. Additionally, when the IOTN was used to assess the need for orthodontic treatment before and after treatment on over a thousand cases, it was found that while 80% needed treatment on dental health grounds, over 1/3 still required treatment after appliance therapy and another ¼ presented with a "borderline need."[57] Ironically, cases that started with little need were more likely to become worse off.[57]

A limitation of the IOTN in both its dental health and esthetic components is that it uses only three grades, "no need", "borderline need," and "definite need." A scale with only three grades lacks the ability to rank order cases with greater or lesser need for treatment within grades.[49] DAI and IOTN failed to rank the same children similarly when both were applied to the same sample of 10 year old school children.[58]

Peer Assessment Rating (PAR)

The Peer Assessment Rating assesses treatment difficulty and malocclusion severity.[39] It was found that there was a close association between orthodontists' perception of severity of dental malocclusion and perceived difficulty of treatment, and it is felt that they may in fact not be entirely separate variables.[59] As a result, it is likely that any measure of malocclusion severity will be essentially evaluating the same features as a measure of treatment difficulty. It may be possible to derive a set of weightings of PAR index and to calculate scores that would represent groupings of malocclusions severity and treatment difficulty, according to the perception of a panel of orthodontists. The PAR index may be considered to represent a good approximation of dentoocclusal change, in studies investigating the effectiveness of orthodontic treatment that are based in the United States.[59] McGorray et al., [39] found that the PAR (American validated version) was highly correlated with the orthodontists' subjective assessment of treatment need.

When United States (US) weightings of the PAR index are used, both the US PAR and UK PAR scores were excellent predictors of need for orthodontic treatment as determined by a panel of orthodontists.[60] The authors felt that an occlusal index used to measure deviation from normal or ideal occlusion might perform as well as indices of treatment need in predicting orthodontists' evaluation of treatment need.[60]

Index of Complexity, Outcome and Need (ICON)

The Index of Complexity, Outcome and Need was the first index that was specifically developed to enable assessment of treatment need and outcome using one set of occlusal traits.[61] Professional opinion was collected from over 90 orthodontists at centers located in nine different countries. Stepwise logistic regression was used to identify how the traits studied contributed to the decision for treatment. The authors developed an equation that predicts 85.3% of the decisions correctly.[44] Then, by using a simplified model containing only the five most predictive variables of esthetics, left and right buccal segment sagittal relationship, the degree of upper crowding, anterior overbite and crossbite, the authors obtained an equation that correctly predicts 84.4% of decisions, with specificity of 89.1% and sensitivity of 82.8%.[44] Later studies found the accuracy of the index to reflect professional opinion for a diverse sample of cases and was estimated at 84% for decisions of treatment need, and 68% for treatment outcomes.[61] The index heavily weights aesthetics.[61] Firestone et al.,[62] found that there was an agreement between an expert panel and the ICON in 155 of 170 models evaluated. These results support the use of ICON as a validated index of orthodontic treatment need. Fox et al.,[63] felt that ICON reflects UK opinion, and found evidence that the ICON may effectively replace PAR and IOTN as a means of determining need and outcome.

Not only does ICON appear to be able to determine need and outcome, but it also correlated with patients' opinions of aesthetics, function, speech, and treatment need. The strength of association, however, was low.[64] It can be concluded that the ICON alone is not necessarily a suitable predictor for appearances, function, speech or treatment need for those individuals attending general dental practice for routine dental care.[64] In combination with a simple question to assess the patients desire for treatment, the shared decision for any particular individual to enter the treatment process can be determined.[64] ICON scores derived from digital models are not valid measures of malocclusion.[65]

Indices improving identification of orthodontic treatment need

When a group of dental students were trained to use the IOTN, they had significantly higher agreement with the expert panel after IOTN training than did the group of dental students which did not get IOTN training.[66] When a group of dentists were trained with a modified IOTN, they were able to achieve either good or excellent agreement leading the authors to propose that the Modified IOTN appears to overcome the training and reliability problems that often accompany the use of orthodontic indices by non-specialists in oral health surveys.[67]

Methods

This study was approved by the University of California San Francisco Committee on Human Research – the Institutional Review Board (IRB) (CHR# H2582-24865-01).

There are six parts to the methods:

1. Creating a collection of 153 sets of orthodontic models
2. Evaluating each model with the Index of Complexity, Outcome and Need (ICON)
3. Evaluating each model with the Handicapping Labio-lingual Deviation California Modification (HLD(CalMod)) Index
4. Evaluating each model by a panel of orthodontic specialists
5. Developing a Gold Standard from the panel for each model

6. Determining if ICON is a valid measure of need for orthodontic treatment
7. Determining if HLD (CalMod) identifies those patients with medically necessary handicapping malocclusions

Establishing a collection of models

One hundred and fifty three sets of models were randomly chosen from the UCSF Division of Orthodontics clinic. The models represented a spectrum of malocclusions and included pretreatment models and posttreatment models. Models were not included if any appliances were visible. Models were trimmed to centric occlusion (CO). All models were evaluated for bubbles or imperfections that could influence ICON grading or interfere with evaluation of the malocclusion. All problem casts were discarded and replaced. All identifiable numbers and codes were removed. Each model was evaluated, and any information that could not be determined from the models alone was listed on the "information sheet" that was kept with each model. This sheet included information such as impacted teeth, missing teeth, and CR-CO shifts. The models were then randomly assigned a number from 1001 to 1153 using randomizer.org, a random number generator. The models were displayed in numbered order on a counter top in a large room.

Evaluating each model with the ICON

The models were evaluated by one calibrated ICON examiner (M.C.C.). The calibration was done at a two day on site course. During this course, instruction was given on how to evaluate the models with the ICON and then each person did a measurement exercise. At the end of the day a calibration exam was conducted.

Each model was evaluated and scored according to the ICON index instructions. At a session over four months later, a subset of 40 models were chosen at random using randomizer.org and placed in the order randomizer.org returned them. Once again, evaluated by the calibrated examiner and scored according to the ICON index instructions.

Evaluating each model with HLD(CalMod) Index

Each model was evaluated and scored with the instructions given by Medi-cal for the HLD(CalMod) index. Each model was examined to determine if it possessed one or more automatically qualifying exception trait. In addition, each model was evaluated by the scoring protocol. even if they had an automatically qualifying exception. Some assumptions had to be made since photos and radiographs were not available. If there was an overjet of >9 mm, lip incompetence was assumed. If there was a negative overjet of >3.5 mm masticating difficulty was assumed. Therefore, when an overjet of > 9 mm or a negative overjet of > 3.5 mm existed. the model was marked as having an automatically qualifying exception.

In a somewhat unclear section of the Medi-cal statues. instructions indicate: "Only teeth which have erupted and are visible on the study models should be considered. measured, counted, and recorded" in §531-11(c)(2). Later. in §531-11(c)(6) it states the following about ectopic teeth:

a. Examples of ectopic eruption (and ectopic development) of teeth include: 1) when a portion of the distal root of the primary second molar is resorbed during the eruption of the first molar; (2) transposed teeth; (3)

teeth in the maxillary sinus; (4) teeth in the ascending ramus of the mandible; and (5) other situations where teeth have developed in locations rather than the dental arches.

b. In all other situations, teeth deemed to be ectopic must be more than 50 percent blocked out and clearly out of the dental arch.

c. In cases of mutually blocked-out teeth, only one will be counted.

Under Section "a" above, we would not be able to count 1, 3, 4, 5 from Section a because most of the time these teeth would not be erupted nor visible on the cast, which is a requirement quoted above from §531-11(c)(2). Therefore, we were only able to count those teeth that were transposed as ectopic, those that are >50% blocked-out and out of the dental arch, and those with obvious errors in eruption. We could not count, and did not count, teeth that were 100% impacted by soft tissue or bone.

If a patient had both an overjet and a negative overjet, both were counted.

At a session over one month later, a subset of 40 casts was chosen at random using randomizer.com and placed in the order randomizer.org returned them. Once again they were evaluated with the HLD(CalMod) index, and scores were recorded.

Panel of orthodontic specialists evaluate each model

Originally, fifteen orthodontists from the San Francisco Bay area were recruited to participate in the study (Table 1). One subject never began the study and a second completed the evaluation on only 23 models and was not included in the study results. The thirteen that were included in the study answered a questionnaire (APPENDIX A) and signed a consent form (APPENDIX B) approved by the IRB. Inclusion criteria required that each orthodontist had least 5 years orthodontic experience and were working at least ½ time. All participants had to be members of the American Association of Orthodontists (AAO). Any orthodontist who indicated experience with any orthodontic indices with the exception of the California Medi-cal/California Children Services (CCS) index, were excluded from the study.

Table 1: Orthodontist Subject Characteristics

Number of Participants	13		
Mean age	50	*Range*	*35 - 70*
Average Years Certified	20.1	*Range*	*6 - 41*
Number of different programs	6		
Private Practice	8		
Group Practice	2		
University Practice	3		
Male	10		
Female	3		

The orthodontic professionals had one on-site session. For this session, the casts were displayed in numerical order on countertops along the perimeter of a large room. The raters were asked to start at staggered points throughout the sample, and were instructed to work at their own pace with no time limit. At the beginning of the session, the following verbal and written instructions were given to the orthodontists:

> *You are the orthodontic consultant for a private corporation for which a limited fund has been established to provide orthodontic treatment for personnel. You are to evaluate these study casts of personnel and answer the following question: In your opinion, to what extent does this occlusion need orthodontic treatment? Please circle the corresponding number: (range 1-12).*

The orthodontists scored the 153 pairs of casts and record the needed for treatment of each as a score of 1 – 12 on an adjectival scale where:

1-3 =	No treatment needed
4-6 =	Treatment optional or elective
7-9 =	Treatment advisable
10-12 =	Treatment essential

All models with a score of "7" or above were considered to be in the treatment category, and all models below this point were considered to be in the no-treatment category.

After they circled the appropriate number, they were asked,

What traits contributed to the decision for treatment (check all that apply):

	Maxillary:	**Mandibular:**
☐ Overbite/openbite	☐ Crowding	☐ Crowding
☐ Overjet	☐ Incisor alignment	☐ Incisor alignment
☐ Reverse overjet	☐ Incisor inclination	☐ Incisor inclination
☐ Impacted teeth	☐ Buccal segment alignment	☐ Buccal segment alignment
☐ Left & Right sagittal		
☐ Crossbite		
☐ Esthetics		

The orthodontic raters were able to score two models per evaluation sheet(APPENDIX C).

Developing Gold standard

The "Gold Standard" score (1-12) was determined to be the average of the scores given by the orthodontist panel. Score breakdown were as follows:

1.0 – 3.5	No Treatment Needed
>3.5 – 6.5	Treatment Optional
>6.5 – 9.5	Treatment Advisable
>9.5 – 12	Treatment Essential

This differed from the orthodontist evaluation sheet because the gold standard score was an average of approximately 13 scores rounded to the closest tenth. This required cut-off points that were distinguishable to the closest tenth. The cut-off between categories was determined by choosing a number that split the difference of the highest number of the first category and the lowest number of the next category.

Validity of ICON in identifying orthodontic treatment need

The original ICON developers established a cut-off value for treatment need of "43" to determine whether a patient should receive treatment. Those casts that scored below this threshold were considered not to have treatment need, and those casts above this threshold had orthodontic treatment need. Similarly, the Gold Standard threshold was determined to be 6.5. Above this threshold score of 6.5, was considered a need for orthodontic treatment and a score below this threshold indicated that treatment was optional. Validity of ICON was evaluated both as to the threshold for treatment, and the correlation between the ICON scores and the Gold Standard scores.

Validity off HLD(CalMod) in identifying patients with handicapping malocclusions

The California Medi-cal system has determined that patients with a score of 26 or above using the HLD(CalMod) and those patients that have an automatically qualifying exception would be eligible for orthodontic treatment. It was determined that a score of 26 or above indicated a handicapping malocclusion with medical justification for orthodontic treatment. It was determined in this study that any models that received a gold standard score of >9.5 had a medically necessary reason for orthodontic treatment. This would correspond with the "Treatment Essential" part of the scale. Validity was evaluated both on the cut-off points and the correlation between the HLD(CalMod) scores and the Gold Standard scores.

Evaluation of Occlusal Characteristics Leading to treatment need

A system was developed to evaluate the occlusal characteristics marked by the orthodontists as those that lead to the decision that a cast had need for orthodontic treatment. A "0" was recorded for those characteristics not marked for a particular cast and a "1" was recorded for those characteristics marked as leading to decision that a cast had need for orthodontic treatment.

Results

ICON Evaluation

Intra-rater reliability for ICON was evaluated using the Lin's concordance correlation which assesses equivalence of 2 measurements (exactly the same values) not just association such as Pearson's correlation coefficient (low scores at one time tend to be low at the second time and high scores at one time tend to be high at the second). Results showed high levels of intraexaminer reliability, with a Lin's concordance correlation of 0.909 (Figure 1). The red line is the 45 degree reference line of equivalence.

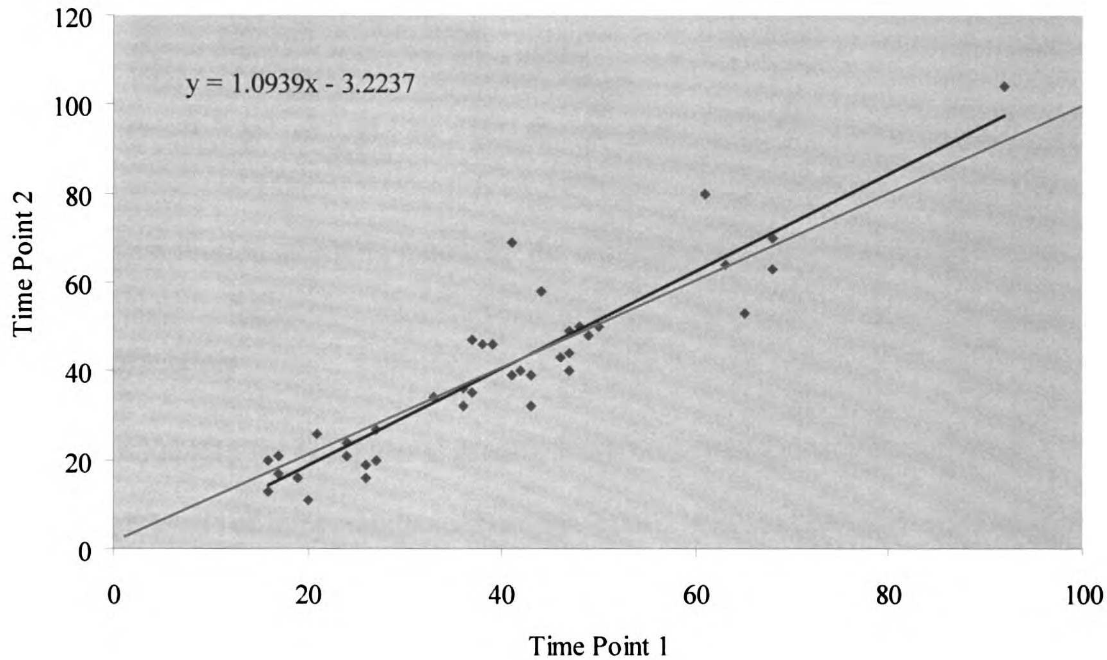

Figure 1. Intra-rater reliability of ICON

The distribution of ICON scores for the 153 sets of models can be seen in Figure 2. The scores appear to be normally distributed, but with a slight positive (right) skew.

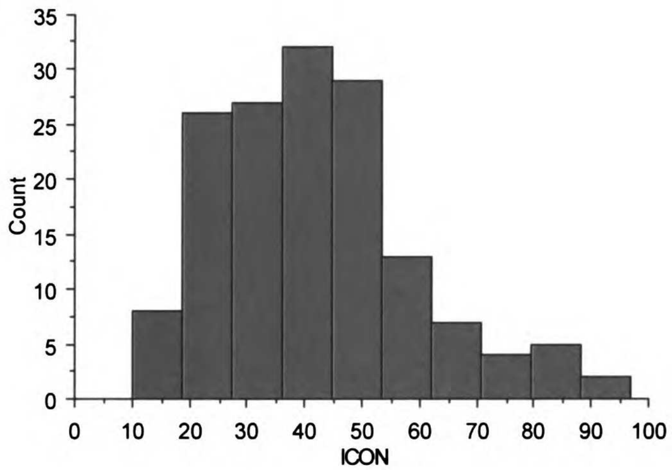

Figure 2: Distribution of ICON scores for the collection of 153 sets of models

HLD Evaluation

Intra-rater reliability for HLD was evaluated Lin's concordance correlation, which showed high levels of intraexaminer reliability, with a Lin's concordance correlation of 0.894 (Figure 3). The red line is the 45 degree reference line of equivalence.

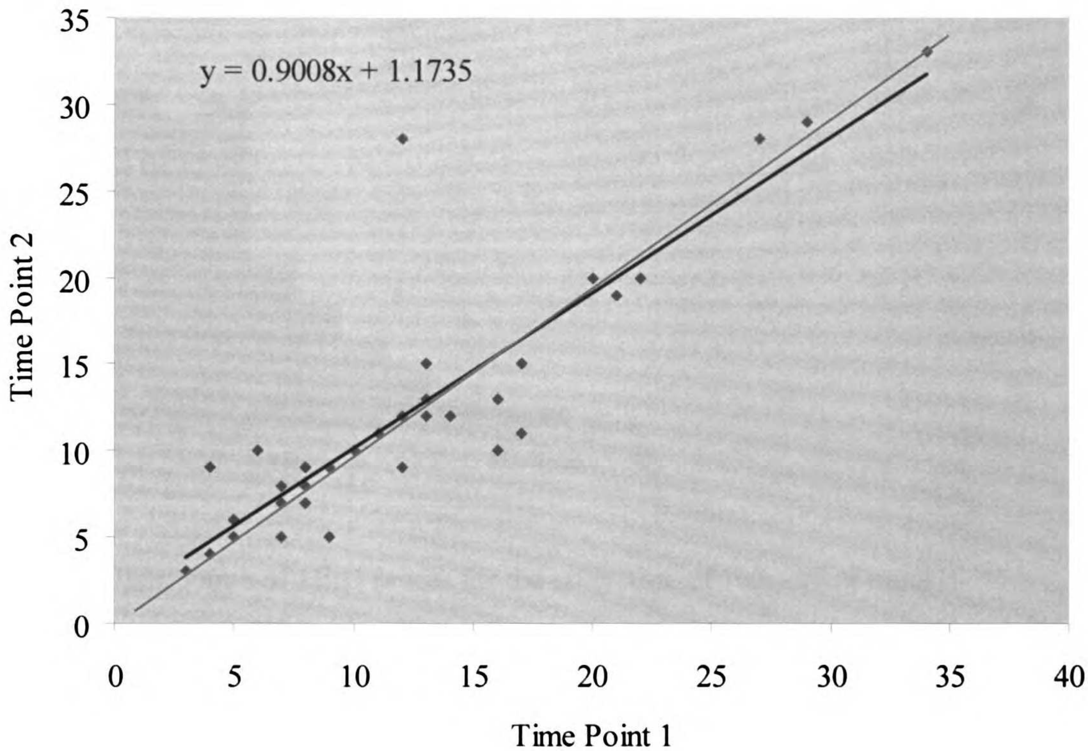

Figure 3. Intra-rater reliability of HLD(CalMod). The scores from time point one versus the scores from time point two, completed 4 months later.

The distribution of scores for the 153 sets of models for HLD can be seen in Figure 4.

The scores are not normally distributed, and tend to be positively (right) skewed.

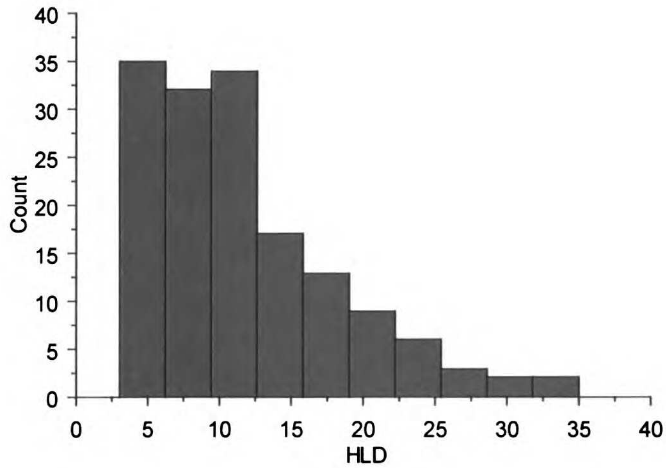

Figure 4: Distribution of HLD scores for the collection of 153 sets of models

Orthodontic Specialist Evaluation

Interrater reliability was evaluated with analysis of variance and Scheffe's multiple comparison test (Appendix G). Rater 4 was found to be significantly different from every other rater except for Rater 5. Rater 5 was significantly different from five of the other 12 raters. Rater 9 was significantly different from 3 other raters. All other raters had a maximum of 2 significantly different findings.

The distribution of model scores given by each rater is shown in Figure 5.

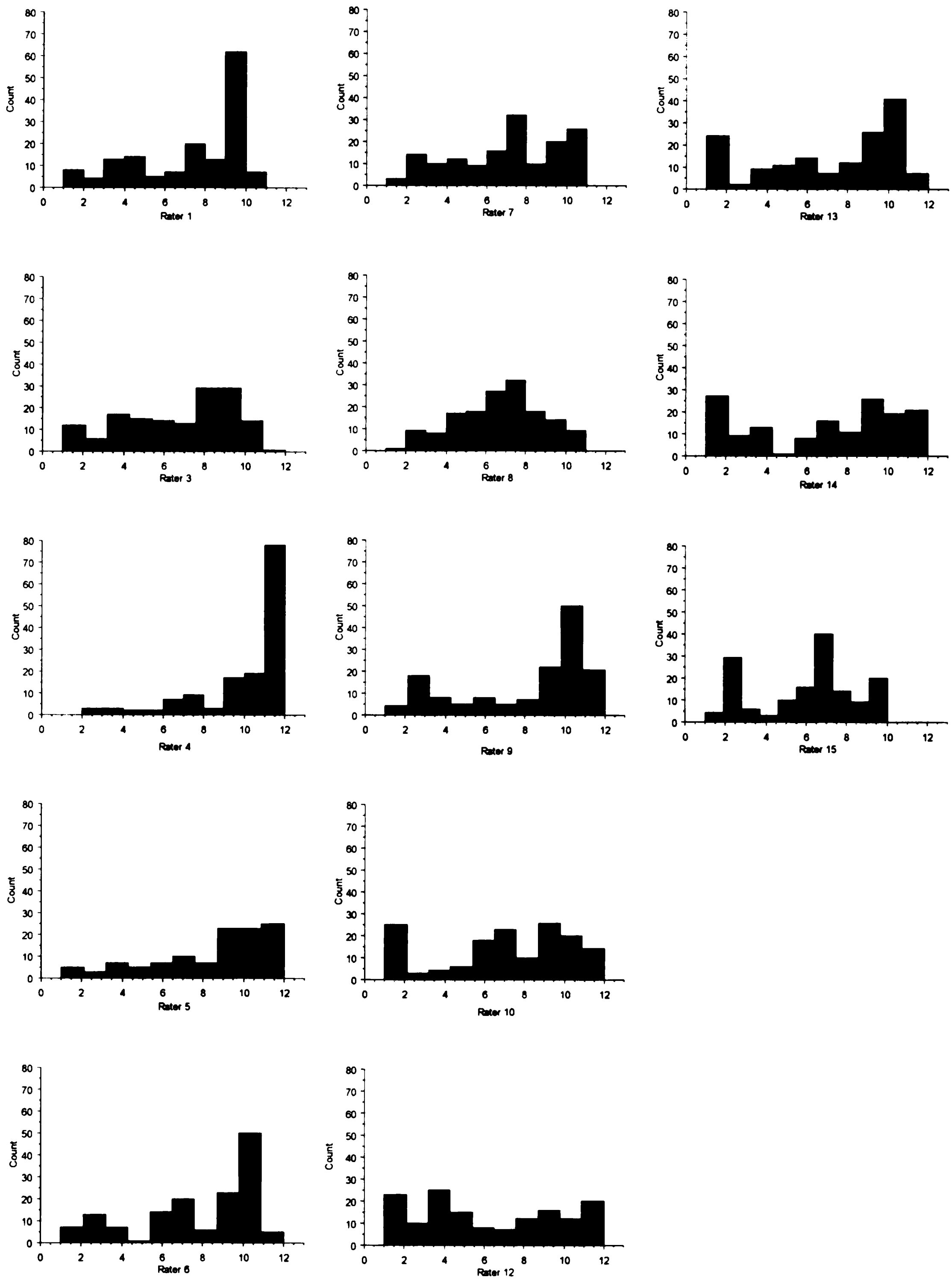

Figure 5: Distribution of model scores for each orthodontic rater

The average score for each rater is shown in Table 2.

Table 2: Descriptive statistics of orthodontic rater scores

	Mean	*Std. Dev.*	*Std. Error*	*Count*	*Minimum*	*Maximum*	*# Missing*
Rater 1	6.9	2.66	0.22	153	1	11	0
Rater 3	6.6	2.58	0.21	150	1	12	3
Rater 4	10.0	2.56	0.21	143	2	12	10
Rater 5	8.3	2.73	0.26	115	1	12	38
Rater 6	7.7	2.70	0.22	146	1	12	7
Rater 7	6.6	2.68	0.22	152	1	11	1
Rater 8	6.2	2.17	0.18	153	1	11	0
Rater 9	8.1	2.96	0.24	148	1	12	5
Rater 10	6.9	3.20	0.26	149	1	12	4
Rater 12	6.3	3.33	0.27	148	1	12	5
Rater 13	7.0	3.28	0.27	153	1	12	0
Rater 14	6.9	3.53	0.29	151	1	12	2
Rater 15	6.0	2.75	0.22	151	1	10	2

Figure 6 shows there is no relationship between rater's age and the mean model score.

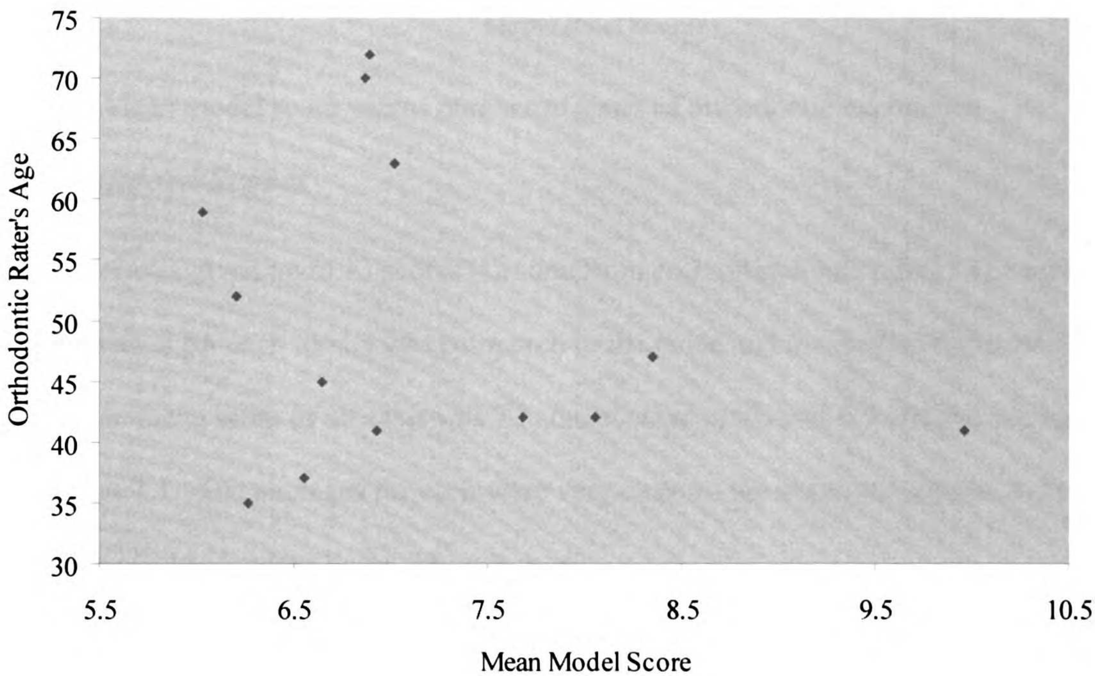

Figure 6. Mean model score versus orthodontic rater's age

Figure 7 shows there is no relationship between rater's orthodontic experience and mean model score.

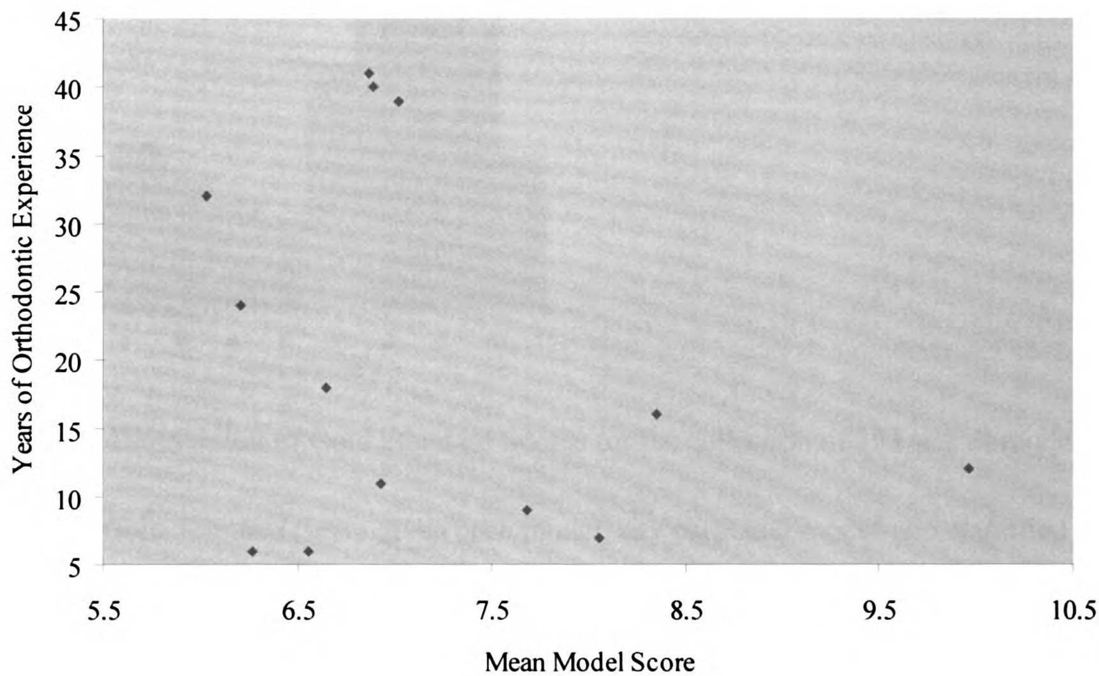

Figure 7. Mean model score versus number of years of orthodontic experience

Gold Standard Scores

Each model was given up to 13 scores (i.e. one from each orthodontic rater). The mean of the 13 scores for each model was compared to the mode and the median (Appendix F). The average mean score of all casts was 7.2, the average mode was 6.9 and the average median was 7.1. The averages for each were very close so the mean was chosen to be used for the Gold Standard Score for each model.

The distribution of Gold Standard Scores is shown in Figure 8. The distribution appears to be bimodal, with a negative (left) skew.

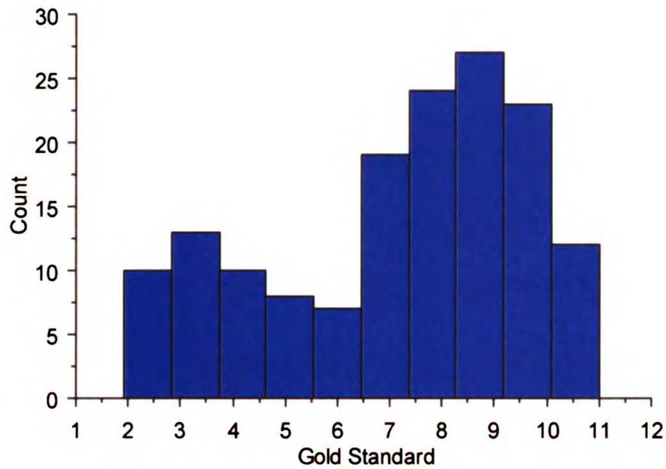

Figure 8: Distribution of Gold Standard Scores for the collection of 153 sets of models

From the Gold Standard Score given each model, any particular model was classified into one of four categories: No Treatment Needed, Treatment Optional, Treatment Advisable and Treatment Essential. The number of models that fell into the four different orthodontic need categories can be seen in Table 3.

Table 3: Distribution of Cases within the 4 Categories

Category	*Gold Standard Range*	*No.*
No Treatment Needed	0 – 3.5	21
Treatment Optional	>3.5 – 6.5	28
Treatment Advisable	>6.5 – 9.5	77
Treatment Essential	>9.5	27

Validity of ICON as index of orthodontic treatment need

The Spearman rank correlation was used to evaluate the correlation between ICON and the Gold Standard. The Spearman rank correlation is a non-parametric measure of correlation. It assesses how well an arbitrary monotonic function could describe the relationship between two variables, without making any assumptions about the frequency distribution of the variable. The Spearman correlation coefficient was 0.754, which demonstrates a moderately high correlation between the ICON score and Gold Standard score ($p<0.01$).

Table 4 shows the sensitivity and specificity of ICON for orthodontic treatment need. ICON has high specificity but low sensitivity. Sensitivity refers to the proportion of people with disease who have a positive test result (i.e. true positive rate). Specificity refers to the proportion of people without disease who have a negative test result (i.e. true negative rate). When an index has a high sensitivity, a negative result rules-out the diagnosis. When an index has a high specificity, a positive result rules-in the diagnosis. Since ICON has a low sensitivity, an ICON score below the cut off of 43 does not rule out the possibility that the model indicates a patient with orthodontic treatment need, but a score of 43 or higher does strongly indicate a patient with orthodontic treatment need. This is also seen by the large number (43) of false negatives.

The positive predictive value of a test is the probability that the patient has the condition being studied when the test for the condition is positive. For this sample, the positive predictive value for ICON is 95.3%, meaning that 93.5% of the patients that score above 43 actually have orthodontic treatment need. Conversely, the negative predictive value is the probability that the patient does not have the condition being studied when the test for the condition is negative. The negative predictive value for ICON is 51.7%, meaning that about half of the models that score a 43 or below do not have the disease. This is a somewhat low value. However, predictive values are influenced by the prevalence, unlike sensitivity and specificity.

The likelihood ratio incorporates both the sensitivity and specificity of the test and provides a direct estimate of how much a test result will change the odds of having a disease. The likelihood ratio for a positive result (+LR) tells how much the odds of the condition increase when a test is positive. The likelihood ratio for a negative result (-LR) tells you how much the odds of the condition decrease when a test is negative.

Table 4: Sensitivity and Specificity of ICON with Conventional Cut-off score of 43

		Gold Standard	
		Orthodontic Treatment Need	*No Orthodontic Treatment Need*
ICON	*Orthodontic Treatment Need*	61	3
	No Orthodontic Treatment Need	43	46
		Sensitivity	58.7%
		Specificity	93.9%
		Prevalence	68.0%
		(+)Predictive Value	95.3%
		(-) Predictive Value	51.7%
		(+) Likelihood Ratio	9.58
		(-) Likelihood Ratio	0.440

Figure 9 shows the quadratic relationship between the Gold Standard and ICON since the relationship between the Gold Standard and the square root of ICON is linear.

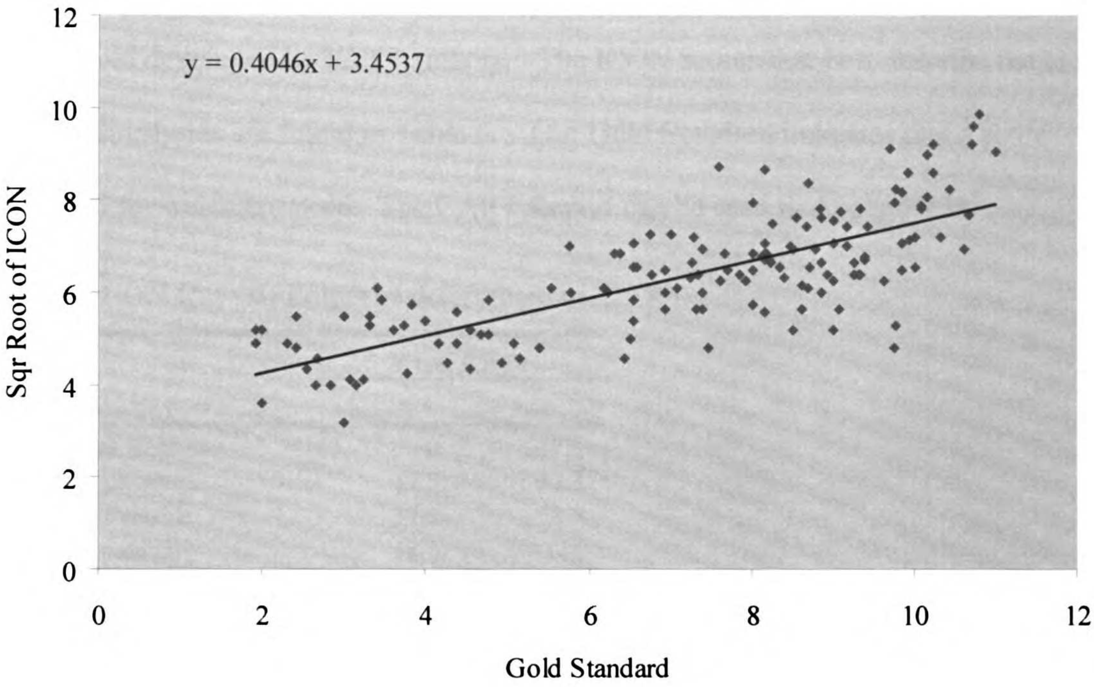

Figure 9: Gold standard score versus square root of the ICON score

The classification and Regression Tree (CART) modeling (Salford Systems, Inc) was used to evaluate the cut-off points of orthodontic treatment need.[68,69] CART iteratively evaluates the predictor to determine the optimal cut-point. Since that is highly dependant, 10-fold cross-validation was used to make the results robust and avoid over-fitting.[70] Each model was given a score of 1 through 4 based on the Gold Standard Score. If the model had a Gold Standard Score of 0 to 3.5, indicating No Treatment Need, then it would be assigned a score of 1. If the model had a Gold Standard Score of $\leq$6.5 but more than 3.5, it was given a score of 2. If the model had a Gold Standard Score of $\leq$ 9.5 but more than 6.5, it was given a score of 3. Finally, if the model had a gold standard score of >9.5 it was given a score 4. The developers of ICON proposed the treatment cut-off of 43 for treatment need. This cut-off point for ICON did not reflect the levels of orthodontic treatment need as determined by the panel of Gold Standard orthodontists.

The gold standard threshold for orthodontic treatment need was dramatically lower than the threshold developed by ICON authors. The ICON scores that best describe the Gold Standard thresholds are found in Table 5. Our Gold Standard indicates that a score above 37.5 for treatment need. The CART Report can be seen in Appendix H.

Table 5: ICON Cut-Off Points as determined by CART

	ICON Range	
Category	*Minimum*	*Maximum*
No Treatment Needed	0	17.5
Treatment Optional	17.5	37.5
Treatment Advisable	37.5	58.5
Treatment Essential	58.5	144

The sensitivity and specificity were once again determined using the new breakdown for ICON. Table 6 shows that the specificity decreased slightly, but the sensitivity increased dramatically.

Table 6: Sensitivity and Specificity of ICON with Gold Standard modification (Treatment Need Cut-Off of 37.5).

		Gold Standard	
		Orthodontic Treatment Need	*No Orthodontic Treatment Need*
ICON New Cut off of 37.5	*Orthodontic Treatment Need*	84	3
	No Orthodontic Treatment Need	20	46
		Sensitivity	80.8%
		Specificity	93.9%
		Prevalence	68.0%
		(+)Predictive Value	96.6%
		(-) Predictive Value	69.7%
		(+) Likelihood Ratio	13.2
		(-) Likelihood Ratio	0.205

Validity of HLD(CalMod) as index of handicapping malocclusions

Validity of HLD(CalMod) was also evaluated in two ways. Spearman rank correlation coefficient was used to evaluate the correlation between HLD(CalMod) and the Gold Standard. The correlation coefficient was 0.710, which demonstrates a moderately high correlation between HLD(CalMod) and Gold Standard ($p<0.01$). HLD(CalMod) has a high specificity and low sensitivity (Table 7).

Table 7: Sensitivity and Specificity of HLD(CalMod)

		Gold Standard	
		Handicapping Malocclusion	*No Handicapping Malocclusion*
HLD(CalMod) with cut-off of 26	*Handicapping Malocclusion*	7	4
	No Handicapping Malocclusion	20	122
		Sensitivity	25.9%
		Specificity	96.8%
		Prevalence	17.7%
		(+)Predictive Value	63.6%
		(-) Predictive Value	85.9%
		(+) Likelihood Ratio	8.17
		(-) Likelihood Ratio	0.77

Figure 10 shows the quadratic relationship between the Gold Standard and HLD(CalMod) since the relationship between the Gold Standard and the square root of HLD(CalMod) is essentially linear.

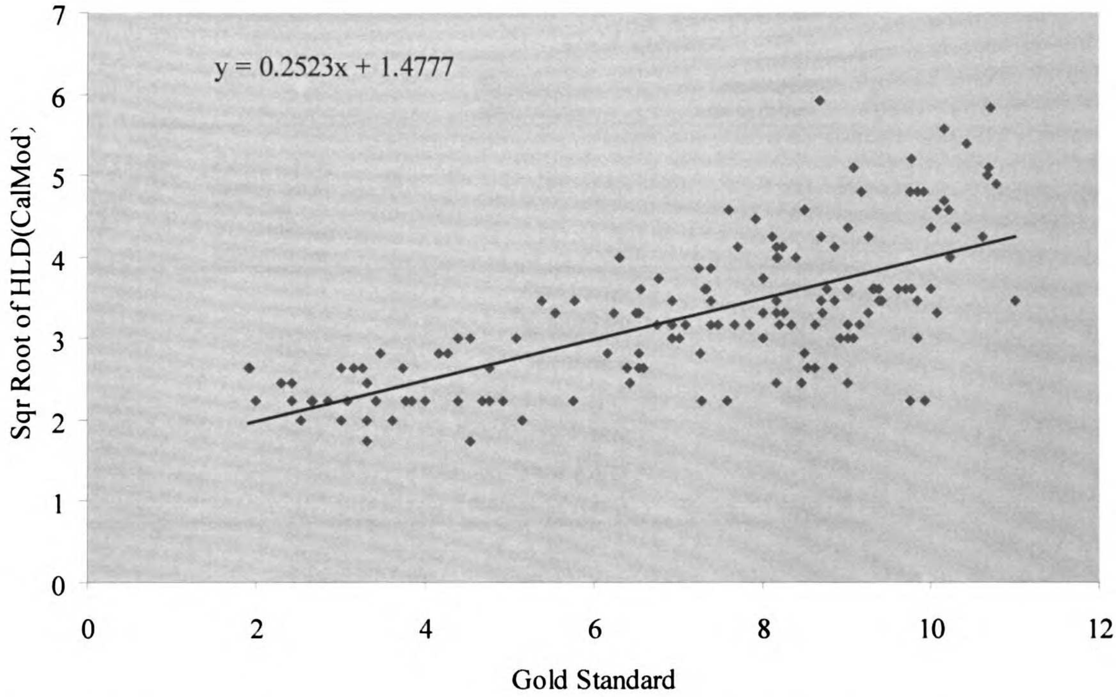

Figure 10. Gold standard score versus square root of HLD(CalMod) score

CART with 10-fold cross-validation was used to determine the score in HLD(CalMod) that reflects the Gold Standard cut off point for Handicapping Malocclusions. The cut-off point determined by CART was 18.5 versus the Medi-cal cut-off point of 26. The CART Report can be seen in Appendix I.

The sensitivity and specificity were once again determined using the new breakdown for HLD(CalMod). Table 8 shows that the specificity decreased slightly, but the sensitivity increased dramatically.

Table 8: Sensitivity and specificity of HLD(CalMod) with a Cut-Off of 18.5

		Gold Standard	
		Handicapping Malocclusion	*No Handicapping Malocclusion*
HLD(CalMod) with cut off of 18.5	*Handicapping Malocclusion*	15	9
	NO Handicapping Malocclusion	12	117
		Sensitivity	55.6%
		Specificity	92.9%
		Prevalence	17.7%
		(+)Predictive Value	62.5%
		(-) Predictive Value	90.7%
		(+) Likelihood Ratio	7.78
		(-) Likelihood Ratio	0.479

The positive predictive value is still poor at 62.5%. Table 9 shows the sensitivity and specificity of ICON in determining handicapping malocclusion. A cut-off point of 58.5 in ICON was used because CART determined that this corresponded to the cut-off point between treatment advisable and treatment essential.

Table 9: Sensitivity and Specificity of ICON with Gold Standard modification in Identifying Handicapping Malocclusions (Cut-Off of 58.5)

		Gold Standard	
		Handicapping Malocclusion	*No Handicapping Malocclusion*
ICON instead of HLD Cut off 58.5	*Handicapping Malocclusion*	17	7
	NO Handicapping Malocclusion	10	119
		Sensitivity	63.0%
		Specificity	94.4%
		Prevalence	17.7%
		(+)Predictive Value	70.8%
		(-) Predictive Value	92.3%
		(+) Likelihood Ratio	11.3
		(-) Likelihood Ratio	0.392

The sensitivity increased from 55.6 to 63.0% and the specificity increased from 92.9 to 94.4% with the use of ICON instead of HLD(CalMod).

Discussion

Validity of ICON

ICON was relatively easy to use and straightforward. This was corroborated by a high intra-rater reliability finding. ICON was also found to have a good correlation with the Gold Standard ratings. However, the cut-off point for ICON did not correspond with the gold standard threshold level for the need of orthodontic treatment, which is consistent with previous studies.[46] While this study found the ideal cut-off to be 37.5, lower than the established 43, Firestone[62] found the ideal cut-off to be 52 which is higher than the standard. This discrepancy can be due to a number of factors. First, two different sets of models were used in each study. Secondly, Firestone determined the cut-off point by optimizing the specificity and sensitivity of each possible cut-off point by using Receiver Operating Characteristic (ROC) Curves, while in this study we used classification and regression tree modeling which optimizes the purity of the groups after splitting. CART was used with 10-fold cross validation, which avoids overfitting models to these particular data and makes findings more robust. Finally, the Firestone study used a visual analogue scale (VAS) for the orthodontists to use to choose the level of need. It did not specify the cut-off for treatment need. They had the orthodontist subjects mark where they thought the cut-off would be after all the ratings had been done. In this study we used a 12 point scale that specified distinctions between the four categories (Appendix C).

By having four categories on our scale, we were then able to use the CART program to determine ICON cut-off points that corresponded to the distinction between "No treatment needed" and "Treatment optional" at 17.5 and between "Treatment advisable" and "Treatment essential" at 58.5. With the Gold Standard modification, ICON is better able to consistently distinguish the difference between those with and without orthodontic treatment need.

Validity of HLD(CalMod)

HLD(CalMod) was not difficult in measurement techniques, but confusing in what to count and what not to count and was found to have inconsistencies in directions. William Parker, an orthodontist in Sacramento, accepted a contract to provide orthodontic consultation in the drafting of narrowly defined criteria and guidelines for determining medically necessary orthodontic treatment for a proposed regulations change package to the California Code of Regulations.[71] He found "the most irritating issues surround the use of the word ectopic". The confusion is discussed in the introduction of this thesis.

The intra-rater reliability was good, but not as consistent as ICON. HLD had a good correlation with the Gold Standard ratings. As was seen with ICON, the cut-off point for HLD(CalMod) did not correspond with the gold standard threshold level for models that displayed handicapping malocclusions. The gold standard modification of HLD(CalMod) had a cut off point of 18.5. Beglin[46] found that a lower and more lenient cut-off point of 12 increased the overall percent of agreement between HLD(CalMod), the expert ratings and the k-value. It was felt that HLD(CalMod) is not a valid measure of handicapping malocclusions. Even with the gold standard modification, the HLD(CalMod) did not perform at a level that is acceptable.

The models that displayed the most handicapping malocclusion according to the gold standard but did not qualify via the HLD(CalMod) are shown in Figures 11 through 15.

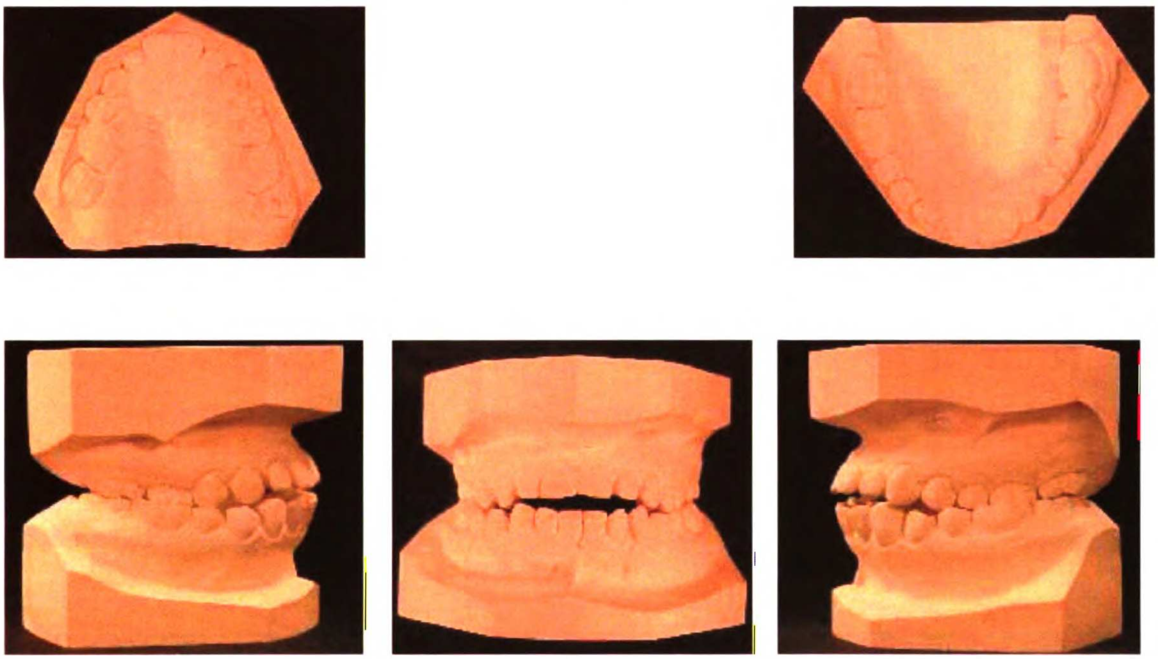

Figure 11 This model had a Gold Standard score of 11.0 (out of a maximum of 12) and an HLD(CalMod) score of 12.

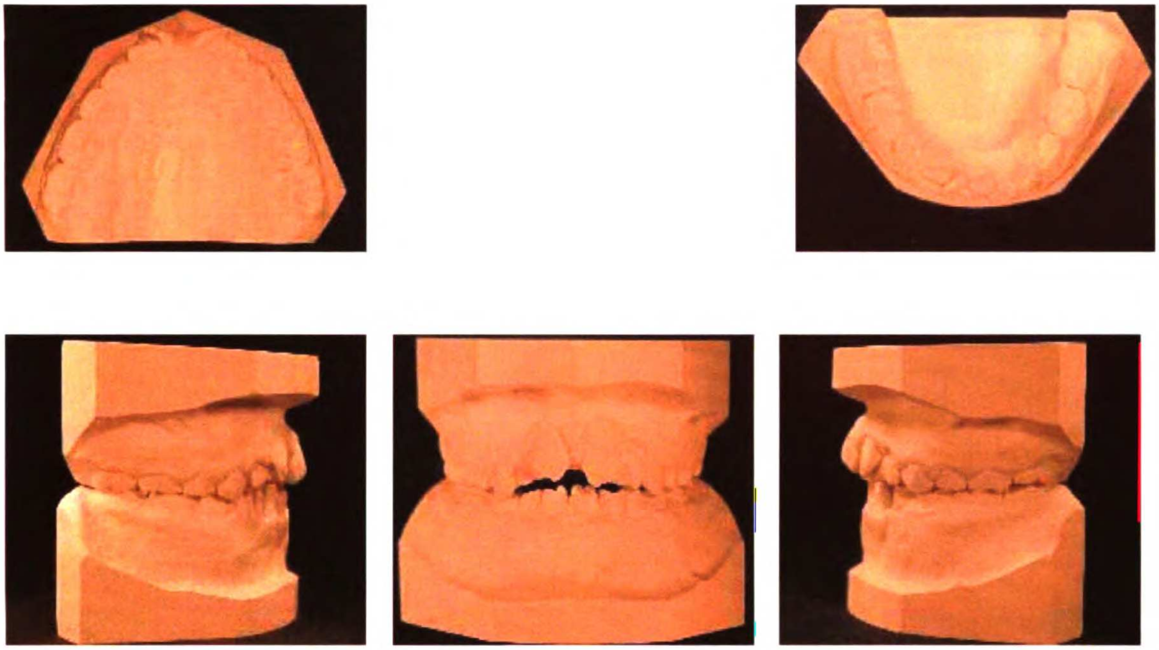

Figure 12: This model had a Gold Standard score of 10.8 (out of a maximum of 12) and an HLD(CalMod) score of 24.

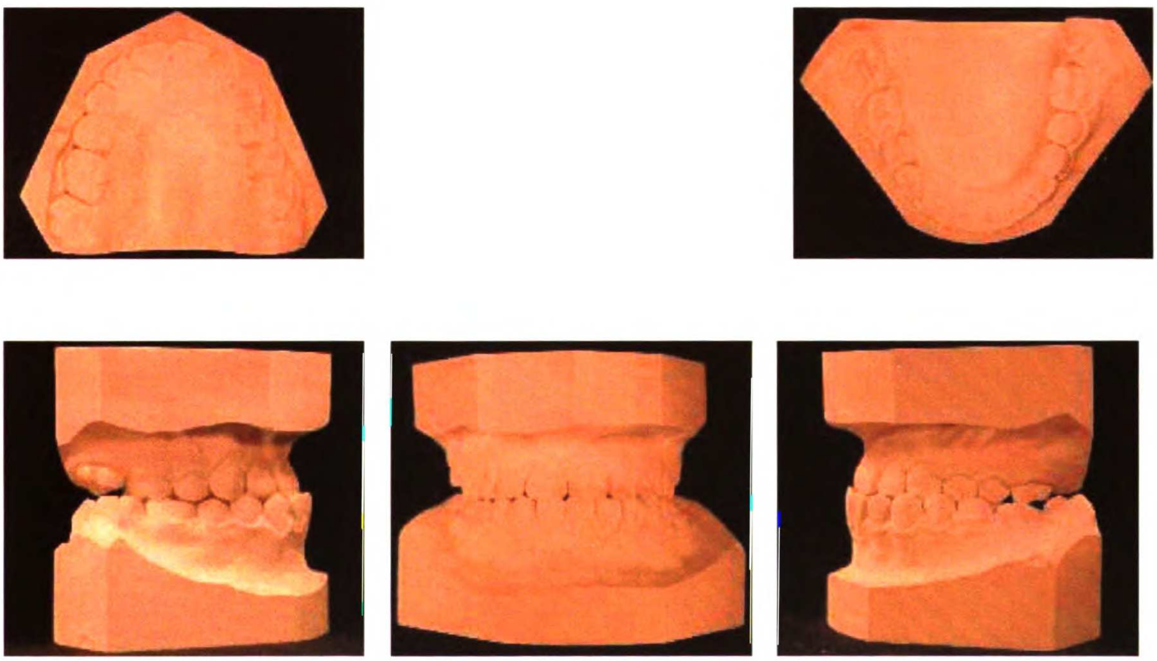

Figure 13: This model had a Gold Standard score or 10.7 (out of a maximum of 12) and an HLD(CalMod) score of 25.

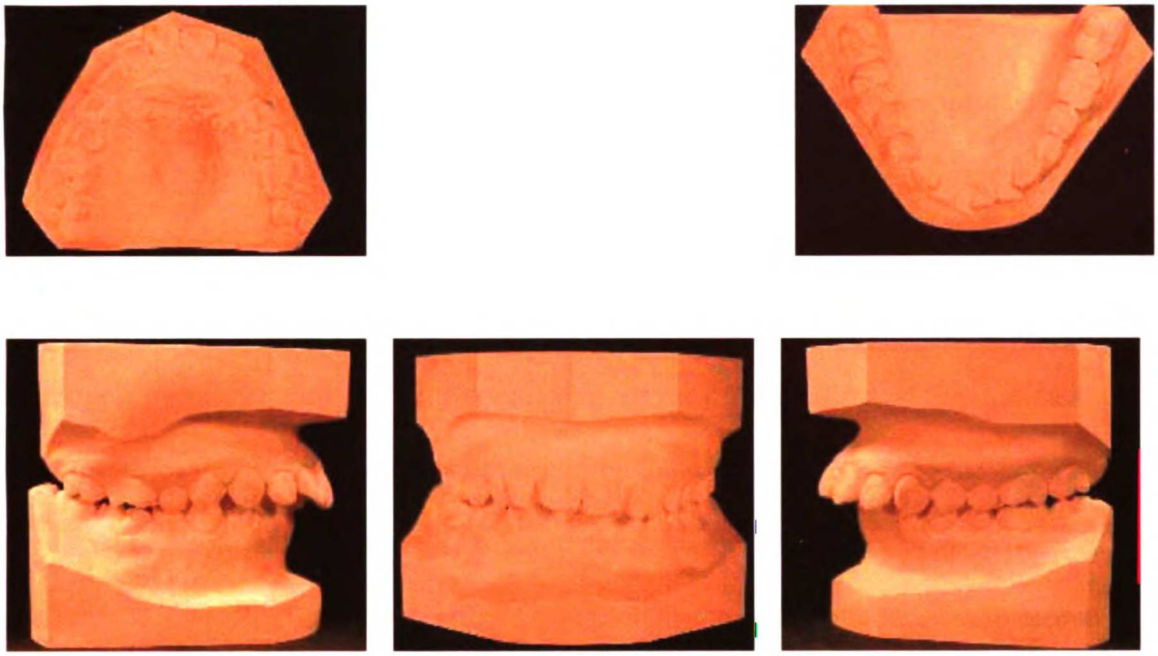

Figure 14: This model had a Gold Standard score of 10.6 (out of a maximum of 12) and an HLD(CalMod) score of 18.

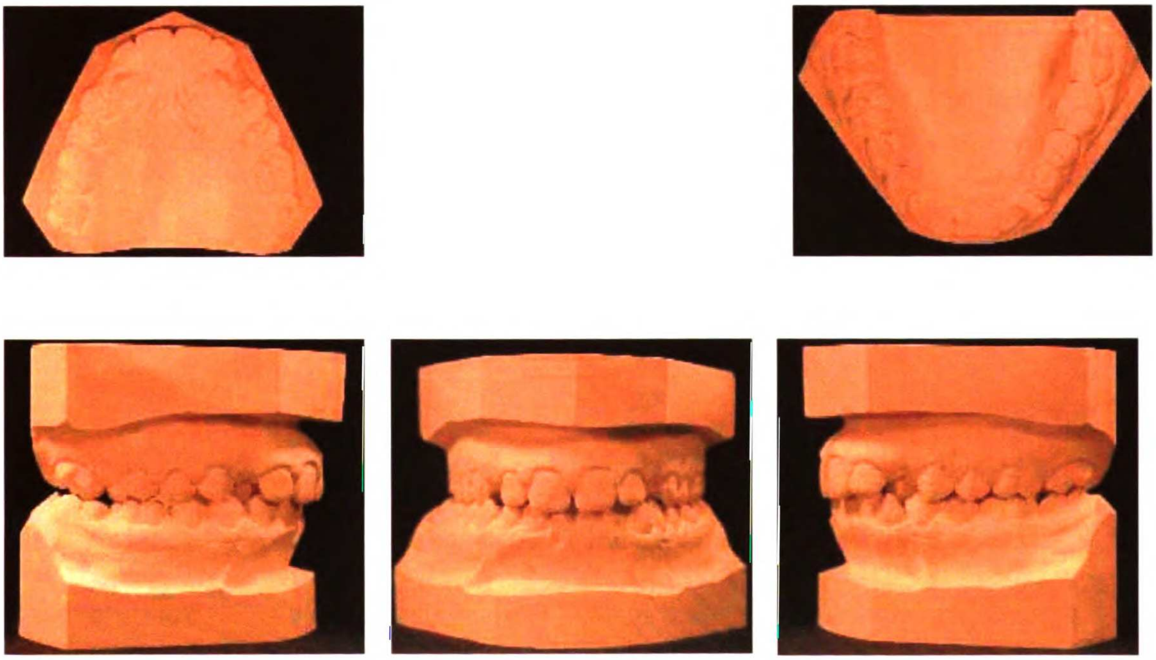

Figure 15: This model had a Gold Standard score of 10.3 (out of a maximum of 12) and HLD(CalMod) score of 19.

Implications

There is no consistent index used among states to identify handicapping malocclusions. Furthermore, there is no consistent definition for handicapping malocclusion. Even when similar indices are used. Han et al.[47] found that there was no consistency between them. HLD(CalMod) and the HLD(Md). the Maryland modified HLD did not approve the same people for orthodontic care with public funding.

Referral patterns are also a concern. When Medi-cal patients are referred for treatment, the process is cumbersome and time consuming for the orthodontist. At the first visit, the HLD(CalMod) index is performed and the completed worksheet is sent to the fiscal intermediary. If authorization is given, six to eight weeks later the patient is scheduled for a second visit. At the second visit, a set of models are taken and once again sent in to the fiscal intermediary. If authorization is given, six to eight weeks later the patient is scheduled for a records appointment. Depending on an office's policy, the patient will probably return once again for a final consultation visit. Thus, a Medi-cal patient will require 4 visits prior to the start of orthodontic treatment. Parker[72] found that only 17% of all the referred patients were scored eligible by a board-qualified orthodontist at the fiscal intermediary.

From late 1991 until 2000, an estimated 160,745 Medi-cal patients were referred to orthodontists by their general dentists because the dentists felt the patients needed orthodontic care.[71,72] Orthodontists felt that 36% of these (58,193) had handicapping malocclusions. The board-qualified orthodontists at the fiscal intermediary felt that only 17% (27,637) of the patients were eligible. This meant that there were 218,935 appointments to start 27,637 patients, resulting in about 10 appointments per patient start.

This problem is a result of a flawed referral process. a problem that is not limited to this study. Richmond et al.,[45] showed that when 74 dentists were asked to assess 320 dental casts for aesthetic and dental health concerns. the panel was divided as what constituted a need for orthodontic treatment on dental health grounds. O'Brien et al.,[73] formulated a set of referral guidelines that were based on national guidelines and evidence from the literature with help from primary and secondary practitioners. The guidelines were disseminated to a group of dentists and they were also offered an optional seminar. In a follow-up with this group of dentists. it appeared that the guidelines were well received by the dentists. Despite the dissemination and acceptance of the guidelines. it was found that there was no difference in the proportion of appropriate referrals between the dentists that received the guidelines and those that did not.

Limitations of the HLD(CalMod) Index are as much a part of how this index was developed as with the flawed referral pattern. The initiation of HLD(CalMod)s use was the result of a law suit for failing to comply with the orthodontic provisions of the Medicaid statutes.[71] In order to settle the lawsuit an inclusion of a unilateral posterior crossbite as a weighted factor was added to the HLD index along with two conditions known to cause loss of structure and tissue. To settle a subsequent lawsuit. overjet greater than 9mm and reverse overjet greater than 3.5mm was inserted as a qualifying exception.[71] This last alteration has probably led to the finding that HLD(CalMod) approved more patients with class II malocclusions than the HLD(Md).[47] Thus. the use of HLD(CalMod) index tends to direct public funding toward patients with severe class II malocclusions.

In their study, Han et al.,[47] found that HLD index had the following weaknesses:

1. It fails to identify localized crowding that significantly damages dental aesthetics (See Figure 12)
2. It fails to identify missing teeth or spacing in the anterior dental segment (See Figure 12)
3. It fails to identify asymmetry (See Figure 13)
4. It fails to identify dysfunctional components such as posterior open bite, speech difficulties and TMJ symptoms.

Other limitations of HLD(CalMod) include not weighting open bites heavily enough (See Figures 11 and 12) and failing to identify bilateral crossbites (Figure 11). Additionally, as can be seen in Figure 15, the index fails to identify bilaterally palatally displaced canines which have space in the arch, but no hope of self-correction. Lastly, those malocclusions that include a large overjet (Figure 14) but fail to meet the 9mm automatically qualifying exception, and possess fairly aligned arches won't qualify for orthodontic treatment.

Conclusion

In all areas, the ICON with Gold Standard modification had better results than the HLD(CalMod) index in identifying handicapping malocclusions as determined by a Gold Standard panel of orthodontists. The ICON with the Gold Standard modification cut-off of 58.5 had higher sensitivity and specificity so you could rule out handicapping malocclusion more comfortably with a negative result and rule in handicapping malocclusion with a positive result. Furthermore, ICON had higher intra-rater reliability.

so the assessment of the malocclusion is more consistent

it was easier and less confusing to use.

The California Medi-cal system discourages orthodontist

due in part to the cumbersome insurance process and the

referrals that monopolizes an orthodontists new exam sl

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APPENDICES

Appendix A: Orthodontist Questionnaire

QUESTIONNAIRE

UNIVERSITY OF CALIFORNIA, SAN FRANCISCO

Assessing the validity of the Index of Complexity, Outcome and Need

Date: __________

1. Participant Number: _____

2. How old are you: _____ Years

3. What is your gender: ☐ Female ☐ Male

4. Do you have another dental specialty besides orthodontics? ☐ Yes ☐ No
   If yes, please indicate: ____________________________________

5. Please indicate the setting of your primary practice site (Check one only):
   - ☐ Private solo practice
   - ☐ Private group practice
   - ☐ Private non-teaching hospital
   - ☐ University/teaching hospital
   - ☐ HMO
   - ☐ Government owned hospital
   - ☐ Public community health center/clinic
   - ☐ Other private

6. Do you work at least ½ time presently: ☐ Yes ☐ No

7. What year did you receive your certificate in orthodontics? _____

8. Where did you receive your certificate in orthodontics? ________

9. Do you have any experience working with orthodontic indices? ☐ Yes ☐ No
   If yes, what kind of experience: ______________________________
   ____
   ____

10. May we contact you in the future for follow up to this research project? ☐ Yes ☐ No

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Orthodontist Questionnaire
CHR Approval #H2582-24865-01

Appendix B: Orthodontist Consent Form

UNIVERSITY OF CALIFORNIA, SAN FRANCISCO
Assessing the validity of the Index of Complexity, Outcome and Need
Orthodontist Consent Form

A. PURPOSE AND BACKGROUND

Mary C Cooke, DDS and Barbara Gerbert, Ph.D. in the Department of Orthodontics and Department of Preventive and Restorative Dental Sciences are conducting a research study to Assessing the validity of the Index of Complexity, Outcome and Need as an index that reflects Orthodontists' perception of orthodontic treatment need. You are being asked to participate in this study because you are an orthodontist who is a member of the AAO and practices in the San Francisco Bay Area at least ½ time.

B. PROCEDURES

If you agree to be in the study, the following will occur:

1. You will complete a confidential written questionnaire that contains a series of questions on knowledge, attitudes, beliefs, and practices regarding orthodontic treatment need. This will take about 10 minutes.

2. At the first meeting you will view 150 casts and decide to what extend the patient represented has orthodontic treatment need. This will take approximately 2 hours.

3. At the second meeting you will view another 40 casts decide to what extend the patient represented has orthodontic treatment need. This will take approximately 60 minutes.

C. RISKS/DISCOMFORTS

1. Confidentiality: Participation in research may involve a loss of privacy; however, your records will be handled as confidentially as possible. The researchers will ask you and the other people in the study to use a randomly assigned number during the sessions. Only Dr. Cooke, Dr. Gerbert and their assistant will have access to the key linking your name to your questionnaire and choice of orthodontic treatment need. After the data has been collected, the documents will be destroyed. No individual identities will be used in any reports or publications that may result from this study.

D. BENEFITS

There will be no direct benefit to you from participating in this study. However, the information that you provide may help orthodontic educators better teach orthodontic treatment need.

E. COSTS

There will be no costs to you as a result of taking part in this study.

F. PAYMENT

You will **NOT** be paid for your participation in this study.

G. QUESTIONS

You have talked to Dr. Cooke or Dr. Gerbert about this study and have had your questions answered. If you have further questions, you may call her at (415) 794-5708.

If you have any comments or concerns about participation in this study, you should first talk with the researchers. If for some reason you do not wish to do this, you may contact the Committee on Human Research, which is concerned with the protection of volunteers in research projects. You may reach the committee office between 8:00 and 5:00, Monday through Friday, by calling (415) 476-1814, or by writing: Committee on Human Research, Box 0962, University of California, San Francisco/San Francisco, CA 94143.

H. CONSENT

You will be given a copy of this consent form to keep.

PARTICIPATION IN RESEARCH IS VOLUNTARY. You are free to decline to be in this study, or to withdraw from it at any point. Your decision as to whether or not to participate in this study will have no influence on your present or future status at UCSF.

If you agree to participate you should sign below.

____________ ______________________________

Date Signature of Study Participant

____________ ______________________________

Date Signature of Person Obtaining Consent

Appendix C: Orthodontist Model Check Off Sheet

MODEL # _________ **PARTICIPANT #** ________

You are the orthodontic consultant for a private corporation for which a limited fund has been established to provide orthodontic treatment for personnel. You are to evaluate these study casts of personnel and answer the following question: In your opinion, to what extent does this occlusion need orthodontic treatment? Please circle the corresponding number: (range 1-12).

1	2	3	4	5	6	7	8	9	10	11	12
No treatment needed			Treatment elective			Treatment advisable			Treatment essential		

What traits contributed to the decision for treatment (check all that apply):

Transverse	Perimeter
☐ Crossbite	☐ Impacted teeth
Sagittal	☐ Maxillary crowding
☐ Overjet	☐ Mandibular crowding
☐ Reverse overjet	☐ Maxillary incisor alignment
☐ Left & Right sagittal	☐ Mandibular incisor alignment
Vertical	☐ Maxillary incisor inclination
☐ Overbite/openbite	☐ Mandibular incisor inclination
Other	☐ Maxillary buccal segment alignment
☐ Esthetics ☐ Other: ______________	☐ Mandibular buccal segment alignment

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MODEL # _________ **PARTICIPANT #** ________

You are the orthodontic consultant for a private corporation for which a limited fund has been established to provide orthodontic treatment for personnel. You are to evaluate these study casts of personnel and answer the following question: In your opinion, to what extent does this occlusion need orthodontic treatment? Please circle the corresponding number: (range 1-12).

1	2	3	4	5	6	7	8	9	10	11	12
No treatment needed			Treatment elective			Treatment advisable			Treatment essential		

What traits contributed to the decision for treatment (check all that apply):

Transverse	Perimeter
☐ Crossbite	☐ Impacted teeth
Sagittal	☐ Maxillary crowding
☐ Overjet	☐ Mandibular crowding
☐ Reverse overjet	☐ Maxillary incisor alignment
☐ Left & Right sagittal	☐ Mandibular incisor alignment
Vertical	☐ Maxillary incisor inclination
☐ Overbite/openbite	☐ Mandibular incisor inclination
Other	☐ Maxillary buccal segment alignment
☐ Esthetics ☐ Other: ______________	☐ Mandibular buccal segment alignment

Appendix D: ICON scores for Each Model

Random Number	Information	DAI	Crowding/ Spacing	XB	OB/OB	AP	ICON total
1001		2	0	1	1	3	32
1002	Impacted upper right canine & retained upper right primary canine	2	0	0	0	3	23
1003	Upper left first molar missing & bridge from upper left 2nd bicuspid to upper left 2nd molar	4	0	1	2	1	44
1004	Lower right bridge from 2nd premolar to 2nd molar	5	0	1	1	3	53
1005	Missing upper right 1st bicuspid. not to be restored	2	0	0	1	4	30
1006		6	1	1	0	3	61
1007		6	2	1	0	2	63
1008	Missing upper right 1st bicuspid & upper left 2nd molar. not to be restored	6	0	1	0	4	59
1009		3	0	1	1	4	42
1010		4	2	0	0	4	50
1011	Upper left 1st molar extracted & lower right 1st molar extracted; both to be replaced with implants. Upper right 1st molar to be extracted and restored	4	2	0	0	4	50
1012	All 4 1st bicupsids extracted	4	1	0	2	3	50
1013	All permanent teeth present	2	0	0	1	4	30
1014	All first bicuspids extracted	1	0	0	1	2	17
1015		8	1	0	1	3	74
1016	Upper 1st bicuspids extracted	2	0	0	0	4	26
1017		3	1	1	0	2	37
1018		1	0	0	1	3	20
1019	Impacted upper right canine & retained upper right primary canine	2	0	0	1	3	27
1020		1	0	0	0	1	10
1021		4	1	0	0	4	45
1022	All permanent teeth present	3	0	1	1	1	33
1023	Missing upper 1st molars and lower right 1st molar- to be restored	1	1	0	0	3	21
1024		3	0	1	1	3	39
1025	All first bicuspids extracted	2	0	0	1	2	24
1026	All permanent teeth present	5	0	0	2	4	55
1027	Extracted lower left 1st molar - to be restored	5	2	1	1	2	60
1028	All permanent teeth present	3	1	1	1	4	47
1029		3	0	0	2	4	41
1030		5	2	1	1	3	63
1031	All permanent teeth present	3	0	0	2	4	41
1032	All 1st premolars extracted	1	0	0	1	2	17
1033	Upper right central incisor extracted. lower left 2nd molar extracted- both to be restored	4	0	0	0	3	37
1034	Upper first premolars extracted	3	0	1	1	3	39
1035		5	2	0	1	2	55
1036		5	1	0	1	3	53
1037	Missing permanent maxillary lateral incisors- to be restored	5	0	1	0	4	52
1038	Upper right 2nd molar extracted. not to be restored	3	0	1	1	2	36
1039		4	0	1	0	3	42
1040		3	0	1	0	2	32

Random Number	Information	DAI	Crowding/ Spacing	XB	OB/OB	AP	ICON total
1041	All four 1st bicuspids extracted	3	1	1	0	3	40
1042		5	2	0	1	3	58
1043		5	1	0	0	1	43
1044		3	0	0	1	2	31
1045		4	0	0	1	3	41
1046	All first bicuspids extracted & Upper first molars to be extracted due to periodontal disease. AP CR/CO shift	3	0	0	0	2	27
1047		1	0	0	1	4	23
1048	All 1st premolars extracted	3	0	0	0	3	30
1049		4	0	0	2	4	48
1050	All 1st premolars extracted	3	0	0	1	4	37
1051		3	0	0	2	3	38
1052	All permanent teeth present	3	0	0	1	1	28
1053		5	1	0	1	2	50
1054	All first premolars extracted	4	1	0	0	3	42
1055	Permanent upper left canine missing-to be replaced prosthetically	3	1	0	2	3	43
1056		4	1	1	0	3	47
1057		1	0	0	0	3	16
1058	All permanent teeth present	3	0	1	2	3	43
1059		4	1	1	1	2	48
1060		4	1	1	2	2	52
1061		3	1	1	0	2	37
1062		1	0	0	0	3	16
1063		4	1	0	0	4	45
1064	All permanent teeth present	4	0	1	1	3	46
1065		6	1	1	1	4	68
1066	All teeth present	7	1	0	1	1	61
1067		4	0	0	1	3	41
1068	All permanent teeth present	5	0	0	2	4	55
1069	All permanent teeth present	5	2	0	2	1	56
1070		4	0	0	1	3	41
1071	All permanent teeth present	8	2	1	1	2	81
1072		1	0	0	0	2	13
1073		2	0	1	1	2	29
1074		3	0	1	0	2	32
1075	All permanent teeth present	3	0	1	1	3	39
1076	Upper left 1st bicuspid missing	2	0	0	0	3	23
1077	Upper right 1st bicuspid missing- not to be restored	1	0	0	0	3	16
1078	Missing upper left 2nd molar and lower left 1st molar. Lower left 1st molar to be restored. All four 1st bicuspids extracted.	1	0	1	0	3	21
1079		1	0	0	0	4	19
1080	All permanent teeth present	2	0	0	1	2	24
1081	Permanent upper laterals missing- not to be restored	4	0	0	1	4	44
1082		3	0	0	1	3	34
1083		4	0	0	1	3	41
1084		5	4	0	0	2	61
1085		8	2	0	1	2	76

Random Number	Information	DAI	Crowding/ Spacing	XB	OB/OB	AP	ICON total
1086	All first bicuspids extracted	2	0	0	1	3	27
1087	Upper canines missing- not to be restored	3	0	0	0	4	33
1088	All 1st bicuspids extracted	3	0	1	2	3	43
1089		3	1	1	1	3	44
1090	All 1st bicuspids extracted	1	0	0	0	4	19
1091		3	1	0	1	2	36
1092		1	0	1	0	2	18
1093		2	0	0	0	4	26
1094	All permanent teeth present	3	0	1	0	1	29
1095	Upper right 1st bicuspid missing- not to be restored	8	0	1	3	3	82
1096	Missing upper right canine and lower right lateral incisor, and upper left 1st bicuspid. None of these to be restored	2	0	0	0	3	23
1097	Upper right lateral to be restored with implant	3	0	0	1	1	28
1098		8	2	1	2	2	85
1099		3	0	0	1	3	34
1100		5	0	0	1	3	48
1101	All permanent teeth present	6	2	1	1	2	67
1102	Impacted upper canines *** REVIEW*** MISSING UPPER CAST	2	0	1	0	0	19
1103		3	0	0	1	4	37
1104	All permanent teeth present	3	0	1	1	2	36
1105	All first premolars extracted	2	0	0	1	3	27
1106		2	0	0	1	2	24
1107	Upper right canine unerupted	3	0	1	0	2	32
1108		4	2	1	0	2	49
1109		4	1	1	0	3	47
1110		4	0	1	1	3	46
1111	Missing lower right 1st molar, to be restored	4	1	1	3	4	62
1112	Upper laterals missing & to be restored	5	1	1	0	2	51
1113		6	1	1	1	3	65
1114	Missing upper right lateral, upper left 1st bicuspids & lower 1st bicuspids- not to be restored	2	0	0	1	3	27
1115		3	0	1	1	2	36
1116	All permanent teeth present	10	2	0	2	3	97
1117	All permanent teeth present & lower right 2nd molar unrestorable	4	0	1	1	4	49
1118	All 1st premolars extracted	5	0	0	2	3	52
1119	Dual centric occlusion bite; LR 6 missing - not to be restored	3	0	1	1	4	42
1120		8	3	1	1	4	92
1121		1	0	1	0	3	21
1122		8	0	1	3	4	85
1123		6	1	1	1	4	68
1124	All permanent teeth present	5	0	0	1	3	48
1125		6	3	1	3	3	83
1126	All 1st premolars extracted	2	0	1	1	3	32
1127	Upper first premolars extracted	4	0	1	1	4	49
1128		8	1	1	0	3	75
1129		5	0	0	0	4	47

Random Number	Information	DAI	Crowding/ Spacing	XB	OB/OB	AP	ICON total
1130	LL6 missing- to be restored	4	1	0	1	1	40
1131	Missing upper right 1st premolar- not to be restored	2	1	0	0	4	31
1132	Unerupted lower right 1st bicuspid	8	0	0	3	2	74
1133		4	1	1	0	3	47
1134	All first bicuspids extracted	2	0	0	2	2	28
1135	All first bicuspids extracted; anomalous lower left 2nd bicuspid	2	0	0	0	2	20
1136		2	0	1	2	4	39
1137	Upper left central and lateral missing- To be restored; all first bicuspids extracted; lower left 2nd premolar missing and to be restored	3	0	0	1	3	34
1138	All first bicuspids extracted. Upper right central missing- to be restored	3	0	0	0	3	30
1139	lower right 1st bicuspid, lower left 2nd bicuspid missing and to be restored; lower left 1st molar unsalvagable and will be extracted- not to be restored	4	0	0	1	3	41
1140	All permanent teeth present	4	0	1	2	2	47
1141		3	1	1	0	4	43
1142		4	0	0	0	2	34
1143	Upper right lateral to be restored with veneer	6	0	1	1	2	57
1144	All first bicuspids extracted	4	2	0	2	4	58
1145	All first bicuspids extracted	2	0	0	1	3	27
1146	All 1st premolars extracted	1	0	1	0	4	24
1147		4	1	1	0	2	44
1148	All permanent teeth present	2	0	0	2	1	25
1149		4	0	1	0	4	45
1150	All permanent teeth present	3	4	0	0	3	50
1151	All permanent teeth present	3	0	0	3	1	36
1152	All permanent teeth present	7	2	1	0	2	70
1153	All permanent teeth present	2	0	0	1	2	24

Appendix E: HLD(CalMod) Scores for Each Model

HLD																
Model #	Cleft Palate	Deep Impinging OB	XB Individual Anterior Teeth	Severe Traumatic Deviations	OJ > 9mm	OJ < -3.5mm	OJ	OB	Neg OJ	Open Bite	Ectopic Eruption	Ant Max Crowding	Ant Mand Crowding	Labiolingual spread	Posterior Unilateral XB	Total
1001	0	0	0	0	0	0	6	4	0	0	0	0	0	0	0	10
1002	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0	5
1003	0	0	0	0	X	0	9	9	0	0	0	0	0	0	0	18
1004	0	0	0	0	0	0	3	3	0	0	0	0	0	0	1	10
1005	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	6
1006	0	0	0	0	0	0	5	1	0	0	0	0	1	2	0	13
1007	0	0	0	0	0	0	3	2	0	0	1	1	0	10	0	23
1008	0	0	0	0	0	X	0	1	4	0	0	0	0	0	1	25
1009	0	0	0	0	0	0	6	3	0	0	0	0	0	0	0	9
1010	0	0	0	0	0	0	6	1	0	0	0	1	1	2		19
1011	0	0	0	0	0	0	5	1	0	0	0	0	0	0	0	6
1012	0	0	0	0	0	0	2	5	0	0	0	0	0	2	0	9
1013	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	7
1014	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1015	0	0	0	0	0	0	9	3	0	0	0	1	0	6	0	23
1016	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1017	0	0	0	0	0	0	4	2	0	0	0	0	0	2	0	8
1018	0	0	0	0	0	0	3	4	0	0	0	0	0	1	0	8
1019	0	0	0	0	0	0	4	4	0	0	0	0	0	0	0	8
1020	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	4
1021	0	0	0	0	0	0	8	2	0	0	0	0	0	0	0	10
1022	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	5
1023	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1024	0	0	0	0	0	0	7	3	0	0	0	0	1	6	0	21
1025	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	7
1026	0	0	0	0	0	0	5	5	0	0	0	0	0	2	0	12
1027	0	0	0	0	0	0	4	4	1	0	0	1	1	3	0	26
1028	0	0	0	0	0	0	2	3	1	0	0	0	0	0	0	10
1029	0	0	0	0	0	0	6	5	0	0	0	0	0	2	0	13
1030	0	0	0	0	0	0	3	1	1	0	0	0	0	0	0	9
1031	0	0	0	0	0	0	5	6	0	0	0	0	0	0	0	11
1032	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	7
1033	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1034	0	0	0	0	0	0	6	5	0	0	0	0	1	4	0	20
1035	0	0	0	0	0	0	6	3	0	3	0	1	1	4	0	35
1036	0	0	0	0	0	0	5	4	0	0	0	0	0	0	0	9
1037	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0	5
1038	0	0	0	0	0	0	4	5	0	0	0	0	0	2	0	11
1039	0	0	0	0	0	0	5	4	0	0	0	0	0	0	0	9
1040	0	0	0	0	0	0	0	0	1	1	0	0	0	0	0	9

HLD																
Model #	Cleft Palate	Deep Impinging OB	XB Individual Anterior Teeth	Severe Traumatic Deviations	OJ > 9mm	OJ < -3.5mm	OJ	OB	Neg OJ	Open Bite	Ectopic Eruption	Ant Max Crowding	Ant Mand Crowding	Labiolingual spread	Posterior Unilateral XB	Total
1041	0	0	0	0	0	0	5	2	0	0	0	0	0	5	1	16
1042	0	0	0	0	0	0	2	1	0	1	0	0	0	0	0	7
1043	0	0	0	0	0	0	9	2	0	0	0	0	0	2	0	13
1044	0	0	0	0	0	0	4	3	0	0	0	0	1	4	0	16
1045	0	0	0	0	0	0	9	4	0	0	0	0	0	0	0	13
1046	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	4
1047	0	0	0	0	0	0	5	4	0	0	0	0	0	3	0	12
1048	0	0	0	0	0	0	2	2	0	0	0	0	0	0	0	4
1049	0	0	0	0	0	0	9	6	0	0	0	0	0	3	0	18
1050	0	0	0	0	0	0	5	5	0	0	0	0	0	0	0	10
1051	0	0	0	0	0	0	3	6	0	0	0	0	0	1	0	10
1052	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	7
1053	0	0	0	0	0	0	6	2	0	0	0	0	0	4	0	12
1054	0	0	0	0	0	0	6	3	0	0	0	0	1	3	0	17
1055	0	0	0	0	0	0	3	7	0	0	0	0	0	0	0	10
1056	0	0	0	0	0	0	3	1	0	0	0	0	0	2	0	6
1057	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1058	0	0	0	0	0	0	3	3	0	0	0	0	0	1	0	7
1059	0	0	0	0	0	0	6	5	0	0	0	0	1	5	0	21
1060	0	0	0	0	0	0	4	3	0	0	0	1	0	7	0	19
1061	0	0	0	0	0	0	3	1	0	0	0	0	1	3	0	12
1062	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1063	0	0	0	0	0	0	7	2	0	0	0	0	1	3	0	17
1064	0	0	0	0	0	0	6	3	0	0	0	0	0	0	1	13
1065	0	0	0	0	0	0	6	4	0	0	0	1	1	3	1	27
1066	0	0	0	0	0	0	8	0	0	1	0	0	1	4	0	21
1067	0	0	0	0	0	0	7	4	0	0	0	0	0	2	0	13
1068	0	0	0	0	0	0	4	6	0	0	0	0	0	0	0	10
1069	0	0	0	0	0	0	4	7	0	0	0	0	0	0	0	11
1070	0	0	0	0	0	0	6	4	0	0	0	0	0	4	0	14
1071	0	0	0	0	0	0	3	4	2	0	0	1	1	4	0	31
1072	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1073	0	0	0	0	0	0	4	2	0	0	0	0	0	1	1	11
1074	0	0	0	0	0	0	4	4	0	0	0	0	0	3	1	15
1075	0	0	0	0	0	0	6	3	0	0	0	0	0	4	0	13
1076	0	0	0	0	0	0	5	3	0	0	0	0	0	2	0	10
1077	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	7
1078	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	4
1079	0	0	0	0	0	0	3	1	0	0	0	0	0	0	0	4
1080	0	0	0	0	0	0	3	3	0	0	0	0	0	0	0	6
1081	0	0	0	0	0	0	4	5	0	0	0	0	1	3	0	17
1082	0	0	0	0	0	0	3	3	0	0	0	0	0	1	0	7
1083	0	0	0	0	0	0	6	3	0	0	0	0	0	1	0	10
1084	0	0	0	0	0	0	6	1	0	0	0	0	0	0	0	7

HLD																
Model #	Cleft Palate	Deep Impinging OB	XB Individual Anterior Teeth	Severe Traumatic Deviations	OJ > 9mm	OJ < -3.5mm	OJ	OB	Neg OJ	Open Bite	Ectopic Eruption	Ant Max Crowding	Ant Mand Crowding	Labiolingual spread	Posterior Unilateral XB	Total
1085	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1086	0	0	0	0	0	0	4	3	0	0	0	0	0	0	0	7
1087	0	0	0	0	0	0	6	3	0	0	0	0	0	2	0	11
1088	0	0	0	0	0	0	3	6	0	0	0	0	0	2	0	11
1089	0	0	0	0	0	0	7	3	0	0	0	0	1	2	0	17
1090	0	0	0	0	0	0	2	1	0	0	0	0	0	0	0	3
1091	0	0	0	0	0	0	6	3	0	0	0	0	0	3	0	12
1092	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1093	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0	5
1094	0	0	0	0	0	0	2	3	0	0	0	0	0	0	0	5
1095	0	0	0	0	0	0	0	0	0	3	0	0	0	0	0	12
1096	0	0	0	0	0	0	4	1	0	0	0	0	0	0	0	5
1097	0	0	0	0	0	0	0	3	0	0	0	0	0	0	0	3
1098	0	0	0	0	0	0	3	4	2	0	0	1	0	4	0	26
1099	0	0	0	0	0	0	3	3	0	0	0	0	0	2	0	8
1100	0	0	0	0	0	0	6	3	0	0	0	0	0	3	0	12
1101	0	0	0	0	0	0	3	3	2	0	0	0	0	7	0	23
1102	0	0	0	0	0	0	1	2	0	0	0	0	0	0	0	3
1103	0	0	0	0	0	0	5	4	0	0	0	0	0	2	0	11
1104	0	0	0	0	0	0	4	4	0	0	0	0	0	4	0	12
1105	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1106	0	0	0	0	0	0	3	4	0	0	0	0	0	1	0	8
1107	0	0	0	0	0	0	3	1	0	0	0	0	0	3	0	7
1108	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1109	0	0	0	0	0	0	5	1	0	0	0	1	0	5	0	16
1110	0	0	0	0	0	0	5	5	0	0	0	0	1	3	0	18
1111	0	0	0	0	0	0	4	0	0	0	0	0	0	3	1	11
1112	0	0	0	0	0	0	2	2	0	0	0	0	0	1	0	5
1113	0	0	0	0	0	0	4	2	2	0	0	0	0	6	0	22
1114	0	0	0	0	0	0	7	3	0	0	0	0	0	0	0	10
1115	0	0	0	0	0	0	4	4	0	0	0	0	0	0	1	12
1116	0	0	0	0	0	0	7	0	0	2	0	1	0	4	0	24
1117	0	0	0	0	0	0	3	2	0	0	0	0	0	1	0	6
1118	0	0	0	0	X	0	10	8	0	0	0	0	0	1	0	19
1119	0	0	0	0	0	0	7	4	0	0	0	0	0	1	0	12
1120	0	0	0	0	0	0	6	4	2	0	0	1	0	5	1	34
1121	0	0	0	0	0	0	4	0	0	0	0	0	0	2	0	6
1122	0	0	0	0	0	0	5	0	0	3	0	0	0	0	1	21
1123	0	0	0	0	0	0	7	4	0	0	0	1	1	4	1	29
1124	0	X	0	0	0	0	8	4	0	0	0	0	0	1	0	13
1125	0	0	0	0	0	0	3	1	0	0	0	1	0	4	0	13
1126	0	0	0	0	0	0	6	3	0	0	0	0	0	0	1	13
1127	0	0	0	0	0	0	2	2	2	0	0	0	0	5	1	23
1128	0	0	0	0	0	0	5	3	0	0	0	0	0	3	0	11

HLD																
Model #	Cleft Palate	Deep Impinging OB	XB Individual Anterior Teeth	Severe Traumatic Deviations	OJ > 9mm	OJ < -3.5mm	OJ	OB	Neg OJ	Open Bite	Ectopic Eruption	Ant Max Crowding	Ant Mand Crowding	Labiolingual spread	Posterior Unilateral XB	Total
1129	0	0	0	0	0	0	3	1	0	0	0	0	0	3	0	7
1130	8	0	0	0	0	0	8	4	0	0	0	0	0	3	0	15
1131	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1132	0	0	0	0	0	0	6	0	0	2	0	0	0	2	0	16
1133	0	0	0	0	0	0	5	4	0	0	0	1	0	2	0	16
1134	0	0	0	0	0	0	9	0	0	1	0	0	0	0	0	13
1135	0	0	0	0	0	0	3	2	0	0	0	0	0	0	0	5
1136	0	0	0	0	0	0	6	5	0	0	0	0	0	2	0	13
1137	0	0	0	0	0	0	3	4	0	0	0	0	0	1	0	8
1138	0	0	0	0	0	0	4	2	0	0	0	0	0	0	0	6
1139	0	0	0	0	0	0	4	4	0	0	0	0	0	1	0	9
1140	0	0	0	0	0	0	3	6	0	0	0	0	0	1	1	14
1141	0	0	0	0	0	0	6	3	0	0	0	0	0	4	0	13
1142	0	0	0	0	0	0	3	1	0	0	0	0	0	3	0	7
1143	0	0	0	0	0	0	4	3	0	0	0	0	0	2	0	9
1144	0	0	0	0	0	0	4	7	0	0	0	0	0	1	0	12
1145	0	0	0	0	0	0	5	4	0	0	0	0	0	0	0	9
1146	0	0	0	0	0	0	3	2	0	0	0	0	0	0	1	9
1147	0	0	0	0	0	0	3	2	0	0	0	0	0	3	0	8
1148	0	0	0	0	0	0	4	6	0	0	0	0	0	1	0	11
1149	0	0	0	0	0	0	8	2	0	0	0	0	0	2	0	12
1150	0	0	0	0	0	0	3	2	0	0	0	0	0	2	0	7
1151	0	0	0	0	0	0	3	6	0	0	0	0	0	1	0	10
1152	0	0	0	0	0	0	2	1	2	0	0	0	0	5	0	18
1153	0	0	0	0	0	0	4	4	0	0	0	0	0	1	0	9

Appendix F: Orthodontist Rater Scores for Each Model

Model #	001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	Median	Mode	Mean	SD
1001	6		9	9		5	6	7	11	6		3	8	6	7	6.5	6	6.916666667	2.108783938
1002	10		10	11		10	10	7	12	9		5	12	11	10	10	10	9.75	2.00567377
1003	9		9	12		10	9	7	11	9		9	10	9	7	9	9	9.25	1.422226168
1004	3		7	12		8	3	5	8	9		4	10	6	6	6.5	3	6.75	2.800162333
1005	1		2	7		4	3	3	3	1		1	1	1	2	2	1	2.416666667	1.781640375
1006	9		8	11		10	8	7	12	10		10	10	7	10	10	10	9.333333333	1.556997888
1007	9		10	12		9	9	8	12	10		10	10	10	8	10	10	9.75	1.288057029
1008	9		9	12		11	10	9	12	12		12	10	12	10	10.5	12	10.66666667	1.302677895
1009	9		8	11		7	7	6	11	9		6	6	9	7	7.5	9	8	1.809068067
1010	9		9	11		10	7	7	11	11		8	10	8	7	9	11	9	1.59544807
1011	9		8	12		10	5	7	11	11			9	9	8	9	9	9	2
1012	10		8	12		10	10	11	12	10		7	9	9	10	10	10	9.833333333	1.466804401
1013	5		3	7		3	3	3	3	1		4	1	1	2	3	3	3	1.758098146
1014	4		2	4		3	3	4	10	1		2	1	1	2	2.5	4	3.083333333	2.466441431
1015	9			12		10	10	7	11	11		10	10	9	10	10	10	9.909090909	1.300349603
1016	4		2	11		4	3	4	8	4		5	1	4	6	4	4	4.666666667	2.674231694
1017	4		5	10		7	4	6	9	7		4	6	6	6	6	6	6.166666667	1.898963034
1018	4		5	5		6	4	5	5			2	6	3	2	5	5	4.272727273	1.831955405
1019	9		8	11		10	10	7	11	7		2	10	10	7	9.5	10	8.5	2.540579748
1020	3		4	6		2	3	2	8	2		2	1	1	2	2	2	3	2.088931871
1021	8		7	10			7	6	10	9		8	8	9		8	8	8.2	1.316561177
1022	2		3	7		3	4	5	3	2		6	6	3	2	3	3	3.833333333	1.749458791
1023	1		3	6		6	2	3	4	2		1	1	1	2	2	1	2.666666667	1.825741858
1024	9		7	10		10	4	6		7			9	7	7	7	7	7.6	1.897366596
1025	1		4	2		3	2	2	1	1		1	3	1	2	2	1	1.916666667	0.99620492
1026	9		8	11		10	9	9	10	10		11	10	9	7	9.5	9	9.416666667	1.164500153
1027	10		8	11		10	8	7	10	9		8	11	10	7	9.5	10	9.083333333	1.443375673
1028	9		7	9		10	7	7	5	7		4	10	10	7	7	7	7.666666667	1.969463856
1029	7		6	10		6	7	6	10	7		6	7	9	7	7	7	7.333333333	1.497472618
1030	8		6	10		10	6	5	10	6		11	7	9	8	8	6	8	2
1031	9		8	12		10	9	9	10	8		9	10	10	7	9	9	9.25	1.288057029
1032	3		5	3		3	3	4	4	1		5	5	2	1	3	3	3.25	1.422226168
1033	4		3	10		6	2	3	3	2		4	1	1	2	3	3	3.416666667	2.503028469
1034	8		8	11		9	7	6	9	6		5	10	9	7	8	9	7.916666667	1.781640375
1035	9		9	10		10	9	7	10	7		7	10	9	7	9	9	8.666666667	1.302677895
1036	9		6	10		7	8	5	6	6		11	4	6	6	6	6	7	2.088931871
1037	9		7	10		7	7	6	9	6			8	4	7	7	7	7.272727273	1.678744119
1038	9		4	7	7	6	4	5	9	6		4	8	7	5	6	4	6.230769231	1.786703023
1039	7		8	11	9	7	7	6	9	6		4	6	4	6	7	6	6.923076923	1.977436828
1040	9		8	12	12	10	7	7	10	7		9	9	11	7	9	7	9.076923077	1.846687957
1041	9		8	12	10	7	7	6	10	10		8	7	9	6	8	10	8.384615385	1.804552647
1042	8		8	12	11	7	7	6	9	9		10	9	9	6	9	9	8.538461538	1.808101427
1043	9		9	12	11	10	9	9	12	9		11	11	9	9	9	9	10	1.224744871
1044	7		8	11	9	10	7	6	10	6		7	9	9	7	8	7	8.153846154	1.625123269
1045	9		8	12		10	10	7	10	9		9	10	10	8	9.5	10	9.333333333	1.302677895
1046	3		4	12	8	2	1	2	3	1		2	1	6	2	2	2	3.615384615	3.254188622

Model #	001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	Median	Mode	Mean	SD
1047	5		5	6	8	6	4	5	7	5		2	8	7	2	5	5	5.384615385	1.938146087
1048	3		5	7	7	3	1	2	2	6		2	1	2	2	2	2	3.307692308	2.175033156
1049	9		10	12	11	10	10	10	11	11		11	12	12	9	11	10	10.61538462	1.043907845
1050	7		6	10	10	9	5	6	10	7		4	5	10	3	7	10	7.076923077	2.49871762
1051	9		8	11	10	9	8	8	10	8		6	10	8	7	8	8	8.615384615	1.386750491
1052	4		4	6.5	5	4	6	5	3	2		2	3	2	2	4	2	3.730769231	1.562788435
1053	7		8	12	8	8	7	6	10	8		8	9	8	7	8	8	8.153846154	1.519109051
1054	6		6	12	9	9	7	6	9	9		6	9	10	2	9	9	7.692307692	2.529315302
1055	9		9	12	10	9		8	10	8		5	5	10	5	9	9	8.333333333	2.269694947
1056	9		6	12	10	10	7	6	9	9		4	9	8	7	9	9	8.153846154	2.115268062
1057	2		2	6.5	6	3	2	1	3	1		1	4	1	2	2	2	2.653846154	1.841473769
1058	7		5	12	9		7	5	8	6		4	6	8	2	6.5	7	6.583333333	2.574643253
1059	8		8	12	9		7	7	10	7		8	9	10	7	8	7	8.5	1.566698904
1060	9		10	12	11	10	10	8	12	10		10	10	12	10	10	10	10.30769231	1.182131929
1061	9		7	12	10	10	8	5	10	8		8	9	10	7	9	10	8.692307692	1.797434069
1062	3		5	7	6	2	2	2	3	1		1	1	2	2	2	2	2.846153846	1.951330907
1063	7		9	11	9	9	7	6	9	7		8	9	8	7	8	9	8.153846154	1.344504484
1064	9		7	10	10	10	10	8	10	7		12	9	10	10	10	10	9.384615385	1.386750491
1065	9		9	10	10	10	10	8	11	10		12	10	10	8	10	10	9.769230769	1.091928428
1066	9		9	12	12	10	10	7	10	10		12	10	11	9	10	10	10.07692308	1.441153384
1067	7		9	12	10	10	10	7	10	10		10	10	8	8	10	10	9.307692308	1.436698495
1068	10		6	12	9	10	9	9	11	7		6	10	10	10	10	10	9.153846154	1.818706218
1069	8		8	10	10		9	9	10	7		4	10	7	7	8.5	10	8.25	1.815338686
1070	7		8	9	10	7	6	6	7	7		5	7	4	5	7	7	6.769230769	1.640825308
1071	9		9	12	11	8	10	11	9	10		11	10	12	10	10	10	10.15384615	1.214231845
1072	1		4	2	3	3	1	2	4	1		1	1	1	2	2	1	2	1.154700538
1073	4		5	9	8	6	7	6	10	6		4	9	4	7	6	4	6.538461538	2.025478734
1074	7		6	9	9	4	8	7	10	9		4	9	7	7	7	7	7.384615385	1.894661867
1075	11		9	9	10	10	10	10	9	10		7	10	11	9	10	10	9.615384615	1.043907845
1076	8		5	9	10	9	5	7	9	7		4	7	11	6	7	9	7.461538462	2.10615703
1077	3		4	9	5	2	3	4	3	3		1	1	1	2	3	3	3.153846154	2.154303981
1078	5		4	11	9	3	2	4	8	5		2	7	3	4	4	4	5.153846154	2.794224813
1079	1		4	6	2	2	2	4	3	1		3	1	2	2	2	2	2.538461538	1.450022104
1080	1		4	2	4	3	2	3	3	1		2	1	2	2	2	2	2.307692308	1.031553471
1081	10		9	7	9	9	7	9	9	1		8	10	9	10	9	9	8.230769231	2.385855757
1082	7		5	9	9	4	7	7	9	7		5	5	4	7	7	7	6.538461538	1.808101427
1083	7		8	9	10	9	7	7	10	9		6	7	7	6	7	7	7.846153846	1.405118847
1084	9		9	10	9	9	7	9	10	9		10	9		6	9	9	8.833333333	2.703274368
1085	8			12	6	9	6	9	10	7		10	5	7	2	7.5	6	7.583333333	2.678477632
1086	4		1	3	2	2	2	4	1	1		1	1	1	2	2	1	1.923076923	1.11516355
1087	7		9	9	9	9	6	6	9	9		9	9	7	6	9	9	8	1.354006401
1088	9		8	9.5	11		7	8	10	8		9	9	9	7	9	9	8.708333333	1.176634904
1089	8		7	11	10	10	9	8	10	8		10	8	9	7	9	8	8.846153846	1.28102523
1090	2		4	8	7	4	6	3	6	6		3	1	6	3	4	6	4.538461538	2.10615703
1091	7		4	8	7	8	6	5	7	4		4	6	4	5	6	4	5.769230769	1.535895296
1092	3		4	4	5	1	7	4	7	5		1	1	4	3	4	4	3.769230769	2.006400016
1093	3		6	9	7	7	7	4	4	5		3	1	3	3	4	3	4.769230769	2.278663576
1094	3		1		3	9	6	6	3	2		3	8	1	3	3	3	4	2.628514963

Model #	001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	Median	Mode	Mean	SD
1095	9		12	12	12	12	10	10	10	12		11	10	12		11.5	12	11	1.12815215
1096	1		1		1	7	2	2	3	3		4	2	1	2	2	1	2.416666667	1.729862492
1097	3		1	5	9	6	2	4	3	1		4	1	2	2	3	1	3.307692308	2.323238235
1098	9		10	12	11	12	10	10	11	12		12	10	12	8	11	12	10.69230769	1.315587029
1099	9		7	7	7	8	6	7	6	7		5	8	3	5	7	7	6.538461538	1.560736184
1100	9		7	7	8	9	7	7	8	9		7	9	4	5	7	7	7.384615385	1.556623565
1101	9		9		10	10	10	9	10	11	11		10	12	7	10	10	9.833333333	1.267304465
1102	4		1		2	8	2	3	3	6	4	9	8	7	2	4	2	4.538461538	2.726884199
1103	6		5		7	7	6	6	5	6	8	3	6	5	2	6	6	5.538461538	1.613246448
1104	9		10		9	10	8	7	10	9	11	5	8	12	7	9	9	8.846153846	1.863963244
1105	1		1		2	3	2	3	3	1	2	4	1	1	2	2	1	2	1
1106	5		4		4	3	4	5	6	4	9	2	5	2	4	4	4	4.153846154	1.28102523
1107	9		7		9	10	7	7	6	8	9	9	10	12	9	9	9	8.615384615	1.609268029
1108	4		6		6	10	5	6		6	7	6	5	3	5	6	6	5.75	1.712255291
1109	8		7	12	9	9	6	7	9	9	10	7	8	7	7	8	7	8.178571429	1.4885091
1110	6		8	12	10	10	6	7	7	10	10	9	5	7	7	7.5	10	8.107142857	1.962911607
1111	9		10	12	12	9	10	8	9	12	11	9	10	10	10	10	10	10.07142857	1.268814451
1112	9		10	12	11	10	9	8	9	10	12	10	10	12	7	10	10	9.928571429	1.491735474
1113	9		10	12	10	10	9	8		10	11	11	10	12	10	10	10	10.15384615	1.14354375
1114	9		7	12	12	10	7	6	10	8	10	11	6	9	9	9	9	9	2
1115	4		4	12	10	4	10	4	10	7	11	2	4	8	7	7	4	6.928571429	3.269069162
1116	9		10	12	12	10	11	10	11	12	12	10	10	12	10	10.5	10	10.78571429	1.050902281
1117	9		4	12	10	10	4	8	11		11	8	4	12	7	9	4	8.461538462	3.634390074
1118	9		9	12	12	10	9	9	10	9	9	11	10	12	9	9.5	9	10	1.240347346
1119	9		9	12	12	11	10	8	9		10	10	10	10	8	10	10	9.846153846	2.905092157
1120	9		10	12	11	10	10	10	11	11	11	12	11	12	10	11	10	10.71428571	0.913873533
1121	5		6	12	8	10	2	6	5	7	8	4	4	7	6	6	6	6.428571429	2.563479778
1122	9		9	12	12	11	11	10	10	12	9	12	9	9	8	10	9	10.21428571	1.42389344
1123	9			12	11	10	9	9		12	11	12	11	9	10	10.5	9	10.41666667	1.240112409
1124	9		8	12	11	9	8	7	10	9		5	10	8	8	9	8	8.769230769	1.786703023
1125	9		10	12	9	10	9	8	10	10		9	9	11	10	10	9	9.692307692	1.031553471
1126	7		8	12	9	6	9	6	10	4		4	5	7	8	7	7	7.307692308	2.358835001
1127	7		10	12	9	9	9	7	10	10			9	10	8	9	10	9.166666667	1.403458931
1128	8		9	11	7	7	9	6	10	9		5	9	8	8	8	9	8.153846154	1.625123269
1129	6		6	10	4	6	6	5	9	9		4	6	6	6	6	6	6.384615385	1.850155919
1130	9		8	10	7	7	7	5	8	10		5	6	6	6	7	7	7.230769231	1.690850188
1131	3		4	10	3	6	4	2	6	6		5	4	3	1	4	3	4.384615385	2.292686253
1132	9		10	12	11	10	10	9	10	11		11	10	10	10	10	10	10.23076923	0.832050294
1133	7		5	10	6	7	5	5	9	7		5	6	4	6	6	5	6.307692308	1.702185624
1134	9		9	12	11	10	9	8	10	9		12	9	9	10	9	9	9.769230769	1.23516842
1135	4		3	11	4	7	5	5	4	5		3	4	2	7	4	4	4.923076923	2.325995789
1136	8		9	12	9	7	9	7	10	10		8	10	9	9	9	9	9	1.354006401
1137	3		1	6	5	10	3	4	3	1		2	1	1	5	3	1	3.461538462	2.601774542
1138	6		1	9	4	7	3	2	3	1		3	1	2	1	3	1	3.307692308	2.562050461
1139	9		9	12	11	7	8	7	10	9		9	9	9	7	9	9	8.923076923	1.497861724
1140	9		5	9	11	9	8	7	6	8		9	5		10	8.5	9	8	1.906925178
1141	8		8	11	6		5	5	10			4	6	4	5	6	5	6.545454545	2.381748785
1142	2		5	12	4	6	4	4	2	9		4	4	2	4	4	4	4.769230769	2.862220762

Model #	001	002	003	004	005	006	007	008	009	010	011	012	013	014	015	Median	Mode	Mean	SD
1143	9		9	12	10	9	10	8	10	3		8	10	9	10	9	10	9	2.081665999
1144	9		9	12	10	7	10	8	9	10		9	5	8	9	9	9	8.846153846	1.675616993
1145	7		9	9	7	3	4	4	4	2		3	1	3	3	4	3	4.538461538	2.601774542
1146	7		6	8	4	6	4	4	5	2		4	8	3	5	5	4	5.076923077	1.846687957
1147	6		8	12	6	9	6	6		6		5	9	7	7	6.5	6	7.25	1.95982374
1148	9		6	9	8		7	5	4	6		3	10	4	7	6.5	9	6.5	2.798809271
1149	9		9	12	11	9	9	8	10	9		9	11	9	7	9	9	9.384615385	1.32529629
1150	4		8	12	9	7	5	4	6	7		4	6	7	6	6	4	6.538461538	2.258885589
1151	10		5	3	9	10	7	9	10	10		9	10	2	2	9	10	7.384615385	3.228479042
1152	7		9	12	10	10	6	7	10	7		7	10	10	8	9	10	8.692307692	1.797434069
1153	4		3	10	5	6	5	4	4	5		2	4	4	1	4	4	4.384615385	2.142368687
														AVG		7.06536	6.88	7.169683856	1.809259195

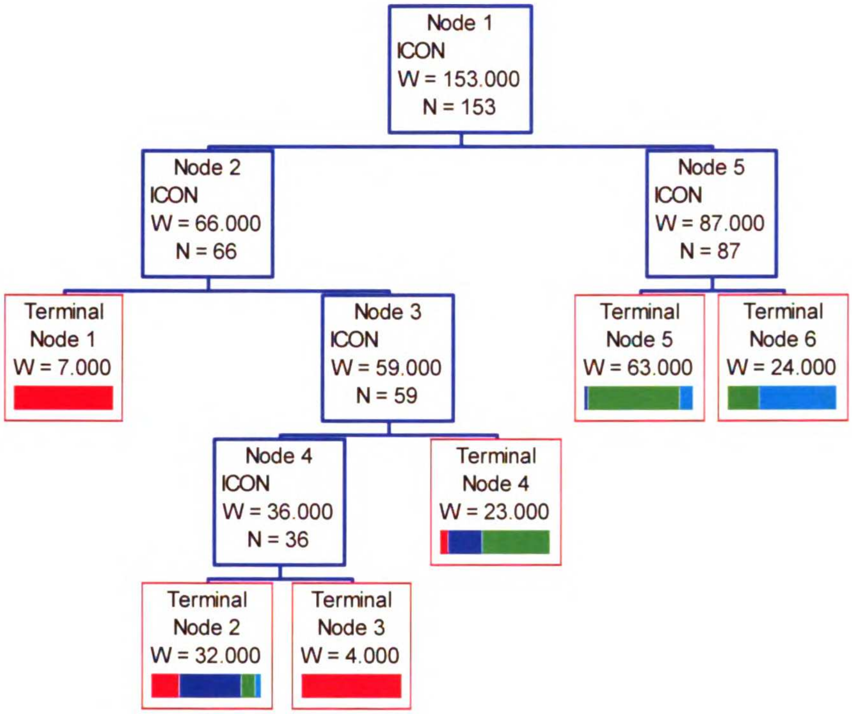
Appendix G: Scheffe Grid

Scheffe for Gold Standard Orthodontic Raters
Effect: Category for Gold Standard Orthodontic Raters
Significance Level: 5 %

	Mean Diff	Crit Diff	P-Value	
Rater 1, Rater 3	.223	1.522	> .9999	
Rater 1, Rater 4	-3.089	1.540	< .0001	S
Rater 1, Rater 5	-1.479	1.634	.1414	
Rater 1, Rater 6	-.809	1.532	.9219	
Rater 1, Rater 7	.317	1.517	> .9999	
Rater 1, Rater 8	.667	1.514	.9817	
Rater 1, Rater 9	-1.185	1.527	.3922	
Rater 1, Rater 10	-.057	1.524	> .9999	
Rater 1, Rater 12	.599	1.527	.9935	
Rater 1, Rater 13	-.150	1.514	> .9999	
Rater 1, Rater 14	-.025	1.519	> .9999	
Rater 1, Rater 15	.836	1.519	.8949	
Rater 3, Rater 4	-3.311	1.548	< .0001	S
Rater 3, Rater 5	-1.701	1.641	.0316	S
Rater 3, Rater 6	-1.031	1.540	.6628	
Rater 3, Rater 7	.094	1.524	> .9999	
Rater 3, Rater 8	.444	1.522	.9997	
Rater 3, Rater 9	-1.407	1.534	.1249	
Rater 3, Rater 10	-.280	1.532	> .9999	
Rater 3, Rater 12	.376	1.534	> .9999	
Rater 3, Rater 13	-.373	1.522	> .9999	
Rater 3, Rater 14	-.247	1.527	> .9999	
Rater 3, Rater 15	.614	1.527	.9919	
Rater 4, Rater 5	1.610	1.659	.0706	
Rater 4, Rater 6	2.280	1.558	< .0001	S
Rater 4, Rater 7	3.405	1.543	< .0001	S
Rater 4, Rater 8	3.755	1.540	< .0001	S
Rater 4, Rater 9	1.904	1.553	.0016	S
Rater 4, Rater 10	3.032	1.550	< .0001	S
Rater 4, Rater 12	3.688	1.553	< .0001	S
Rater 4, Rater 13	2.938	1.540	< .0001	S
Rater 4, Rater 14	3.064	1.545	< .0001	S
Rater 4, Rater 15	3.925	1.545	< .0001	S
Rater 5, Rater 6	.670	1.651	.9912	
Rater 5, Rater 7	1.795	1.637	.0136	S
Rater 5, Rater 8	2.145	1.634	.0003	S
Rater 5, Rater 9	.294	1.646	> .9999	
Rater 5, Rater 10	1.422	1.644	.2031	
Rater 5, Rater 12	2.078	1.646	.0008	S
Rater 5, Rater 13	1.328	1.634	.3064	
Rater 5, Rater 14	1.454	1.639	.1669	
Rater 5, Rater 15	2.315	1.639	< .0001	S
Rater 6, Rater 7	1.125	1.535	.5003	
Rater 6, Rater 8	1.475	1.532	.0770	
Rater 6, Rater 9	-.376	1.545	> .9999	
Rater 6, Rater 10	.752	1.542	.9573	
Rater 6, Rater 12	1.408	1.545	.1325	
Rater 6, Rater 13	.658	1.532	.9852	
Rater 6, Rater 14	.784	1.537	.9395	
Rater 6, Rater 15	1.645	1.537	.0200	S
Rater 7, Rater 8	.350	1.517	> .9999	
Rater 7, Rater 9	-1.501	1.529	.0622	
Rater 7, Rater 10	-.374	1.527	> .9999	
Rater 7, Rater 12	.282	1.529	> .9999	
Rater 7, Rater 13	-.467	1.517	.9994	
Rater 7, Rater 14	-.341	1.522	> .9999	
Rater 7, Rater 15	.520	1.522	.9983	
Rater 8, Rater 9	-1.851	1.527	.0021	S
Rater 8, Rater 10	-.724	1.524	.9656	
Rater 8, Rater 12	-.068	1.527	> .9999	
Rater 8, Rater 13	-.817	1.514	.9086	
Rater 8, Rater 14	-.691	1.519	.9757	
Rater 8, Rater 15	.170	1.519	> .9999	
Rater 9, Rater 10	1.128	1.537	.4990	
Rater 9, Rater 12	1.784	1.540	.0052	S
Rater 9, Rater 13	1.034	1.527	.6441	
Rater 9, Rater 14	1.160	1.532	.4388	
Rater 9, Rater 15	2.021	1.532	.0003	S
Rater 10, Rater 12	.656	1.537	.9860	
Rater 10, Rater 13	-.093	1.524	> .9999	
Rater 10, Rater 14	.032	1.529	> .9999	
Rater 10, Rater 15	.893	1.529	.8443	
Rater 12, Rater 13	-.749	1.527	.9551	
Rater 12, Rater 14	-.624	1.532	.9908	
Rater 12, Rater 15	.237	1.532	> .9999	
Rater 13, Rater 14	.126	1.519	> .9999	
Rater 13, Rater 15	.986	1.519	.7119	
Rater 14, Rater 15	.861	1.524	.8747	

Appendix H: CART Analysis for ICON

CART REPORT FOR ICON



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Target Frequency Table

======================

Variable: GOLD_STAN_CAT_FOR_1234$
N Classes: 4

Data Value	N	Wgt Count
1	21	21
2	28	28
3	77	77
4	27	27
Total	153	153

PRIORS SET EQUAL

CURRENT MEMORY REQUIREMENTS
TOTAL: 10906. DATA: 306. ANALYSIS: 10906.
AVAILABLE: 10000000. SURPLUS: 9989094.

The data are being read ...

153 Observations in the learning sample.
FILE: C:\Documents and Settings\Dr Mary Cooke\Desktop\CART Data.XLS[xls7]

CART is running.

=============
TREE SEQUENCE
=============

Dependent variable: GOLD_STAN_CAT_FOR_1234$

Tree	Terminal Nodes	Cross-Validated Relative Cost	Resubstitution Relative Cost	Complexity Parameter
1	19	0.599 +/- 0.060	0.348	0.000000
3	16	0.575 +/- 0.060	0.352	0.001498
4	13	0.575 +/- 0.060	0.364	0.002986
5	11	0.559 +/- 0.060	0.373	0.003257
6	10	0.520 +/- 0.059	0.379	0.004880
7	7	0.520 +/- 0.059	0.412	0.008187
8*	6	0.515 +/- 0.059	0.426	0.010562
9**	4	0.531 +/- 0.055	0.490	0.023820
10	3	0.594 +/- 0.037	0.565	0.056558
11	2	0.691 +/- 0.017	0.691	0.094767
12	1	1.000 +/- 0.000	1.000	0.231491

Initial misclassification cost = 0.750
Initial class assignment = 3

================
NODE INFORMATION
================

```
***********************************************
*            Node 1: ICON             *
*              N: 153            *
***********************************************

**********************************  *********************************
*         Node 2          *  *          Node 3          *
*          N: 66          *  *          N: 87          *
**********************************  *********************************
```

Node 1 was split on ICON
A case goes left if ICON <= 37.500
Improvement = 0.163284   Complexity Threshold = 0.231481

Node	Cases	Wgt Counts	Cost	Class
1	153	153.00	0.750	3
2	66	66.00	0.546	1
3	87	87.00	0.485	4

Weighted Counts

Class	Top	Left	Right
1	21.00	21.00	0.00
2	28.00	25.00	3.00
3	77.00	18.00	59.00
4	27.00	2.00	25.00

Within Node Probabilities

Class	Top	Left	Right
1	0.250	0.454	0.000
2	0.250	0.406	0.060
3	0.250	0.106	0.426

4	0.250	0.034	0.515

```
**********************************************
*           Node 2: ICON           *
*              N: 66          *
**********************************************
```

```
==========================  ==========================
=    Terminal Node 1    = =    Terminal Node 2    =
=        N: 7           = =        N: 59          =
==========================  ==========================
```

Node 2 was split on ICON
A case goes left if ICON <= 17.500
Improvement = 0.046620 Complexity Threshold = 0.056548

Node	Cases	Wgt Counts	Cost	Class
2	66	66.00	0.546	1
-1	7	7.00	0.000	1
-2	59	59.00	0.522	2

Weighted Counts

Class	Top	Left	Right
1	21.00	7.00	14.00
2	25.00	0.00	25.00
3	18.00	0.00	18.00
4	2.00	0.00	2.00

Within Node Probabilities

Class	Top	Left	Right
1	0.454	1.000	0.357
2	0.406	0.000	0.478
3	0.106	0.000	0.125
4	0.034	0.000	0.040

```
**********************************************
*           Node 3: ICON           *
*              N: 87          *
**********************************************
```

```
==========================  ==========================
=    Terminal Node 3    = =    Terminal Node 4    =
=        N: 63          = =        N: 24          =
==========================  ==========================
```

Node 3 was split on ICON
A case goes left if ICON <= 58.500
Improvement = 0.066821 Complexity Threshold = 0.094757

Node	Cases	Wgt Counts	Cost	Class
3	87	87.00	0.485	4
-3	63	63.00	0.374	3
-4	24	24.00	0.126	4

Weighted Counts

Class	Top	Left	Right
1	0.00	0.00	0.00
2	3.00	3.00	0.00
3	59.00	52.00	7.00
4	25.00	8.00	17.00

	Within Node Probabilities		
Class	Top	Left	Right
1	0.000	0.000	0.000
2	0.060	0.099	0.000
3	0.426	0.626	0.126
4	0.515	0.275	0.874

========================

TERMINAL NODE INFORMATION

========================

[Breiman adjusted cost, lambda = 0.011]

```
Node         N  Prob  Cost      Class
--------------------------------------------------------------------------------
  1        7 0.0833 0.0000  1
                 Parent C.T. = 0.057
                 [0.1156]

           7 1.0000     1
           0 0.0000     2
           0 0.0000     3
           0 0.0000     4

  2       59 0.4668 0.5219  2
                 Parent C.T. = 0.057
                 [0.5446]

          14 0.3570     1
          25 0.4781     2
          18 0.1252     3
           2 0.0397     4

  3       63 0.2697 0.3740  3
                 Parent C.T. = 0.095
                 [0.4127]

           0 0.0000     1
           3 0.0993     2
          52 0.6260     3
           8 0.2747     4

  4       24 0.1801 0.1262  4
                 Parent C.T. = 0.095
                 [0.1831]

           0 0.0000     1
           0 0.0000     2
           7 0.1262     3
          17 0.8738     4
```

Node	Learn				
1	7.00	7.00	0.00	0.00	0.00
2	59.00	14.00	25.00	18.00	2.00
3	63.00	0.00	3.00	52.00	8.00
4	24.00	0.00	0.00	7.00	17.00

MISCLASSIFICATION BY CLASS

(Cross Validation)

Class	Prior Prob	Wgt Count		Wgt Count	Misclass	Misclass	Cost
1							
	0.250	21.00	21	14.00	14	0.667	
		(21.00	21	14.00	14	0.667)	
2							
	0.250	28.00	28	3.00	3	0.107	
		(28.00	28	4.00	4	0.143)	
3							
	0.250	77.00	77	25.00	25	0.325	
		(77.00	77	26.00	26	0.338)	
4							
	0.250	27.00	27	10.00	10	0.370	
		(27.00	27	12.00	12	0.444)	
Total	1.000	153.00	153	52.00	52		
		(153.00	153	56.00	56)		

VARIABLE IMPORTANCE

	Relative Importance	Number Of Categories	Penalty
ICON	100.000		

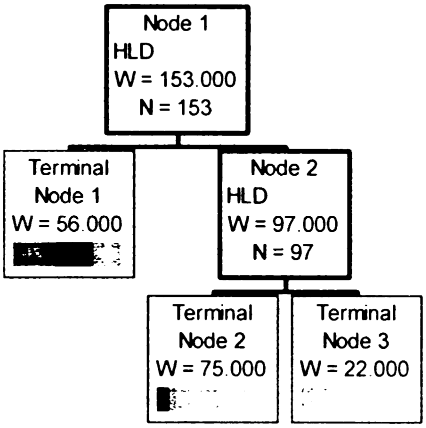
OPTION SETTINGS

Construction Rule Gini (priors altered by costs)
Estimation Method 10-fold cross-validation
Misclassification Costs Unit
Tree Selection 1.000 se rule
Linear Combinations No

Initial value of the complexity parameter = 0.000
Minimum size below which node will not be split = 10
Node size above which sub-sampling will be used = 153
Maximum number of surrogates used for missing values = 0
Number of surrogate splits printed = 0
Number of competing splits printed = 0
Maximum number of trees printed in the tree sequence = 10
Max. number of cases allowed in the learning sample = 153
Maximum number of cases allowed in the test sample = 0
Max # of nonterminal nodes in the largest tree grown = 153
(Actual # of nonterminal nodes in largest tree grown = 22)
Max. no. of categorical splits including surrogates = 1
Max. number of linear combination splits in a tree = 0
(Actual number cat. + linear combination splits = 0)
Maximum depth of largest tree grown = 15

Appendix I: CART Analysis for HLD(CalMod)

CART REPORT FOR HLD(CalMod)



CART version 5.0.9.156

Records Read: 153
Records Written in Learning sample: 153

Discrete Variable	N Levels in Model
GOLD_STAN_CAT_FOR_1234$	4

Target Frequency Table

Variable: GOLD_STAN_CAT_FOR_1234$
N Classes: 4

Data Value	N	Wgt Count
1	21	21
2	28	28
3	77	77
4	27	27
Total	153	153

PRIORS SET EQUAL

CURRENT MEMORY REQUIREMENTS
TOTAL: 10906. DATA: 306. ANALYSIS: 10906.
AVAILABLE: 10000000. SURPLUS: 9989094.

The data are being read ...

153 Observations in the learning sample.
FILE: C:\Documents and Settings\Dr Mary Cooke\Desktop\CART Data.XLS[xls7]

CART is running.

=============
TREE SEQUENCE
=============

Dependent variable: GOLD_STAN_CAT_FOR_1234$

Tree	Terminal Nodes	Cross-Validated Relative Cost	Resubstitution Relative Cost	Complexity Parameter
1	12	0.702 +/- 0.055	0.515	0.000000
2	10	0.713 +/- 0.054	0.523	0.002997
3	9	0.737 +/- 0.052	0.527	0.003257
4	6	0.724 +/- 0.052	0.542	0.003798
5	4	0.660 +/- 0.043	0.553	0.003918
6**	3	0.589 +/- 0.036	0.572	0.014891
7	2	0.691 +/- 0.017	0.691	0.089236
8	1	1.000 +/- 0.000	1.000	0.231492

Initial misclassification cost = 0.750
Initial class assignment = 3

================
NODE INFORMATION
================

```
         *********************************************
         *            Node 1: HLD               *
         *              N: 153            *
         *********************************************

  ================================  *********************************
  =     Terminal Node 1      =  *         Node 2           *
  =         N: 56            =  *         N: 97           *
  ================================  *********************************
```

Node 1 was split on HLD
A case goes left if HLD <= 8.500
Improvement = 0.141018   Complexity Threshold = 0.231482

Node	Cases	Wgt Counts	Cost	Class
1	153	153.00	0.750	3
-1	56	56.00	0.483	1
2	97	97.00	0.552	4

Weighted Counts

Class	Top	Left	Right
1	21.00	21.00	0.00
2	28.00	19.00	9.00
3	77.00	14.00	63.00
4	27.00	2.00	25.00

Within Node Probabilities

Class	Top	Left	Right
1	0.250	0.517	0.000
2	0.250	0.351	0.156
3	0.250	0.094	0.396
4	0.250	0.038	0.448

```
*********************************************
*          Node 2: HLD         *
*            N: 97           *
*********************************************

==================================  ==================================
=      Terminal Node 2      = =      Terminal Node 3      =
=          N: 75            = =          N: 22            =
==================================  ==================================
```

Node 2 was split on HLD
A case goes left if HLD <= 18.500
Improvement = 0.060808 Complexity Threshold = 0.089226

Node	Cases	Wgt Counts	Cost	Class
2	97	97.00	0.552	4
-2	75	75.00	0.488	3
-3	22	22.00	0.141	4

Weighted Counts

Class	Top	Left	Right
1	0.00	0.00	0.00
2	9.00	9.00	0.00
3	63.00	56.00	7.00
4	25.00	10.00	15.00

Within Node Probabilities

Class	Top	Left	Right
1	0.000	0.000	0.000
2	0.156	0.227	0.000
3	0.396	0.512	0.141
4	0.448	0.261	0.859

=========================
TERMINAL NODE INFORMATION
=========================

[Breiman adjusted cost, lambda = 0.005]

```
Node        N  Prob   Cost       Class
------------------------------------------------------------------------
  1        56 0.4836 0.4831  1
                  Parent C.T. = 0.231
                  [0.4946]

           21 0.5169       1
           19 0.3508       2
           14 0.0940       3
            2 0.0383       4

  2        75 0.3548 0.4875  3
                  Parent C.T. = 0.089
                  [0.5032]

            0 0.0000       1
            9 0.2265       2
```

56 0.5125 3
10 0.2610 4

3 22 0.1616 0.1406 4
Parent C.T. = 0.089
[0.1746]

0 0.0000 1
0 0.0000 2
7 0.1406 3
15 0.8594 4

Node	Learn				
1	56.00	21.00	19.00	14.00	2.00
2	75.00	0.00	9.00	56.00	10.00
3	22.00	0.00	0.00	7.00	15.00

========================
MISCLASSIFICATION BY CLASS
========================

(Cross Validation)

Class	Prior Prob	Wgt Count	Count	Wgt Misclass	Misclass	Cost
1						
	0.250	21.00	21	0.00	0	0.000
		(21.00	21	0.00	0	0.000)
2						
	0.250	28.00	28	28.00	28	1.000
		(28.00	28	28.00	28	1.000)
3						
	0.250	77.00	77	21.00	21	0.273
		(77.00	77	22.00	22	0.286)
4						
	0.250	27.00	27	12.00	12	0.444
		(27.00	27	13.00	13	0.481)
Total	1.000	153.00	153	61.00	61	
		(153.00	153	63.00	63)	

==================
VARIABLE IMPORTANCE
==================

	Relative Importance	Number Of Categories	Penalty
HLD	100.000		

===============
OPTION SETTINGS
===============

Construction Rule Gini (priors altered by costs)
Estimation Method 10-fold cross-validation
Misclassification Costs Unit
Tree Selection 0.000 se rule
Linear Combinations No

Initial value of the complexity parameter = 0.000
Minimum size below which node will not be split = 10
Node size above which sub-sampling will be used = 153
Maximum number of surrogates used for missing values = 0
Number of surrogate splits printed = 0
Number of competing splits printed = 0
Maximum number of trees printed in the tree sequence = 10
Max. number of cases allowed in the learning sample = 153
Maximum number of cases allowed in the test sample = 0
Max # of nonterminal nodes in the largest tree grown = 153
(Actual # of nonterminal nodes in largest tree grown = 16)
Max. no. of categorical splits including surrogates = 1
Max. number of linear combination splits in a tree = 0
(Actual number cat. + linear combination splits = 0)
Maximum depth of largest tree grown = 15
(Actual depth of largest tree grown = 7)
Exponent for center weighting in split criterion = 0.000
Maximum size of memory available = 10000000
(Actual size of memory used in run = 47425)

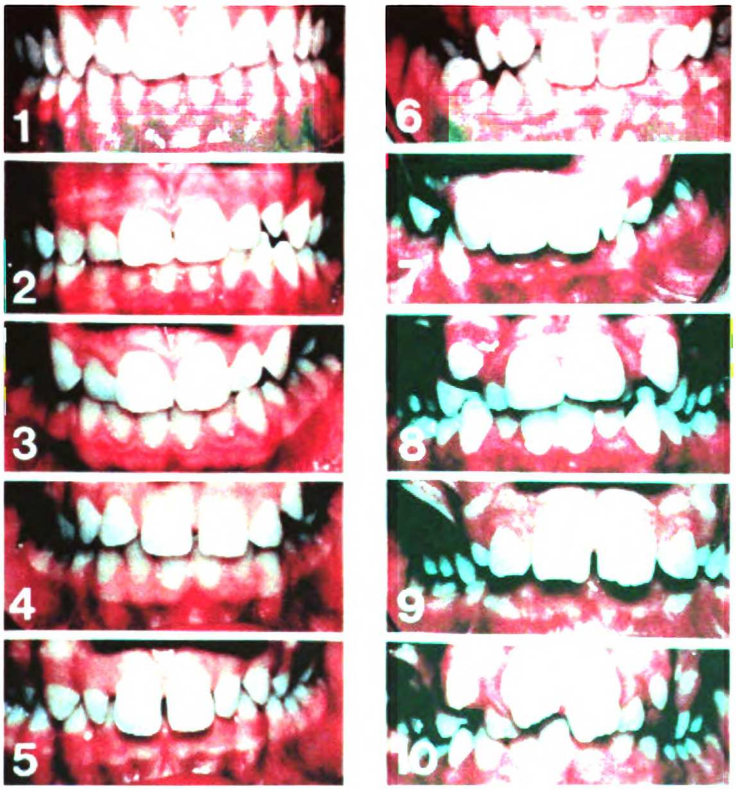
Appendix J: General Assumptions of the ICON

GENERAL ASSUMPTIONS OF THE INDEX

- When the index is used to assess treatment outcomes, it is assumed that an appropriate level of co-operation was obtained from the patient.
- The index may require confirmation of the presence of teeth using radiography.
- Except for the aesthetic assessment, occlusal traits are not scored to deciduous teeth unless they are to be retained in the permanent dentition to obviate the need for a prosthetic replacement, for example, when the permanent tooth is absent.
- The index contains five components, all of which must be scored.

DENTAL AESTHETIC COMPONENT

- The dental aesthetic component of the IOTN (Shaw *et al.*, 1991a) is used.
- The dentition is compared to the illustrated scale and a global attractiveness match is obtained without attempting to closely match the malocclusion to a particular picture on the scale. The scale works best in the permanent dentition.
- The scale is graded from 1 for the most attractive to 10 the least attractive dental arrangement. Once this score is obtained it is multiplied by the weighting of 7.



CROSSBITE

- A normal transverse relationship in the buccal segments is observed when the palatal cusps of the upper molar and premolar teeth occlude, preferably into the occlusal fossa of the opposing tooth, or at least between the lingual and buccal cusp tips of the opposing tooth. Crossbite is deemed to be present if a transverse relation of cusp to cusp or worse exists in the buccal segment. This includes buccal and lingual crossbites consisting of one or more teeth, with or without mandibular displacement.