The Development of an Objective Orthodontic Treatment-need Index

by

Dr. Ken Danyluk

A thesis submitted to the Faculty of Graduate Studies of the

University of Manitoba in partial fulfillment of the requirements

for the degree of

MASTER OF SCIENCE

Department of Oral Biology
University of Manitoba

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ABSTRACT

The growing realization that infinite demands conflict with the need to reduce the inflationary trends in resources has rekindled national debates on the provision of publicly-funded orthodontic services.

The development of an objective system for orthodontic service prioritization is a complex challenge, since complex trade-offs are required to balance equity, freedom of choice, comprehensiveness and cost containment. This project was designed to test the ability of the Dental Aesthetic Index (DAI) to objectively categorize and prioritize the orthodontic treatment-need of patients from publicly-funded resources. A two-stage assessment process was used to test the standard-DAI; both involved the assessment of thirty-eight randomly selected pre-treatment records (study models, lateral cephalograph, panorex, photographs) from a much larger sample of cases previously submitted for publicly-funded orthodontic treatment approval. The initial selection criteria included a wide range of malocclusions in subjects without psychological or social complications. The sample comprised thirty cases approved and eight cases not approved for orthodontic treatment. In addition, thirty-three of the cases exhibited a permanent dentition while five cases exhibited a mixed dentition.

Initially, 16 Manitoba Orthodontic specialists were required to independently quantify the malocclusion severity of each case by a pre-determined analog system. Subsequently, these same records were independently evaluated relative to the standard Dental Aesthetic Index (DAI) by six Graduate Orthodontic students with the following results:

- Initial Pearson coefficient calculations revealed a high degree of congruence ($r = 0.92$) between the Orthodontists' and standard-DAI assessments of malocclusion severity, indicating a strong ability of the standard-DAI to discern varying malocclusion severities.

- Subsequent 2x2 matrix table analysis of the standard-DAI versus the publicly-funded determination of treatment-need was calculated for the total case sample, as well as the permanent and mixed dentition subsamples. The standard-DAI exhibited a high degree of accuracy in determining orthodontic treatment-need for the total sample and permanent dentition subsamples, but at the expense of over-estimation. Analysis of the mixed dentition subsample indicated a low degree accuracy assessment with an extremely high degree of service-need over-estimation.
- Logistic regression analysis of the standard-DAI indicated that four components were critical in evaluating orthodontic treatment-need; **mandibular overjet, maxillary overjet, vertical anterior overbite and the anteroposterior molar relationship**. The four components were re-weighted and then applied to the raw data results with subsequent matrix table analysis revealing that the modified-DAI improved the accuracy of the treatment-need results and reduced the prevalence of treatment-need over-estimation.

The results indicate that the modified-DAI is not only a simple, quick and objective method to priorize orthodontic service-need, but may also be readily modified to accommodate the prevailing allocations of publicly-funded resources. Further assessments are required at a more national level prior to its general acceptance.

Introduction

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INTRODUCTION

1.0 General Overview of the Problem

Health care spending is one of the most intensely debated topics in North America, as illustrated by review of the health care expenses of the advanced economic countries in the world. For instance, relative to 6% in the United Kingdom, Japan spends 6.5% of gross domestic product (GDP) on health care. By contrast, Canada and the United States spend 9.2% and 12.1% of their respective GDP's on health care (Foote and Stoffman, 1996). Canada therefore spends more on health care than most other advanced countries, with questionable health returns (Foote and Stoffman, 1996). This implies either a large amount of waste is built into Canada's health care system, or the programs and procedures are relatively costly on a per capita basis.

The health care debate is not an entirely Canadian dilemma, and draws attention to the trade-offs involved in health care planning. These include such issues as balancing equity, freedom of choice, comprehensiveness and cost containment. Potential solutions to this problem are being actively pursued by different government agencies in a variety of ways. For instance, Oregon state has placed funding priorities for health care delivery on the basis of the cost effectiveness of different treatments and the public's views on health care treatment priorities. Although the scheme has been in operation for only a short time (initiated in 1994), service use continues to outstrip the available financial resources. Sweden has developed a financial remuneration priority-based system, with the greatest importance attached to life-threatening diseases relative to mild disorders. By contrast, New Zealand has opted to emphasize the use of guidelines to specify which patients should receive treatment (Ham, 1995). At this time, a single process to ration health care has yet to be universally accepted. However, with increasing financial restraints from all levels of government and the public and political outcry regarding government spending, public-funded health care programs have reached a point of decision making that focuses

on demand to balance public values, financial constraints and accountability. **These concerns are particularly relevant to the provision of publicly-funded orthodontic services.**

This introduction is divided into two major but inter-related sections. The first is primarily intended to over-view the most pertinent determinants affecting the publicly-funded orthodontic markets. Subsequently, the potential impact of recent fiscal changes to the dental program funded by Health Canada are analyzed to identify the major strategic issues affecting the provision of orthodontic services to the First Nations Treaty and Inuit communities. In addition, a rationale is provided for the use of an index to distinguish between those to be provided with treatment from those who should not.

1.1 The Nature of the Problem

Although Canada's publicly-funded dental market has always been minor relative to the private sector, a significant proportion of those eligible for benefits require orthodontic services. Yet no comprehensive epidemiological data are available to define the size of this burden. Also, those eligible for Non-Insured Health Benefits (NIHB) benefits generally exhibit higher dental disease prevalences (e.g., nursing caries) than most other Canadians (Milnes,1996). This leads to concerns whether the limited resources should be devoted to the provision of essential, as opposed to elective (e.g., orthodontic) services. This dilemma has potentially serious political consequences, since the high disease burdens for those eligible for NIHB benefits have not diminished but may rather intensify their orthodontic service demands. This is a common dilemma for many other health services and indicates a more fundamental problem, i.e., no resources can support unlimited orthodontic or other health care service demands. Such a concern is particularly relevant to the NIHB program funded by Health Canada, wherein increased demands for orthodontic services can only be provided at the expense of resources for other dental services. **The need to rationalize the provision of orthodontic services by publicly-**

funded resources, to ensure that such services are provided primarily to those that will receive the most benefit, therefore cannot be overstated.

Strategic development to rationalize the provision of orthodontic services in the NIHB dental program involve complex trade-offs to balance equity, freedom of choice, comprehensiveness and cost-containment. This common health care task (Getzen and Poullier, 1992; Turner, 1990) involves decisions between those who should/should not be provided with specific services. This proposal is designed to evaluate a potential instrument to rationalize the provision of orthodontic services to those eligible for NIHB benefits. An overview of recent changes to this market is required to appreciate the urgency of this enquiry.

1.2 Recent Changes in the Orthodontic Market

Dental service expenditures (i.e., excluding those associated with drugs, hospitalization and transportation) are surpassed only by those for cardiovascular (heart and stroke) diseases and mental disorders (Leake, 1992). But whereas they comprise significant components of the total health care budget, no national epidemiological data are available to define the dental, or more specifically orthodontic, service-needs of Canadians, especially those eligible for NIHB benefits. These data deficiencies have not been a significant concern to the predominant private market, however, since discretionary funds are often available to augment their private insurance payments. By contrast, such data deficiencies hamper the strategic development for the publicly-funded market to equate the availability of resources to the cost-effective provision of (orthodontic) services. These concerns are aggravated by the current use of relatively arbitrary criteria to discriminate between those who should/should not be provided by NIHB-funded orthodontic services. This is not a minor problem, since approximately 40% of those eligible for NIHB dental benefits are under 20 years of age, i.e., the age-group most prevalent for orthodontic anomalies.

In the absence of Canadian epidemiological data, strategic development of a program is necessarily based on information primarily extrapolated from data derived from the United States (U.S.). These have indicated marked declines in the decayed missing and filled surfaces (DMFS) in 5-17 year old children between the 1970s and 1980s (U.S. Dept of Health, 1972, 1981, 1989). As a result, almost 50% of U.S. children are dental caries free. Similar trends have also been reported from other countries (Burton *et.al.*, 1984; Picton, 1986) and have undoubtedly contributed to the increased demands for esthetic improvements, especially overcrowding. These trends are undoubtedly analogous to those in the Canadian market (Lewis *et.al.*, 1982), although there is a growing suspicion that general dentists are increasingly providing orthodontic and other esthetic services to compensate for revenue shortfalls from the declining demands for other services.

Major changes in dental disease status have similarly impacted on adult populations, although the relevant epidemiological information for Canada must again be abstracted from the U.S. (U.S. Dept of Health, 1987). In this market, marked increases in natural tooth retention have been associated with concomitantly higher levels of decayed and filled coronal tooth surfaces and demands for dental esthetic improvements (U.S. Dept of Health 1987). Continued increases in adult orthodontic service demands must therefore be anticipated in the future, although there are concerns whether the public will be prepared to continue to divert their discretionary funds for the provision of such services. In the case of the NIHB dental program, there is a national guideline that only eligible clients under the age of 18 years at the time of initial assessment are eligible for orthodontic services. Although growing orthodontic service demands characterize both publicly and privately-funded markets (Douglas and Furino, 1990), children and adolescents eligible for NIHB benefits are the principal concerns of this proposal. Nevertheless, **the development of strategies to constrain the demands for orthodontic services from the NIHB program will undoubtedly impact on those dependent on private funds.**

1.3 An Overview of the NIHB Dental Program

The 1950's witnessed a significant commitment by the Department of National Health and Welfare (now termed Health Canada) to provide dental (including orthodontic) services for people of First Nations Treaty and Inuit communities. Initially provided by salaried dentists in fixed and mobile dental facilities for the more remote northern populations, the scope of this NIHB dental program was augmented by the provision of services by fee-for-service generalist and specialist dentists in their private practices. The differential cost-efficiencies of these two payment systems have yet to be investigated, although the fee-for-service component consumes approximately 80% of the NIHB dental program's expenditures, but 100% of the orthodontic services (Cooney and Lavelle, 1996).

The NIHB dental program was established in 1962, although the Federal Government has always been committed to provide First Nations Treaty and Inuit communities with autonomous control of their health programs and resources in a timeframe dependant on many political and socio-economic parameters. When initially established, the primary short-term objective of this program was to provide effective and economic preventative and treatment services to people of First Nations Treaty and Inuit communities, i.e., to obtain the same oral (including orthodontic) health levels as those enjoyed by other Canadians living in similar locations. As a result, a proportion of those eligible for NIHB benefits consider the provision of orthodontic services part of their "rights". This is a strategic problem for the NIHB program, since no epidemiological data have been systematically collected to assay the impact of orthodontic services on the occlusal, functional or esthetic parameters of those eligible for benefits. The effectiveness of orthodontic services provided by this NIHB program, therefore, remains controversial.

All NIHB programs are characterized by no eligibility limit on the basis of age, income or residence, although orthodontic benefits are only available to patients aged 18 years or younger on initial case assessment. A major benefit to the providers is that the benefits can be billed directly to the NIHB for immediate payment. Based on 1987-97 data, the First Nations Treaty and Inuit communities comprise Canada's fastest growing population sector. The size of these communities increased 56% from 1987 to 1996, due partly to changes involving the Indian Act attributable to Bill C-31, which resulted in over 100,000 additional eligible clients in the 1985-95 period. There was therefore a dramatic 23% increase in the eligible client population from 1988 to 1989, but only 6% from 1989 to 1990. Subsequent annual increases have remained at 3% level, primarily due to their high birth rates and current (1996) data indicate that 40% of the 620,000 eligible clients for the NIHB dental program are under 20 years of age. Therefore, a significant proportion of those eligible for NIHB benefits are in the age-group commonly associated with orthodontic service demands, although no epidemiological data were available at the time to define the impact of these changes on their potential service expenditures. With only 40% of NIHB-eligable claimants utilizing their dental benefits, approximately $8.3 million were recorded for NIHB orthodontic expenditures in the 1995 fiscal year (Annual Government of Canada Report, 1996).

Included in the complexity of the problems facing NIHB, is the preponderance for Native adolescents to exhibit greater degrees of malocclusion severity relative to Caucasian adolescents in the same geographical area (Harrison and Davis, 1996; Zammit, 1995). Furthermore, only a proportion of the orthodontic anomalies are associated with dental neglect, although this cannot be defined by epidemiological data. Evidence from a British Columbian study showed that 13.0% of 15 year old Caucasian children received orthodontic services, as opposed to 3.8% of the First Nations Treaty and the Inuit communities of the same age-group (Harrison and Davis, 1996), despite their significantly greater service-needs (Zammit, 1995). Yet without epidemiological data, the proportion of

those needing orthodontic services who actually receive such treatment will remain obscure.

The scope of this dilemma is illustrated in **Table 1.1**. For instance, if only those in the 10-19 year age group demanded orthodontic services conservatively estimated at $3,000, then the potential expenditures on such services alone would greatly exceed the total resources allocated to the NIHB dental program. This dilemma was further compounded by the 1995 Federal budget, which set 6%, 3% and 3% growth limits for the NIHB fiscal envelope over the subsequent three consecutive years, whereas a 1% limit for 1998/99 was set by the 1996 Budget. As these expenditure restrictions are further compounded by the associated transportation expenditures, the need to rationalize the provision of orthodontic services by the NIHB program cannot be overstated.

Table 1.1 Potential Orthodontic Expenditures for the 10-19 Age-group Population from the NIHB Dental Program Based on 1995/96 Data

Age Group	Male	Female	Total
10-19	64,173	61,240	125,413
	Potential Service Costs		**$ 376,239,000.00**

Data adapted from the Progam Analysis Division of Health Canada
Potential service costs ($) based on a conservative $3000 fee per case
Source: NIHB data base

1.4 Strategic Options to Control NIHB Orthodontic Service Expenditures

Although the need to constrain orthodontic service expenditures is not unique to the NIHB dental program, reports in the literature indicate that a needs-based approach is the most logical strategic option, provided guidelines to control the prioritization of services are accepted by both providers and their patients (Kitzhaber, 1993; Musgrove, 1993). Such strategies are unfortunately difficult to devise for the orthodontic market funded by the NIHB program, due to the lack of both the associated epidemiological data

and common currencies to compare the relative merits of orthodontic and other dental services.

A logical option involves the implementation of a pre-determination (prior-approval, pre-treatment, pre-authorization) system. This is a common administrative procedure for most indemnity insurance programs (Rocky, 1988), where the primary intent is to check on client eligibility or consistency of request with prior services (Cooney *et.al.*, 1986). Moreover, U.S. evidence indicates that the implementation of such prior approval systems may lead to 6-8% savings for general dental expenditures (Friedman, 1975; Carr, 1977), as confirmed by a Canadian study (Cooney *et.al.*, 1995). Under the NIHB umbrella of services for Aboriginal people, orthodontic treatment is included, provided certain pre-requisites for service-need are met (*see Appendix A*). The current use of these criteria in determining orthodontic treatment-need relies on the subjective pre-treatment evaluations by a regional board. As suggested by Bedford and Davey (1993), "Unfortunately, the program still lacks total standardization and will continue to do so..... as individual dental officers view treatment requests and special circumstances differently". With the current economic policies existing in Canada driving the reform of all publicly-funded forms of health care, including orthodontics, the current system of subjective analysis is not appropriate in this period of accountability. Rather a flexible objective system is required, that can be applied in the face of varying levels of funding.

1.5 Thesis Objectives

This thesis is primarily intended:

- **To examine the effectiveness of a potential index for a pre-determination system to control the provision of orthodontic services by the NIHB dental program.**

- **To evaluate the potential of this system for the acquisition of epidemiological data on the orthodontic service needs of those eligible for NIHB benefits.**

This proposal is therefore not intended to examine other important parameters of the NIHB orthodontic program, e.g., the proportion that discontinue service prior to completion, the oral hygiene criteria required prior to service commencement, or the proportion of expenditures to be devoted to elective orthodontic relative to other essential (e.g., restorative) services.

Literature Review

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LITERATURE REVIEW

2.0 Introduction

Dentistry has a long history of utilizing objective indices to measure the deviation of oral health components from the ideal, rather than relying on their subjective clinical evaluations e.g., plaque scores, DMF scores and various periodontal indices (Loe and Silness, 1963; Greene and Vermillion, 1964; Russell, 1956; Klein *et.al.*, 1938). The use of such indices to objectively determine the existence of an oral health problem, or to assay the change of an existing problem, may gain increased use in the future to rationalize the insatiable demands for publicly-funded dental services. With the ever increasing financial and political strains placed on the public health system, there is also a need to ensure that funds are allocated where they will provide the greatest health benefit. The replacement of subjective clinical evaluations by objective methods of appraisal, such as indices, is therefore appealing to both practitioners and public health officials. If such indices are to be incorporated as a determinant of dental treatment-need in the public health care forum, however, their validity and reliability in quantifying the severity of a disease state must be closely scrutinized. More specifically, ***in the quantitative evaluation of malocclusion severity and prioritized service-need, there are concerns whether existing occlusal indices can perform such evaluations effectively and efficiently*** (Shaw *et.al.*, 1995; Richmond and Andrews, 1993). This topic, therefore, warrants further consideration.

2.1 The Development of an Orthodontic Treatment-need Index

Developing an objective index to evaluate the deviation of a malocclusion from normal presents a unique problem. For instance, malocclusions exhibit variable multifactorial etiologies, which underscore the complexity of developing an objective index to evaluate a particular malocclusion (Foster and Menezes, 1976). Such assessments are further complicated by a malocclusion comprising deviations from accepted ideals rather than disease states or abnormalities. The evaluation of malocclusion severity therefore requires the objective evaluation of these contributing occlusal, esthetic and functional components.

2.1.0 Occlusal Factors

Defining an ideal occlusion is inherently difficult. For instance, numerous attempts to define "ideal occlusion" have been followed by no general consensus on the most appropriate technique (Mohl *et.al.*, 1988; Ramfjord and Ash, 1983; Andrews, 1972; Hellman, 1921). The basic problem is the complexity of the current models of evaluation (Ast *et.al.*, 1965). Although the occlusal components of a malocclusion play a role in the determination of severity, this factor is not the sole determinant of malocclusion severity and/or future dysfunction. Also, attempts to link various occlusal components of a malocclusion with temporomandibular disorders have, at best, resulted in weak statistical correlations (Pullinger *et.al.*, 1993). In addition, investigations of the role of occlusion as an etiological factor primarily indicate a predominantly casual relationship (Horup *et.al.*, 1987; Helm and Petersen, 1989; Davies *et.al.*,1991). Therefore, the reliance on occlusal factors as the sole determinant of malocclusion severity and orthodontic service-need should be viewed with some skepticism.

2.1.1 Esthetic Factors

Many orthodontists and administrators responsible for providing orthodontic treatment in publicly-funded programs have expressed a belief that undesirable occlusal traits may negatively impact on socio-psychological functioning. This stems from the assertion that when a person's physical attributes deviate too far from socially defined appearance norms, they may be disqualified from full social acceptance. This non-acceptance may in turn result in psychological problems that are social in nature. Authors, such as Albino and Tedesco (1991) and Burstone (1958), have summarized the research findings regarding the potential impact of facial appearance on the psycho-social development of a person. These indicate a possible backlash of poor facial esthetics on a person's self-esteem, self-image and general social interactions. Shaw *et.al.* (1985) also furthered this concept, i.e., dentofacial appearance may reflect on the social attractiveness and public perception of a person. Although such a link has not been completely validated (Kenealy *et.al.*, 1989), the potential impact of esthetics warrants consideration in the assessment of orthodontic service-needs, i.e., in assays of malocclusion severity.

2.1.2 Functional Factors

Although evaluations of a prospective patient's occlusal function may facilitate the detection of deleterious interferences from occlusal trauma, evaluations of mandibular function cannot withstand scientific appraisal. For instance, traditional centric relation recordings are merely conveniences for transferring interocclusal relationships between the patient and the laboratory; and have no physiological or functional basis (Ash, 1995). The pathological significance of a discrepancy between traditional measures of centric relation and centric occlusion also remains to be demonstrated. Although it has been suggested that centric occlusion should not be more than 1-2 mm anterior to centric relation (Posselt, 1952; Mohl *et.al.*, 1988) when gnathological definitions are used (R.U.M.

position or U.M. position), the physiological basis for this concept is tenuous. In addition, physiologic definitions of centric relation are more difficult to consistently relate to intercuspation, i.e., there is a need for prospective studies to validate these concepts. Therefore, the use of an objective system to evaluate mandibular function as a part of the over-all assessment of malocclusion severity, needs further substantiation prior to inclusion in any index.

If the ideal of the components of a malocclusion can be separately evaluated, then the assessment of a malocclusion will be facilitated. Indeed, endorsement of such an indexed approach by the World Health Organization (1966), led to the development of specific criteria as guidelines for occlusal indices. Subsequent concerns for the lack of guideline specificity (Summers, 1971; Salzmann, 1969), however, culminated in the development of criteria for an ideal malocclusion index (Shaw *et al.*, 1991);

- ***reliability***
- ***validity***
- ***acceptable to the public and the profession***
- ***sensitive to the needs of the patient***
- ***sensitive throughout the scale***
- ***amenable to statistical analysis***
- ***able to detect shifts in group conditions***
- ***administratively simple to operate such that non-dental personnel can use it***
- ***examinations should require minimum judgment.***

An analysis of indices developed to evaluate malocclusion severity (prioritize service-need) relative to these criteria is therefore warranted.

2.2 Methods of Assessing and Grading Malocclusion Severity

Essentially, four main types of indices have been developed to evaluate malocclusions:

- **2.2.0 Diagnostic**
- **2.2.1 Epidemiological**
- **2.2.2 Treatment success (outcome)**
- **2.2.3 Treatment-need**

Their brief review is intended to provide an understanding of the controversies related to the application of such indices to quantify orthodontic service-need.

2.2.0 Indices of Diagnostic Classification

Classically, the original method to diagnose malocclusions relied on the two-dimensional anteroposterior relationships between the maxillary and mandibular permanent first molar teeth (Angle, 1899). Although this remains the most widely used method of malocclusion description by the orthodontic specialty today, there are numerous inherent deficiencies:

- Lack of ability in discerning the degree of disability relating to dental health, function or esthetics (Pickering and Vig, 1975).
- Poor reproducibility (Katz, 1992; Rinchuse and Rinchuse 1989; Gravely and Johnson 1974).
- The classification disregards tooth relationships relative to facial profile.
- The validity of the index has never been evaluated.

Angle's classification system has therefore limited application in assessing malocclusion severity, service priority or effectiveness.

An alternative classification system is based on the positional relations of the incisor teeth, rather than the first molars. Although the derived classifications are mainly

descriptive, the problems associated with drifted molars in a crowded arch can be avoided (Ballard and Wayman, 1964).

There have been subsequent attempts to devise a classification system that encompasses a three-dimensional evaluation of dental, skeletal and arch shape parameters (Proffit and Ackerman, 1973). This system was designed to overcome those weaknesses of Angle's classification, which failed to demonstrate the relation of tooth and jaw factors with facial appearance. Using a modified Venn diagram and computer analysis, cases are classified into nine diagnostic categories, although this system proved too complex for routine orthodontic service evaluations. Diagnostic parameter assessments are therefore unlikely to benefit the prioritization of patients relative to their orthodontic service-needs.

2.2.1 Epidemiological Indicies

Numerous indices developed for epidemiological orthodontic surveys have proved invaluable for manpower planning and research, although their application in the assessment of service priority remains limited. For instance, an epidemiological instrument (facial orthometer) has been devised to quantitatively assess three malocclusion components, i.e., dentition, occlusion and space anomalies (Pelton and Elsasser, 1953). Unfortunately, the inherent complexity of this Dento-facial index (DFI) constrains its potential clinical applications.

Bjork *et.al.* (1964) introduced a system to register malocclusion for epidemiological purposes, based on the objective registration of three main occlusal categories; i.e., anomalies in the dentition or occlusion, and deviations in space conditions. Using an objective registration procedure, a total of 567 features among the three categories are required to be recorded. The complexity of this system therefore hampers its general application.

2.2.1.a The Index of Tooth Position (ITP)

Developed as an epidemiological tool (Massler and Frankel, 1951), this index is based on the teeth as individual units rather than arch segments, i.e., tooth displacement, infra-occlusion and supra-occlusion are recorded with the total number of maloccluded teeth providing a score for a particular malocclusion. Unfortunately, this epidemiological index is too imprecise to evaluate the service-need of individual malocclusions.

2.2.1.b The Malalignment Index (MI)

Based on the discrete evaluation of each arch, divided into two posterior and one anterior segments, the derived two-unit scale of this index tends to underestimate malocclusion severity. Subsequent modifications have provided little further benefit, due to their 0 to 2 scale evaluations of tooth displacement (Van Kirk and Pennel, 1959). This index is therefore inadequate to evaluate the service-needs of individual patients.

2.2.1.c The Occlusal Feature Index (OFI)

This index is based on four primary occlusal features considered important to any orthodontic examination (Poulton and Aaronson, 1961):

- Lower anterior crowding.
- Cuspal interdigitation.
- Vertical Overbite.
- Horizontal overjet.

The sum of scores for specific deviations from normal in each of these parameters then yield an over-all index within the 0-9 range of malocclusion severity. The OFI scores exhibit reasonable inter-examiner reliability and correlates well with service needs, but is too imprecise to priorize orthodontic service priority.

2.2.1.d The "FDI System"

The "FDI system" was developed by a group assessing dento-facial anomalies for the Federation Dentaire Internationale (FDI) Commission on Classification and Statistics of Oral Conditions (COCSTOC) (Baume *et al.*, 1973). This system was further revised by the World Health Organization (WHO), resulting in the WHO/FDI Basic Method for Recording Malocclusion (Brzroukov *et.al.*, 1979). Designed for the clinical examination of patients with a full complement of permanent teeth, this index focuses on three basic areas of occlusal evaluation; dental, inter-arch and intra-arch relations. Specific designed traits are recorded using codings for aspects of malocclusion together with the FDI system of identification to localize individual tooth malrelations.

One of the major difficulties in using any of the evaluation systems discussed above, stems from the determination of malocclusion as a single morphological variable (Helm, 1968), thereby oversimplifying the complexity of a malocclusion. Even with attempts to identify contributing components of a malocclusion based on population distributions (Fisk, 1960), the reliability and validity of these derived qualitative systems remain controversial. Their applications are therefore confined to estimating the orthodontic service requirements of populations rather than individual case assessments (Lavelle, 1976; Magnusson, 1976).

2.2.2 Indices of Treatment Success (Outcome)

A number of indices have been developed to evaluate orthodontic service outcomes. For instance, Eismann (1979) devised a method based on scores assigned to fifteen morphological criteria, which were then summed to provide an index of service outcome. Unfortunately assignment of scores was largely subjective, thereby detracting from the objectivity of the overall numerical grade. Subsequently, Gottleib (1975) devised an

alternative system, based on ten accepted criteria for orthodontic correction, although this system was inherently biased by the allocation of five points to a corrected feature, as opposed to a single point for a worsened feature. Berg (1979) devised a method to evaluate treatment outcome based on criteria for sagittal, vertical and transverse occlusal changes, alignment, axial inclination and apical resorption. Cases that met the stated criteria were graded 'A', whereas those that did not were graded 'B'. This index therefore attempted to incorporate iatrogenic factors in the assessment of service outcomes, although the method is too was inherently crude to warrant general application.

2.2.2.a The Peer Assessment Rating Index (PAR)

Developed as an occlusal index specifically designed to measure malocclusion severity and treatment success (Richmond *et al.*, 1992 a,b), the PAR index has proved to be a simple tool that sacrifices neither validity or reliability (Buchanan, 1993). The sum of the weighted scores of the following occlusal components provide an over-all evaluation of malocclusion severity:

- Overbite.
- Overjet.
- Midline discrepancy.
- Crowding.
- Spacing.
- Impactions.
- Anteroposterior buccal segment relationship.
- Maxillary and mandibular anterior contact point displacement.

For instance, a score of zero represents an ideal occlusal alignment, whereas increases in the score reflect progressive occlusal irregularities. The treatment success of a given case can then be evaluated by calculating the percentage change in pre-treatment to post-treatment scores.

The development, validity and reliability testing of this PAR index included input from the *British Orthodontic Standards Working Party* (a group comprised of British orthodontists, general dentists and dental public health officials). Initial development of this index required the Working party's evaluation of 272 dental casts reflecting varying malocclusion severity, as well as the establishment of the individual features deemed necessary in the measurement of malocclusion severity. Statistical manipulation of the derived data reflected the importance of the components agreed upon by consensus, and resulted in their prioritized weighting. Interestingly, the validity ($r = 0.85$, $p < 0.001$) of the weighted PAR scores reflected orthodontic opinions of malocclusion severity, where the intra-examiner reliability (0.93) was high. However, a low level of agreement was noted between the consensus opinion of orthodontists and general dentists regarding malocclusion severity (Richmond *et.al.*, 1992a; Fleiss *et.al.*, 1979) leading to the use of statistical models to account for examiner variability, e.g., Intraclass Correlation Coefficient (ICC). The ICC results of the PAR index then revealed extremely high levels of reliability (0.96, $p < 0.05$) (Buchanan *et.al.*, 1993).

In addition, to evaluate pre-treatment malocclusion severity, the PAR index has also been suggested as an assay of malocclusion improvement and treatment success (Richmond *et al.*, 1992c; 1993). Subsequent studies have tested this utilization, with comparisons of change in PAR scores relative to the subjective assessments of post-treatment changes. Unfortunately, varying degrees of success assessed by the PAR system reflect of some inadequacies of the index (O'Brien *et al.*, 1993; Richmond and Andrews, 1993) rather than changes in the malocclusion status per se.

Although the PAR index provides significant advances in malocclusion assessment, a number of deficiencies are evident:

- The questionable validity of this British-derived index in assessing malocclusion severity in North America. Attempts have been made to validate the PAR index using the consensus of American orthodontists from the North Eastern United States with the subsequent weightings derived reflecting the consensus of that

geographical region (De Guzman *et.al.*, 1995; Bahiraei, 1995).

- The index relies entirely on the evaluation of study models to reflect the severity of a patient's dentofacial malocclusion handicap, without objective measures of the esthetic or functional malocclusion components.

The PAR index therefore requires further development to have general clinical application.

2.2.3 Indices of Treatment-need

Various indices have been devised to categorize the orthodontic treatment-need of patients, ie. to provide a method of assessing treatment priority. As such indices may be invaluable for the allocation of limited resources to priority groups (Otuyemi and Jones, 1995), their more detailed discussion is crucial to this thesis:

- Handicapping Labiolingual Deviation Index [HLDI](Draker, 1960, 1967).
- Treatment Priority Index [TPI] (Grainger, 1967).
- Handicapping Malocclusal Record [HMAR] (Salzmann, 1968).
- Occlusal Index [OI](Summers, 1971).
- Swedish National Board for Health and Welfare Index (Linder-Aronson, 1974).
- Index of Treatment Need [IOTN] (Brooks and Shaw, 1989).
- Dental Aesthetic Index (Cons *et.al.*, 1986).

In all indices, a weighting system is applied to certain features of a malocclusion, reflecting the assertion that some deviations of occlusal components are more important than others in the severity of a malocclusion. In this way, an index may provide an element of flexibility to reflect changes in clinical opinion. As the summed score of these components reflects the degree of malocclusion severity, they may then be used to assay treatment priority.

2.2.3.a Handicapping Labiolingual Deviation (HLD) Index

Initially designed by Draker (1960, 1967) as an epidemiological tool to rank malocclusion and assess the need for orthodontic treatment, this index evaluates the presence or absence of the following components of a given malocclusion, providing a weighted ranking of the following components:

- Traumatic deviation, referring to patients with congenital defects or other craniofacial pathologies.
- Cleft of the palate.
- Overbite.
- Overjet.
- Mandibular protrusion measured as the linear distance from the labial surface of the lower incisor to the labial surface of the upper incisor.
- Anterior open-bite.
- The deviation of incisors, in millimeters, from the normal arch form, recording only the most deviated individual tooth.

Unfortunately, the HLD suffers from a number of deficiencies, which limit the reliability and validity of the index in evaluating treatment-need:

- The index does not account for missing, impacted or spacing between teeth and ignores transverse discrepancies such as midline deviations and cross-bites..
- The deviation of the incisor position only accounts for the most severely deviated tooth in each arch.
- The component weightings are subjective and represent the opinion of its' originator. This use of clinical judgment is therefore inconsistent with the independent evaluation of handicapping/non-handicapping malocclusions (Fletcher, 1963).

Therefore the reliability of the HDL index to assess orthodontic treatment-need remains controversial.

2.2.3.b Treatment Priority Index (TPI)

In 1965, the Council on Orthodontic Health Care (COHC) and the American Association of Orthodontists (AAO) established criteria to define a handicapping malocclusion, which led to the development of the Treatment Priority Index (Grainger, 1967) in connection with the Burlington Interceptive Orthodontic Research Project (Grainger, 1961). Based upon study cast evaluations and clinical examinations of 375 twelve year old children from three Ontario communities, this index was considered representative of the most common types of malocclusions, and included the following components:

- Overjet.
- Overbite.
- Reverse overjet.
- Anterior open bite.
- Congenital absence of incisors.
- Disto-occlusion (molars).
- Mesio-occlusion (molars).
- Posterior crossbite with maxillary teeth lingual to normal position.
- Posterior cross-bite with maxillary teeth labial to normal position.
- Displacement of individual teeth.
- Cleft palate and other dentofacial anomalies.

When these parameters are evaluated on a weighted 1 to 10 scale, the total score is considered to reflect malocclusion severity. Unfortunately, a number of inherent deficiences limit the application of this index, including the following:

- A lack of accountability for midline deviations, spacing and arch asymmetry.
- Teeth missing due to caries or trauma are ignored, ie. only congenitally missing maxillary incisors are recorded.
- With the lack of mixed dentition analysis (Turner, 1983, 1990), the index cannot be used to predict the future malocclusion severity of the permanent dentition from an analysis of the mixed dentition (Ghafari *et.al.*, 1989).
- As the relationships of the permanent first molars are used to calculate the

severity of the malocclusion with this index, it cannot be applied to cases where one or more of the permanent molars have been lost.
- Although the reliability of the TPI has been confirmed (Popovitch and Thompson, 1971 ; Albino *et.al.*, 1978; Lewis *et.al.*, 1982), the validity of the index in discerning varying degrees of malocclusal severity remains controversial (Grewe and Hagan, 1972).

All of the factors discussed limit the usefulness of the TPI as a measure of malocclusion severity.

2.2.3.c Handicapping Malocclusion Assessment Record (HMAR)

The Handicapping Malocclusion Assessment Record (HMAR) was designed by Salzmann (1968) to priorize orthodontic service-need according to the severity of the malocclusion and was endorsed by the American Dental Association (ADA) and the American Association of Orthodontists (AAO). The components measured are:

- Crowding.
- Missing and rotated teeth.
- Spacing.
- Overbite.
- Overjet.
- Crossbite.
- Anteroposterior discrepancy.

The HMAR, unfortunately, exhibits numerous inherent deficiencies:

- The subjective weightings assigned to the individual components.
- The inability of the index to evaluate the malocclusion in the mixed dentition.
- Deviations from "ideal" of the various components are scored as either present or absent, so there are no intermediate severity levels.
- The HMAR exhibited the poorest levels of reliability and validity when assessing malocclusion severity relative to the alternative Handicapping Labio-lingual Deviation or Occlusal indicies (Grewe and Hagan, 1972).

The clinical application of this index are therefore limited.

2.2.3.d Occlusal Index (OI)

Based on the Malocclusion Severity Estimate of Grainger and the Treatment Priority Index (Grainger, 1967), the Occlusal Index (Summers, 1971) is derived from the following measured components:

- Molar relationship.
- Tooth displacement.
- Overjet.
- Overbite.
- Openbite.
- Posterior crossbite.
- Congenitally missing maxillary incisors.
- Dental midline relation.
- Developmental dental age.

The scores for the various components are differentially weighted to validate the application of this index for different dental age groups. To evaluate future malocclusion severity in the permanent dentition from an existing mixed dentition, the method suggested by Moyer (1963) to assess the probability of future crowding is incorporated into the OI to record existing tooth displacement. Summers described two divisions and seven syndromes in the OI. Once the appropriate code sheet is selected based upon developmental age, the appropriate division is based on the molar relationship, followed by all of the component scores being placed in the syndrome of the established division.

In comparison with other occlusal indices (HMAR, TPI, HLDI), the OI exhibited the highest validity and reproducibility (Albino *et.al.*, 1978; Gray and Demirjian, 1977; Grewe and Hagan, 1972; Hermanson and Grewe, 1970), although the absolute validity relative to the "gold standard" of subjective orthodontists' consensus remains low (Turner, 1990). Other inherent deficiencies include the following:

- Complexity in the use of the index (Scivier *et.al.*, 1974; Pickering and Vig, 1975; Elderton and Clark, 1983).

- Tends to under-estimate orthodontic treatment-need (Tang, 1994), especially in cases with full unit disto-occlusion (Buchanan *et.al.*, 1993).
- Fails to account for early incisor or molar loss (Pickering and Vig, 1975).
- Does not account for any interproximal spacing, except for maxillary midline diastemas greater than 2 millimeters (Tang and Wei, 1990).

Therefore this index also has limited clinical application.

2.2.3.e Swedish National Board for Health and Welfare Index

The Swedish Medical Board Index (Linder-Aronson, 1974) is based on the occlusal components assumed to constitute a threat to the long-term stability and health of the dentition. The graded components are then utilized as indicators of orthodontic treatment priority. Though used extensively by the Swedish Health Board, ***the vague and arbitrary grade divisions lead to low levels of reproducibility, particularly when the index is used by non-professionals*** (Brooks and Shaw, 1989).

2.2.3.f Index of Orthodontic Treatment Need (IOTN)

Based on the belief that orthodontic treatment benefits patients' esthetics and their psycho-social well-being (Richmond, 1990; Brook and Shaw, 1989; Shaw, 1981; Shaw *et.al.*, 1980), the IOTN was designed to priorize orthodontic service-need on the basis of occlusal traits and perceived esthetic impairment.

This British-derived index comprises two main components; the Dental Health Component (DHC) and the Aesthetic Component (AC). The DHC is a modified version of the Swedish National Board for Health and Welfare Index (Linder-Aronson, 1974), utilized as an evaluator of various occlusal traits that may have a deleterious effect on the long-term dental health. With the identification of the most severe component of the occlusion as the sole dictator of malocclusion grading, a grade of 1 reflects "no need" and 5 "great treatment-need". As a result, scores from multiple minor occlusal variations cannot be included, limiting the description of a malocclusion to it's most severe trait.

The AC component of the index is based on the Standardized Continuum of Aesthetic Need (SCAN) Index (Evans and Shaw, 1987) and consists of a 10-point scale derived from a series of ten anterior intra-oral photographs rated for attractiveness by lay persons. Both examiners and patients independently select the photograph which most closely matches the dental attractiveness of the patient, with the resultant score intended to reflect the general dental attractiveness rather than any specific morphological similarities between the photograph and the patient. A summation of both the AC and DHC scores then serves as a reflection of the malocclusion severity and resulting treatment-need of the patient.

The IOTN has a number of inherent deficiencies:

- The use of only frontal photographs of the dentition limit overjet and lip-incisor evaluations (Fields *et.al.*, 1982).
- Poor oral hygiene, gingival conditions and the appearance of poor restorative treatment can influence the appearance of the photographs and subsequent scoring (Woolas and Shaw, 1987).
- Esthetic opinions vary between countries and demographic composition of the population.
- The DHC component validity is high (Shaw *et.al.*, 1991) but varies for the AC component (Richmond *et.al.*, 1995b).
- The reproducibility of the DHC is high (Kappa values of 0.78 to 0.84) while that for the AC is acceptable for the orthodontists (0.71 to 0.87), moderate for general dentists (0.64 to 0.66) and variable for the lay persons tested (0.29 to 0.73) (Brook and Shaw, 1989; Burden, 1995).
- Although the IOTN has been tested for many population samples (Wang *et.al.*, 1994; Lunn *et.al.*, 1994; So and Tang, 1993), the continued need for further modifications and testing to determine treatment-need is required (Richmond *et.al.*, 1994b) ***due to the inherent deficiencies identified above***.

2.2.3.g Dental Aesthetic Index (DAI)

The DAI is based on a complex regression equation that links objective measurements of ten occlusal traits relative to their dental aesthetic social acceptability (Cons and Jenny, 1994). The index was derived from the percentage distribution of malocclusion traits in 1,337 study casts (Cons *et.al.*, 1978), where 18 occlusal patterns were delineated (Proshek *et.al.*, 1979). From the original sample group, two random 100 cast sub-samples were selected and evaluated relative to the *Social Acceptability Scale of Occlusal Conditions* (SASOC) designed to measure the public's perception of their esthetic acceptability (Jenny *et.al.*, 1980). The SASOC was derived from the subjective assessment stylized lip masking of lateral and frontal photographs of these two sub-samples by a group of evaluators comprising students (n=880), their parents (n=403) and orthodontists (n=66), based on such polar adjectives as beautiful/ugly, desirable/ undesirable, etc.. Their subsequent multivariate statistical analysis (factor analysis and stepwise multiple regression) identified ten occlusal traits, whose weightings reflected their relative influence on dental aesthetics. The specific occlusal trait components of a malocclusion were then placed into the appropriate locations within the DAI regression equation, where the resulting scores were prioritized relative to a continuum ranging from "13" ("most socially acceptable") to "100" ("least acceptable").

Although the DAI index was derived from a study cast sample base of Caucasian adolescents from the United States (Ast *et.al.*, 1965), this index has since been validated for other population samples, e.g., Native American United States students (Cons *et. al.*, 1983, 1989), ethnic groups in Japan, China and other Asian countries (Ansai *et.al.*, 1993). For instance, in one study 413 Chinese, 418 Latvian and 428 Native American students were asked to rate 200 cases for dental esthetics using the original methodology used in the development of the DAI. These ratings were linked through statistical regression with the occlusal trait measurements of the same 200 cases. The resulting ethnic group-specific DAI equations were scored and compared to the scores derived by the Standard-DAI.

Subsequent evaluations of the inter-group social acceptability ranking of dental esthetics for the 200 cases ranged from 0.81 to 0.87 in the Spearman rank order correlations. When the ability of the ethnic group-specific DAI equation to correctly classify the 200 cases above and below various percentiles, or cut-off points, on the Standard-DAI scale was tested, the per cent agreement of the three ethnic group-specific DAI equations at the 90th, 85th and 80th cut-off percentiles on the Standard-DAI ranged from 92 to 100 percent. The sensitivities of the three ethnic group-specific DAI equations at the various cut-off points on the Standard-DAI ranged from 73 to 100 percent and the specificities ranged from 83 to 100 percent (Cons *et.al.*, 1994). On the basis of these data, the dental esthetic perceptions between cultural groups were considered to be sufficiently synonymous with the original DAI data. These findings also support similar research results involving the perceptions of dental esthetics in the USA with those of eleven ethnic groups (Cons and Jenny, 1994). Data from Cons *et.al.* (1994) also confirmed that the Standard-DAI scale can be used, instead of ethnic group-specific DAI equations.

In order for the DAI to be used to assess orthodontic treatment-need of different populations, meaningful cut-off points are required to be established relative to a prioritized continuum. By using the subjective consensus of two orthodontic evaluators on the 200 study cast subset of the original sample used to derive the DAI, a clinical determination of handicapping malocclusions in need of treatment was established by a score of 36 or higher being deemed as an indicator of orthodontic treatment-need (Jenny *et.al.*, 1992). In other research involving DAI treatment-need cut-off points, a hit rate result of 0.74 was found between the subjective evaluation (n = 10 orthodontists) of orthodontic treatment-need, when a DAI cut-off score of 32.5 was tested (Keay *et.al.*, 1993). However, the study did show that although the sensitivity of the DAI was sufficiently high (0.92) to indicate the correct prediction of cases requiring treatment, the low positive predictive power results (0.60) suggests that the DAI may over-estimate the

demand for treatment, as more recently confirmed by Caisley (1995). Unfortunately, such cut-off points have limited validity (Keay *et.al.*, 1993).

Although the DAI has been embraced by the WHO and incorporated into the *Oral Data Collection Instrument*, there are some deficiencies:

- Deviations for crowding and spacing components are scored as present or absent, with no distinction between varying degrees of discrepancy.
- Only the incisor teeth are scored, while the remaining teeth are excluded.
- As the DAI was established from the study casts exhibiting a permanent dentition, accommodations must be made for the evaluation of a mixed dentition evaluation.
- In mixed dentition evaluations, the space from a recently exfoliated deciduous tooth should not be scored as missing if it appears that the permanent replacement will soon erupt (Jenny and Cons, 1996), ie. eruption status requires the judgment of an experienced clinician rather than non-professional dental personnel.
- The DAI does not account for missing molars, impacted teeth or posterior crossbites.
- ***To be utilized as a screening tool for orthodontic treatment-need, further studies of the validity of established cut-off points are necessary.***

2.3 Conclusion

Many indices have been devised to assess the need for orthodontic treatment, but they generally fall short when evaluating a particular malocclusion (Shaw *et.al.*, 1995; Richmond and Andrews, 1993). These shortcomings range from validity and reliability weaknesses, to imprecise evaluations of malocclusion components (Tang and Wei, 1993). To date, a comprehensive treatment-need index to evaluate ***all*** malocclusion components, while fulfilling the desirable criteria for an index has yet to be developed. The Dental Aesthetic Index comes closest to these requirements. **This study was therefore designed to test the capacity of the DAI to reflect the subjective appraisal of Manitoba Orthodontists in grading malocclusion severity. In addition, the potential**

application of the DAI to prioritize orthodontic treatment-need for patients referred for publicly-funded orthodontic treatment was evaluated.

Specifically, this study is intended:

- **To examine the effectiveness of a potential index for a pre-determination system to control the provision of orthodontic services by the NIHB dental program.**

- **To evaluate the potential of this system for the acquisition of epidemiological data on the orthodontic service needs of those eligible for NIHB benefits.**

Methods and Materials

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3.0 Sample Selection
3.1 Orthodontic Malocclusion Severity Assessment
3.2 Data Evaluation

METHODS AND MATERIALS

This study was primarily intended to validate the application of the Dental Aesthetic Index (DAI) to distinguish patients who should/should not be approved for publicly-funded (NIHB) orthodontic services. A secondary objective was to test the ability of the DAI to discern varying degrees of malocclusion severity. Finally, an additional objective was to determine if objective criteria could be devised to allocate public resources for the provision of elective, in addition to essential, services to those eligible for NIHB benefits. The objectives of the study may therefore be summarized as follows:

- Examine the degree of congruence between the two forms of orthodontic malocclusion severity assessment.
- To examine whether the distinction between those that should/should not be offered orthodontic treatment can be rendered more objective by the application of an index.

3.0 Sample Selection

This study was based on the pre-treatment records, conventionally required for pre-determination (prior approval) submission to all (privately and publicly-funded) insurance agencies. The pre-treatment records for 38 patients were therefore randomly selected from a much larger sample submitted to the NIHB dental program in Manitoba for prior approval assessment. The selection criteria to define the cases included in this study were as follows:

- All records were obtained from a private practice orthodontic office located in Manitoba.
- All records were previously submitted to the NIHB program for prior approval assessment before June 1, 1996, although their assignment to the approval/non-approval

categories was obscured from all study participants during the investigation.

- All cases included in the study comprised the following pre-treatment records;
  - maxillary and mandibular study models articulated in centric relation/centric occlusion,
  - current lateral cephalometric radiograph,
  - current panoramic (or equivalent) radiograph,
  - patient's age,
  - extra-oral frontal and profile photos.

Based on the data from a pilot study, the sample cases used in the study (n = 38), consisted of 30 cases approved and 8 cases not approved, by NIHB for orthodontic treatment. In all instances, the cases were randomly selected by the Orthodontists providing the records, who were excluded as evaluators in this study. The sample of pre-treatment records represented a wide range of malocclusion severity in both the permanent (n = 33) and the mixed (n = 5) dentitions. Subsequently, all records were duplicated and re-identified with a specific code known only to the principal investigator. This precaution was considered essential to avoid the potential for bias in case assessment. Finally, the assessors were required to evaluate each of the 38 cases independently, i.e., assessor collaberation was prohibited to avoid potential evaluation bias.

3.1 Orthodontic Malocclusion Severity Assessment

Each case was assessed relative to their malocclusion severity by two examiner groups; practicing Manitoba Orthodontists and Graduate Orthodontic students from the University of Manitoba.

3.1.0 Assessments by Orthodontist Specialists

Initially, each case was assessed subjectively by Orthodontic specialists from the Province of Manitoba. Accordingly, all (n =18) Orthodontists were invited to participate in the study. All of the Orthodontists that did participate in the study (n =16), were required to evaluate the following:

- The malocclusion severity utilizing a seven point Visual Analogue Scale (VAS), anchored by the terms "mild" = 1 to " very severe" = 7. The validity and reliability using this system of evaluation is well-established (Richmond *et al.*, 1992a; Bennet *et al.*, 1991; Cons *et.al.*, 1986) and was primarily used to economize evaluator time. Subsequently, the mean case VAS scores were calculated for each case [see ***Appendix B*** for an example of the data collection form used].
- This assessment was repeated four weeks later on 5 randomly selected cases derived from the original sample. The primary objective of this second evaluation was to evaluate the consistency of malocclusion severity assessments by this subjective technique.
- Indicate on a provided list of occlusal, functional and esthetic components, the most important components in order of ***priority***, when evaluating the severity of ***any*** given malocclusion [see ***Appendix C*** for an example of the data collection form used].

All the responses from the Orthodontists were kept confidential to avoid potential bias. This was accomplished with a pre-organized number identification as a means of identifying and matching each Orthodontist's responses to the questions, with only the principal investigator having access to the information.

Each Orthodontist was also asked to answer a series of questions relative to their professional background (e.g., education, practice demographics). Collation of this information was intended to evaluate the potential impact of assessor age/experience on

the malocclusion severity assessments [see ***Appendix D*** for an example of the data collection form used].

3.1.1 Assessments by Orthodontic Graduate Students

The same cases were subsequently scored via an objective treatment-need index, the Dental Aesthetic Index (DAI), by the Graduate Orthodontic Students from the University of Manitoba (n = 6). Subsequently, the mean DAI score was calculated for each case. These assessments were again held during two sessions, separated by a four week interval, to evaluate the consistency of the evaluations [see ***Appendix E*** for an example of the DAI data collection form].

3.1.1.a The Dental Aesthetic Index

The DAI is specifically designed to measure dental esthetics (Cons *et.al.*, 1986) relative to societal-defined appearance norms, i.e., the index is designed to delineate esthetic conditions that are potentially psychosocially handicapping. The DAI then links the clinical and esthetic component mathematically to produce a single score that combines their component attributes.

The esthetic component of the DAI is based on the public perceptions of the dental esthetics derived from 200 photographs of occlusal configurations. These were selected by a disproportionate, stratified random sampling procedure from a larger sample of 1,337 study models, collected in an earlier study (Ast *et.al.*, 1965). The 1,337 study models represented a probability sample of half a million New York State high school students aged 15-18 years. The disproportionate, stratified random sampling procedure that selected the 200 photographs used as 'stimuli', ensured that even the most extreme cases were represented. As approximately 2,000 adolescents and adults participated in the esthetic rating of the '200 stimuli', each showing a full-face view and both right and left

profile views, their assessment was considered to be representative of the North American 'norm'.

Subsequently, forty nine potential anatomic measurements of their study models were reviewed by an international committee to define those that assessed the important occlusal traits. These selected measurements then served for the development of an orthodontic index for each patient (Baume *et.al.*, 1973). The public's rating of the dental esthetics of each 'stimulus' was subsequently statistically related to anatomic measurements yielding a series of 10 anatomic parameters derived from their study models. Subsequently these data were subjected to regression analysis, where the derived coefficients indicated the weightings to each of the 10 component measurements of the index, i.e. the DAI comprises the sum of 10 weighted component measurements derived from the maxillary and mandibular study models of each case plus a constant (Cons *et.al.*, 1986). The DAI then combines occlusal, esthetic and physical parameters as a single score.

Originally developed to define the permanent dentition (Cons *et.al.*, 1986), the DAI may be adapted for mixed dentition assessments by counting the number of missing incisors, canines and premolars required in the regression equation, provided the space from a recently exfoliated deciduous tooth is not scored as missing, when it appears that there will be a permanent successor (WHO in press).

Subsequent to defining the DAI score for a patient, the placement on a scale determines where the cases falls between the most and least socially acceptable dental appearance, i.e., the farther a DAI score is placed along a continuum of dental appearance between 13 (the most socially acceptable) and 100 (the least socially acceptable), the more likely the occlusal condition is socially and physically handicapping (Cons *et.al.*, 1986). The DAI score then defines a series of decision points along a 1-100 scale each indicative of a severity assessment that equates to Orthodontist's assessments of treatment-need, as illustrated in **Table 3.1.**

Table 3.1 DAI Score Interpretations Relative to Orthodontic Treatment-need

DAI score	Orthodontic service inference
25 or lower	Normal/slight malocclusion: no/slight treatment-need
26-30	Definite malocclusion; treatment elective
30-35	Severe malocclusion; treatment highly desirable
36 or higher	Very severe/handicapping malocclusion; treatment mandatory

Although a DAI score of 36 may then be defined as the threshold that discriminates between handicapping and non-handicapping malocclusions (Jenny *et.al.*, 1992), these thresholds may be varied for publicly or privately funded programs, to equate the resource availability with the most cost-effective delivery of orthodontic services. The potential flexibility is essentially concentrated in the intermediate malocclusion severity levels (DAI scores 0-36), although ***other threshold scores may obviously be applied depending on the availability of resources (Jenny & Cons, 1993)***.

3.1.1.b Reliability of the DAI

In a study where the DAI scores were computed for 9 models by 131 auxiliaries, the high reliability of the DAI scores were subsequently confirmed by concordance and Intraclass Correlation statistical tests (Spencer *et.al.*, 1992). Similarly, the reliability of five dental auxiliaries to determine the DAI scores on 33 models has been shown for two trials (Cons *et.al.*, 1986). Although deep overbites that impinge on soft tissue, as well as other gross anomalies, were excluded components measured in the DAI score, they can be readily recognized by auxiliaries and referred for further orthodontic specialist consultation. Therefore, ***the reliability of the DAI score is well established.***

3.1.1.c Validity of the DAI

The validity of the DAI score for the assessment of orthodontic treatment-need has been confirmed by both U.S. and international studies. For instance, two studies have shown that the DAI scores were significantly associated with perceptions of orthodontic treatment-need by students and their parents (Spencer *et.al.*, 1992; Cons *et.al.*, 1986). Another study has shown that 88% agreement between decisions of Orthodontists relative to the DAI scores in the orthodontic treatment-need assessments of a sample comprising 1,337 handicapping malocclusion study casts (Jenny *et.al.*, 1992). Further evidence of support for the DAI index stems from its ***approval by both the U.S. Indian Health Service and WHO for both individual and epidemiological assessments of orthodontic treatment-need.***

3.2 Data evaluation

The information obtained from the Orthodontists' subjective assessments and Graduate students' DAI scores was subsequently used to evaluate the potential application of the DAI for the NIHB dental program. The validity testing was essentially undertaken to determine the ability of the DAI to detect malocclusion severity and to assess the orthodontic treatment-need of the sample. Subsequent statistical analysis revealed four critical DAI components were more statistically relevant in evaluating the service need. These components were statistically re-weighted, resulting in the development of the modified-DAI. Validity testing of the modified-DAI was then repeated to determine the impact on the orthodontic treatment-need of the sample.

After data were collated into a spreadsheet, they were verified for accuracy and consistency prior to their statistical analysis by a battery of univariate and multivariate

techniques (based on the biostatistical advice from Dr. T. Hassard) to test two null hypotheses:

i) The DAI is unable to determine malocclusion severity.
ii) The DAI is unable to determine treatment-need.

These hypotheses were then tested by the following analyses:

1) Intra and inter-examiner reliability study for the subjective Orthodontists' assessment (malocclusion severity) and the objective DAI scores assessments of the same cases by the Graduate Orthodontic students were evaluated by computation of the Intraclass Correlation Coefficient (ICC). This technique was used to evaluate assessment reliability for the thirty-eight cases and the repeat evaluations of five randomly selected cases from the original sample.

2) Pearson correlation coefficients were computed to determine the congruence between the mean DAI scores and the mean Orthodontic group malocclusion severity assessment for each case based on the total sample, as well as the permanent and mixed dentition subsamples.

3) To test the ability of the DAI to discern orthodontic treatment-need, logistic regression analysis of the DAI scores was used to obtain the cut-off scores to discriminate the approved from the non-approved cases. The NIHB treatment-need categorization was evaluated in a 2x2 matrix table relative to their DAI scores. This matrix table in turn proved invaluable for the assessment of DAI accuracy for treatment-need evaluations via the investigation of; sensitivity, specificity, false positive and negative fractions, accuracy of the test and the likelihood ratio of a positive and negative test. This again was computed for the total sample, as well as separately for the permanent and mixed dentition subsamples.

4) In addition, logistic regression of the standard-DAI was used to determine which components were more critical than others in evaluating orthodontic treatment-need. Subsequently, these components were re-weighted to reflect their relative importance in the treatment-need evaluations and the cases re-scored in accordance with their revised weightings. Calculation of a new treatment-need cut-off point and a similar 2x2 matrix investigation was then instigated to evaluate the ability of the modified-DAI to discern orthodontic treatment-need for the total sample, as well as the permanent and mixed dentition subsamples.

Essentially, therefore, the intent of this study was to devise a more rational mechanism to discriminate between those who should/should not be provided with NIHB-funded orthodontic services.

Results

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4.3 The Ability of the DAI to Assess Orthodontic Treatment-need
4.4 The Development and Testing of the Modified-DAI
4.5 Summary

RESULTS

The results are presented as a series of discrete sections, prior to defining their over-all conclusions.

4.0 Data Obtained From the Sessions Involving the Orthodontists

4.0.0 Demographics of the Participating Orthodontists

The demographic information reflecting the Orthodontists' participating in this study was obtained from a questionnaire (*see **Appendix D***) completed by participant. Graduation from dental school ranged from 1958 to 1989 with a group mean of 1975. The graduation from a post-graduate orthodontic program ranged from 1966 to 1994 with a group mean of 1978, indicating a range of experience as a certified Orthodontist ranging from two to thirty years with a mean of eighteen years.

At the time of this study, the number of patient care hours provided per week by the participants ranged from twelve to thirty eight with a group mean of twenty-eight and one-half. From the twelve participants that responded to the question regarding the number of new case starts within the year prior to the study, a range of fifty to four hundred was noted with a group mean of one hundred and eighty one. Finally, the group means for the four patient sub-group categories were calculated. These averages reflect the relative percent of patients treated within each sub-group and are as follows:

Children (< 10 yrs. of age) = 14%

Adolescents (10 - 16 yrs. of age) = 60.40%

Adults (> 16 yrs. of age) = 20.25%

Cases involving Orthognathic surgery = 5%

These data indicated that the experience and case loads of the Manitoba Orthodontists participating in this study were analogous to those in other Canadian regions.

4.0.1 Orthodontists' Priorities of the Occlusal, Functional and Esthetic Components in Assessing Malocclusion Severity

Each Orthodontist was asked to indicate the numerical priority of the occlusal, functional and esthetic components important to them when evaluating the severity of a malocclusion. An example of the questionnaire is provided in ***Appendix C***. The group mean for each of the components was calculated with the results listed in descending order of priority in **Table 4.1** .

Table 4.1

Prioritized list of occlusal, functional and esthetic components in malocclusion severity assessments.

Priority Rank	Parameter
1	overjet
2	maxillary and mandibular anterior segment irregularity
3	buccal segment occlusion
4	overbite
5	buccal segment crowding/spacing
6	centric relation-centric occlusion discrepancy
7	frontal facial asymmetry
8	relationship of the dental midlines to the facial midline
9	nasolabial angle
10	soft tissue facial angle
11	relationship of dental midlines
12	upper and lower lip prominence relative to Burstone's profile line
13	amount of upper incisor reveled on smiling
14	interlabial gap at rest
15	vertical facial thirds
16	throat length
17	lower anterior face height ratio
18	patient's perception of orthodontic treatment-need
19	impact of the malocclusion on speech/mastication
20	over-all dental health

Whereas the ranks listed 1-5 were analogous to the components measured in the DAI index (*see Appendix E*), those listed 18-20 were additional components identifying a need for future consideration.

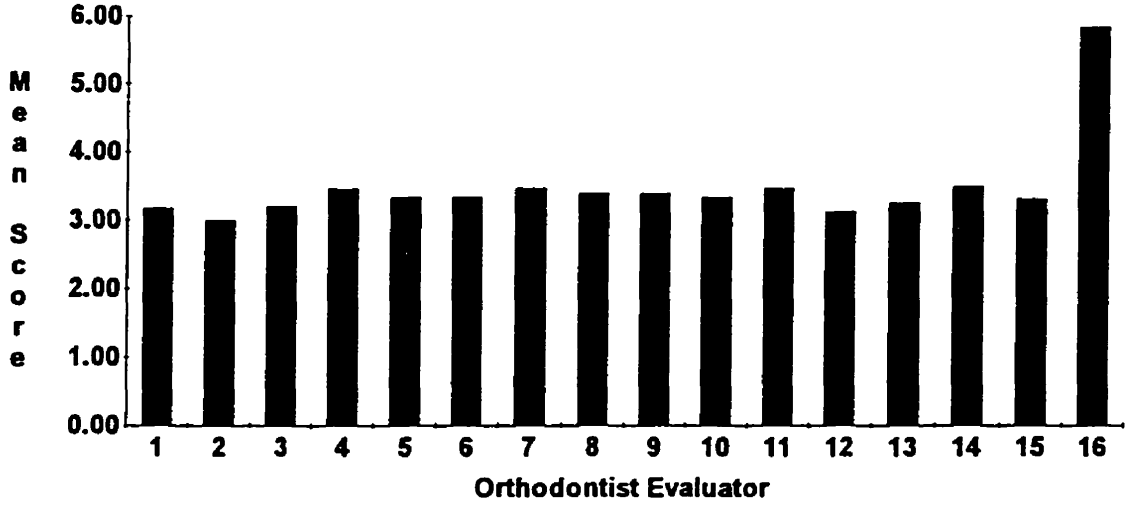
4.0.2 Orthodontists' Evaluation of Malocclusion Severity

Each Orthodontists' subjective assessments of malocclusion severity for each of the 38 cases in this study are summarized in **Table 4.2**. As the mean Analog scores ranged from 1.50 to 6.94, the case sample was derived from a wide range of malocclusion severities with their normal distribution being indicated by the congruence between the sample mean (3.45) and median (3.40). The average standard deviation calculated for each of the cases ranged from 0.25 (case No. 20) to 1.79 (case No. 9), with a mean standard deviation of 0.97.

The variation in individual case assessments between the various orthodontic specialists was a major concern. For instance, whereas the mean sample score ranged from 3.18 to 3.50 for the first 15 Orthodontist assessors, that of 5.84 for the 16th Orthodontist was statistically anomalous (*see Table 4.3, 4.4; Figure 4.1*). Statistically this was not a concern, since exclusion of this 'anomalous' assessor exerted little impact on the total mean sample score (i.e., mean sample score of 3.48 based on all the assessors, relative to 3.32 from the first 15 assessors). However, since the malocclusion categories of the 16th Orthodontist were inconsistent with the other assessors, they emphasized the need for a more objective system. This was further underscored by the assessments of Orthodontist #16, who categorized 10 of the malocclusions included in this study (26%) as very severe, whereas Orthodontist #1 assigned only one malocclusion (3%) to this category. Such inconsistencies did not apply to the total case sample, however, in that all but one of the orthodontists categorized case #20 as very severe and case #2 as mild to moderately severe malocclusions. Therefore, although the Intraclass Correlation Coefficient of 0.97 ($p<0.05$) indicates a very high level of inter-examiner agreement and reliability (Fleiss,

1990)(inter-examiner variance = 0.40; random error of chance = 0.59), the lack of congruence with the malocclusion severity status assigned to each case and the political implications of variations in subjective orthodontic severity assessments, suggests that the need for a more objective system of categorization cannot be overstated.

Figure 4.1 Orthodontists' Mean Scores
Total Case Sample



4.1 Data Obtained From the Sessions Involving the Graduate Orthodontic Students

4.1.0 DAI Evaluation of Malocclusion Severity

Evaluations of malocclusion severity for the total case sample are summarized in **Table 4.5**. As the DAI case scores ranged from 25.50 to 68.00, they confirmed the wide array of malocclusion severities included in the study, whereas congruence between the total sample mean and median DAI scores (39.21 and 39.35 respectively) indicated their normal (non-skewed) distribution. Based on the similarities between total sample means and standard deviations from each of the assessors (***see Table 4.3, 4.6; Figure 4.2, 4.3***), the DAI scores provided more consistent assessments than those based on the Analog scores. This was confirmed by their Intraclass Correlation Coefficient of 0.99 ($p<0.05$),

indicating an extremely high level of inter-examiner agreement (inter-examiner variance = 0.05; random error of chance = 1.51)(Fleiss, 1990).

Figure 4.2 DAI Mean Score Assessments
Total Case Sample

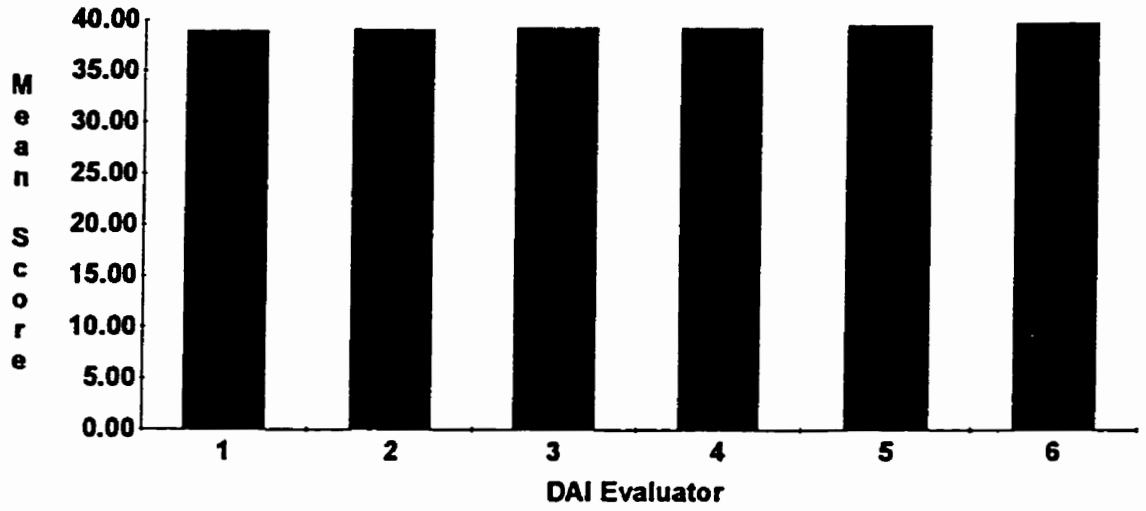
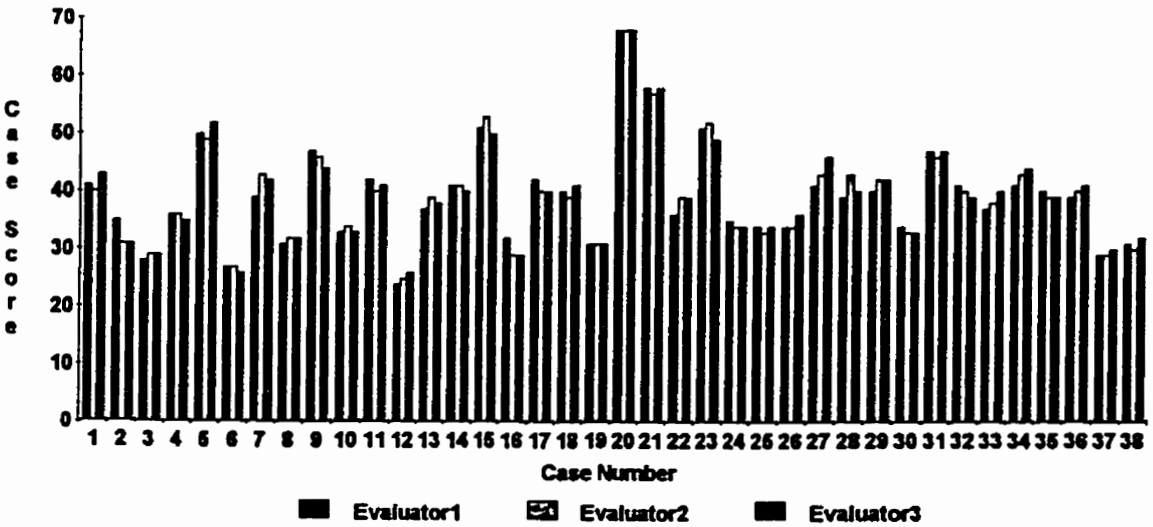


Figure 4.3 DAI Scores of 3 Evaluators
Total Case Sample



4.1.1 The Evaluation of DAI Component Scores

The mean DAI-component scores for each of the cases was calculated and summarized in **Table 4.7**. Each of the values represents the raw data provided by the Graduate Orthodontic students with subsequent weightings for each of the components being applied as per the standard-DAI equation (***see Appendix E***). Analysis of these component values further exemplified the malocclusion diversity and severity of the cases included in this study (***see Table 4.8***). For instance, the number of missing teeth ranged from zero (most cases) to 2 (one case), whereas crowding in the incisal segments extended from zero to both incisal segments. Similarly, incisal segment spacing ranged from none to 1.33 incisal segments, whereas measurements of the maxillary central incisor diastema extended from zero to 1.50 millimeters (one case). The largest maxillary anterior irregularity ranged from 1.17 millimeters to 6.67 millimeters, whereas the largest mandibular anterior irregularity extended from 0.17 to 4.33 millimeters. Moreover, the upper extremes in maxillary (8.33 millimeters) and mandibular (6.17 millimeters) overjet illustrated that both Angle Class II and Class III dental malocclusions were represented in the case sample. An extreme anterior vertical overbite of 4.83 millimeters indicated that at least one severe anterior openbite case was represented within the study sample. In addition, the anteroposterior molar relationship value of zero (Angle Class I molar relationship) and 1.83 extreme (tendency to full cusp Angle Class II or III molar relationship) further confirmed the sample diversity. For further illustration, see **Tables 4.8, 4.9 and Figures 4.4 to 4.10**.

Figure 4.4 MEAN DAI-COMPONENT SCORES

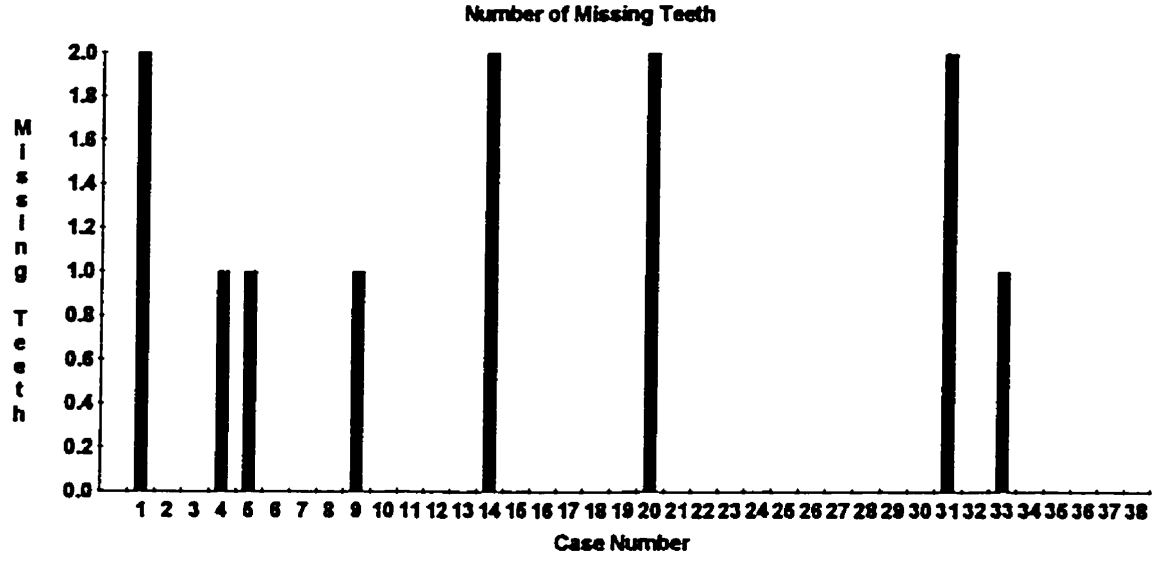


Figure 4.5 MEAN DAI-COMPONENT SCORES

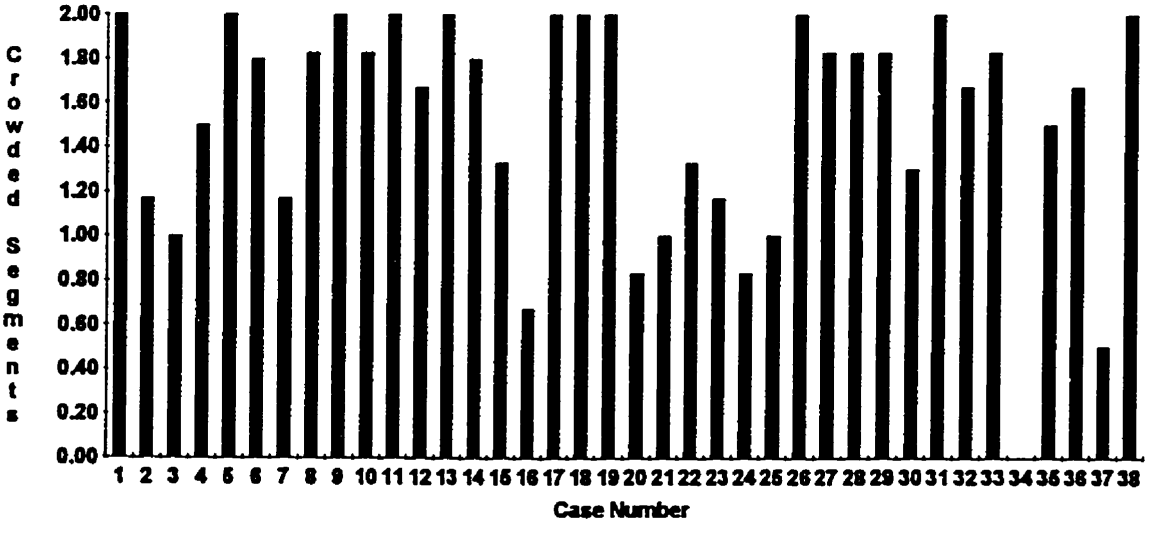


Figure 4.6 MEAN DAI-COMPONENT SCORES

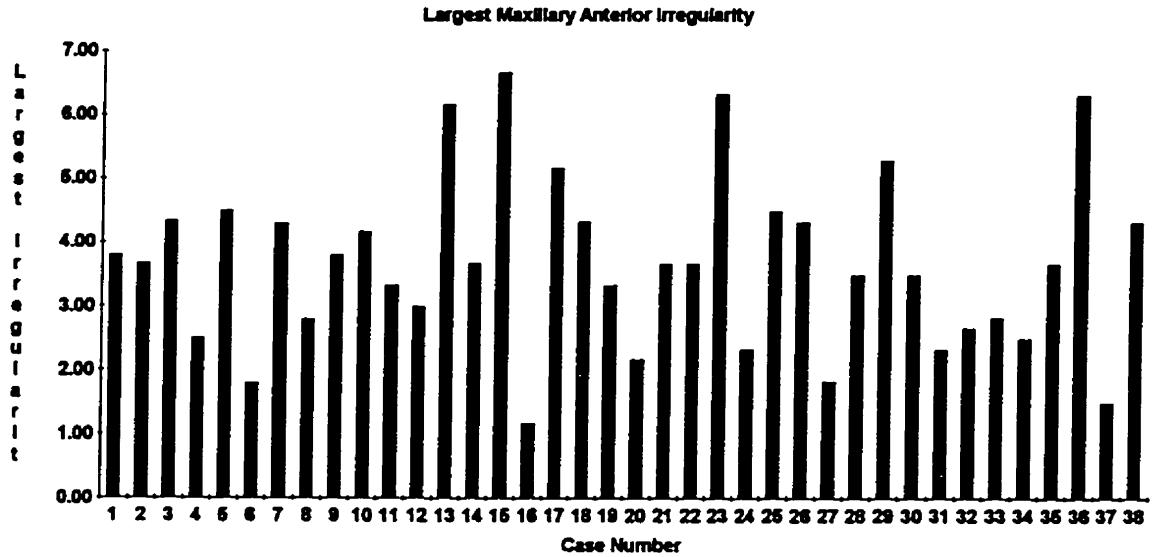


Figure 4.7 MEAN DAI-COMPONENT SCORES

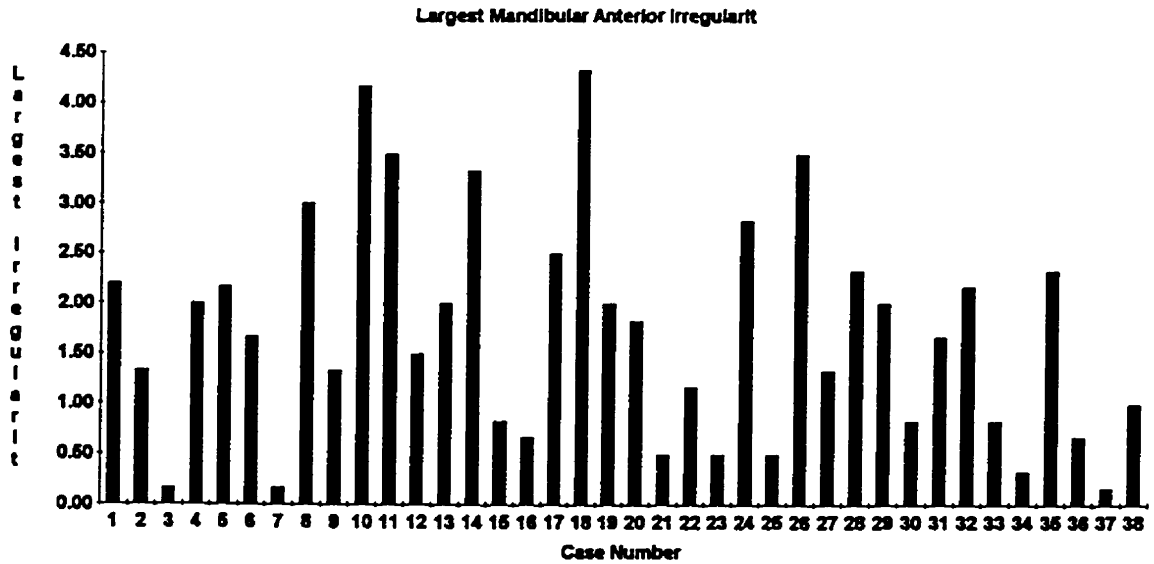


Figure 4.8 MEAN DAI-COMPONENT SCORES

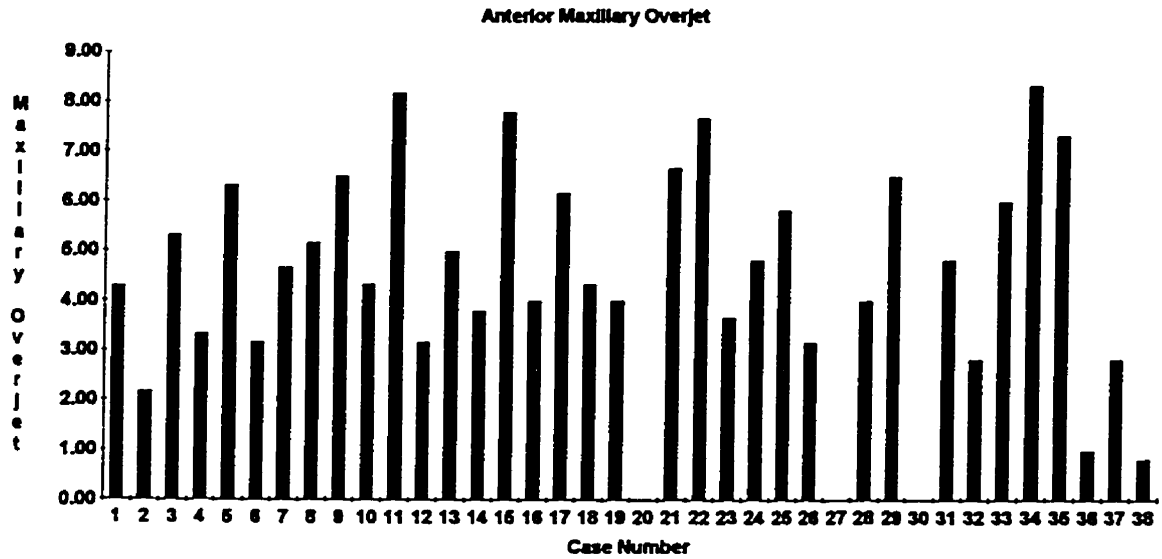


Figure 4.9 MEAN DAI-COMPONENT SCORES

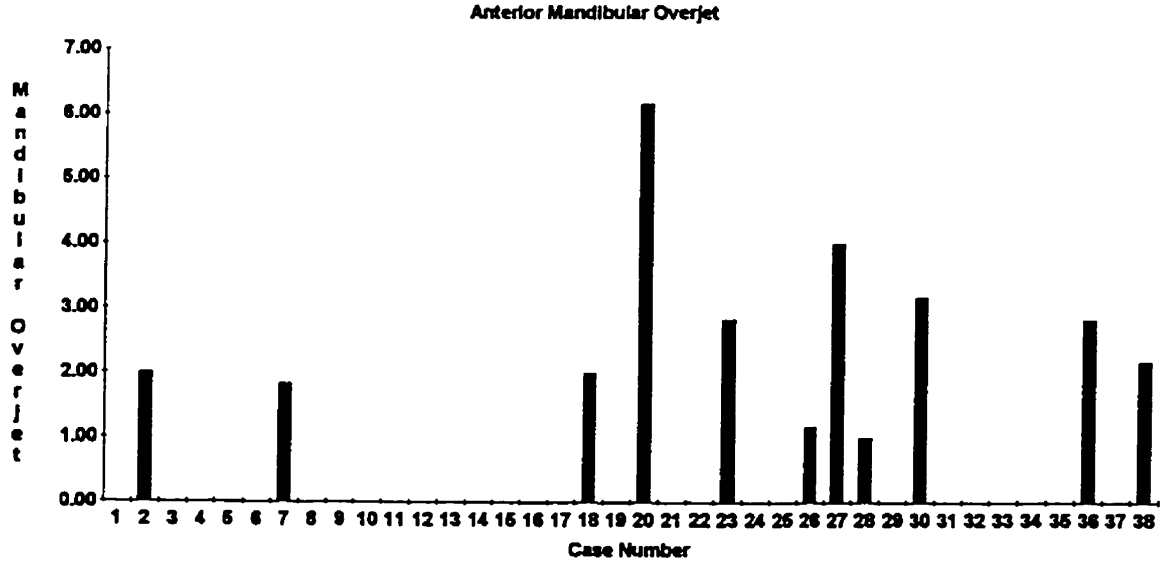
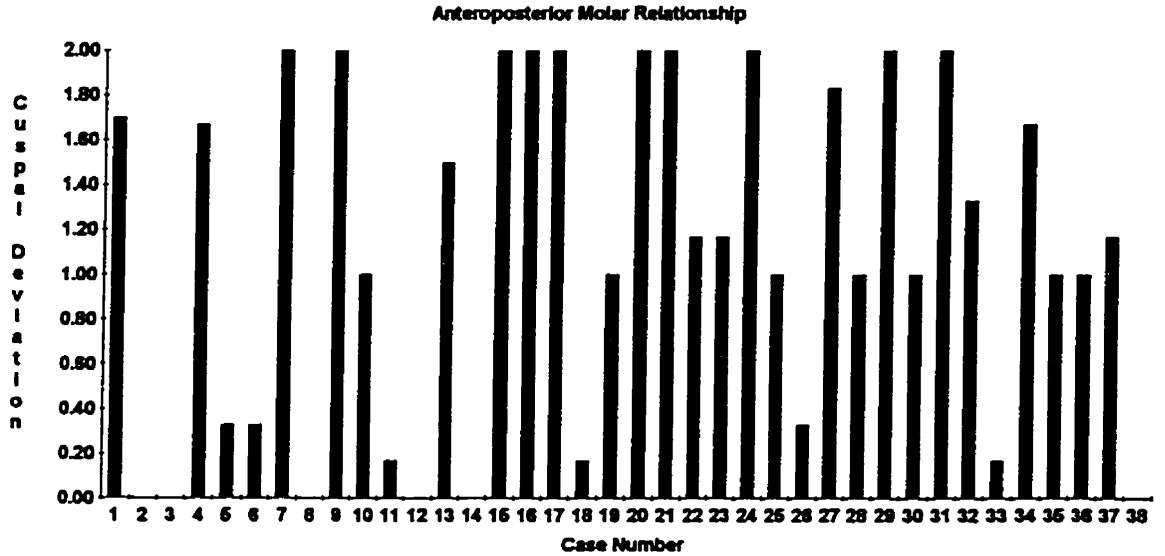


Figure 4.10 MEAN DAI-COMPONENT SCORES



4.2 The Ability of the DAI to Assess Malocclusion Severity

To test the ability of the DAI to discern varying degrees of malocclusion severity, comparison of the Orthodontists' case assessment were compared to the DAI scores for each case. The comparisons were completed using the mean group DAI and Orthodontists' assessment scores for each of the thirty eight cases. In addition, further Pearson correlation analysis was carried out separately for the mixed and permanent dentitions subsamples taken from the original case sample.

4.2.0 DAI Assessments of Malocclusion Severity Relative to Their Analog Scores Assigned by the Orthodontists

The DAI scores for each case were evaluated to determine their relative malocclusion severity assessments compared to those derived from the Orthodontists' Analog scores. For instance, the Pearson correlation coefficient (r) determined between the mean DAI and Analog scores for each of the thirty eight cases (***see Figure 4.11***) provided a 0.92r value, indicative of a strong correlation between these two parameters. Moreover, analyses of these parameters for the mixed (***Figure 4.12; Table 4.2***) and permanent dentition (***Figure 4.13***) subsamples indicated moderate and high correlation values ($r = 0.66$; $r = 0.94$ respectively), although the small sample size may have contributed to the low correlation coefficient obtained for the mixed dentition cases. This assertion requires further study, due to the potential advantages of interceptive orthodontic services as an option to reduce overall NIHB program expenditures.

Figure 4.11 - DAI vs. Orthodontists'
Assessment of Malocclusion Severity

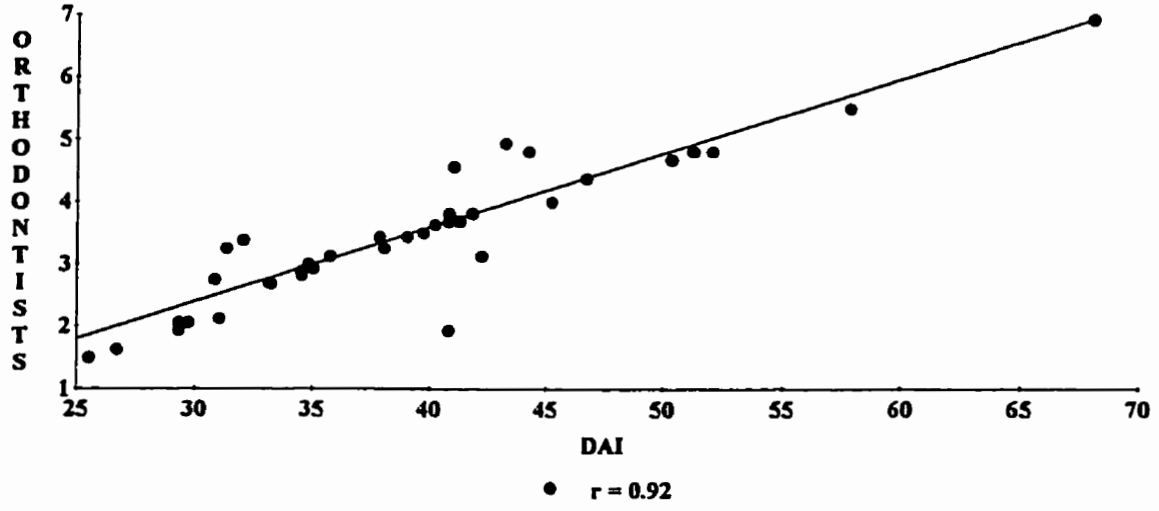


Figure 4.12 - DAI vs. Orthodontists'
Mixed Dentition Only

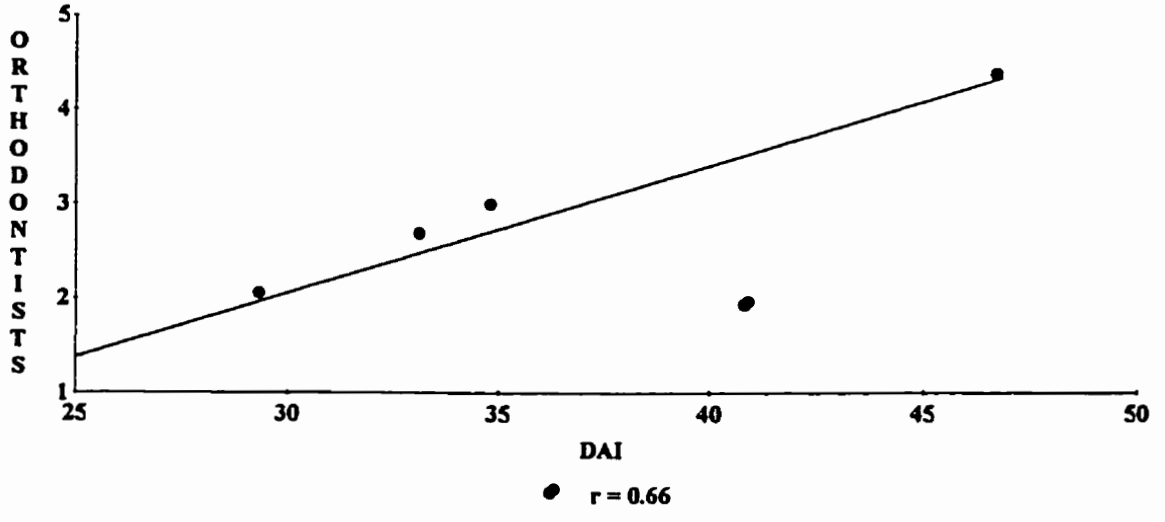
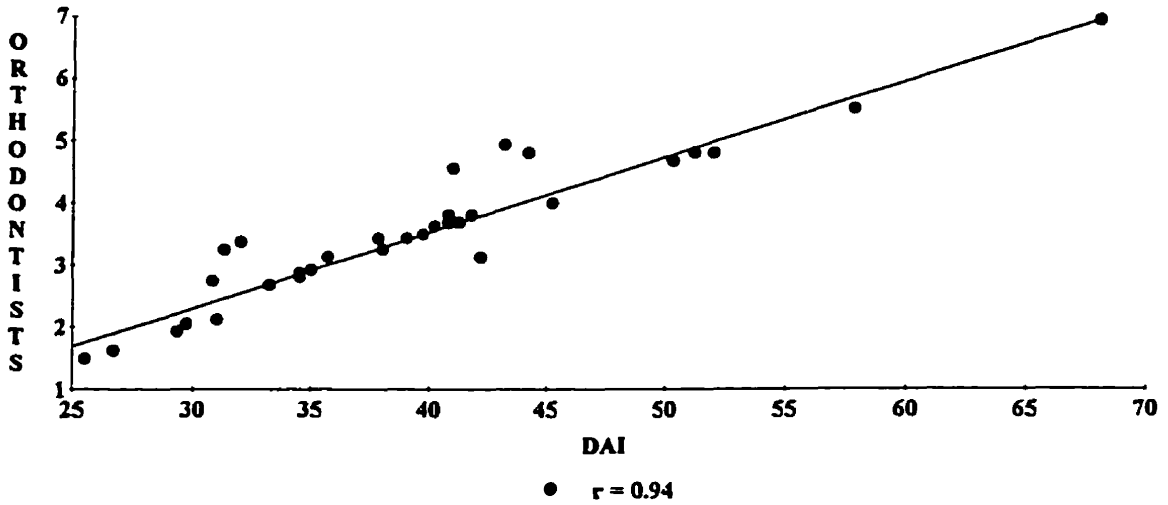


Figure 4.13 - DAI vs. Orthodontists'
Permanent Dentition Only



4.3 The Ability of the DAI to Assess Orthodontic Treatment-need

In order to evaluate the potential application of the DAI to discriminate those that should/should not be provided with orthodontic services, the calculation of a DAI score to reflect a treatment-need cut-off point was first determined. Using the cut-off score as a guide to the DAI-defined orthodontic treatment-need, a 2x2 matrix table comparison of the DAI versus NIHB assessments of treatment-need was completed. This comparison was not only determined for the total case sample, but also the permanent and mixed dentition subsamples. As thirty cases were approved and eight cases not approved by NIHB for orthodontic services in the total case sample (***see Table 4.2***), a list of guidelines have been developed (Matthews *et.al.*, 1995) to evaluate the 2x2 matrix table results, as listed in **Table 4.10**.

Table 4.10 Criteria Guideline for a Test of Acceptable Clinical Performance (Mathews *et.al.*, 1995)

- **Sensitivity + Specificity = 160+**
- **Accuracy = 80+%**
- **False Positive Fraction = < 20%**
- **False Negative Fraction = < 20%**
- **Likelihood Ratio of a Positive Test = > 1.0**
- **Likelihood Ratio of a Negative Test = < 1.0**

To test the ability of the DAI to assess orthodontic treatment-need, a DAI cut-off score was first determined via logistic regression analysis. The calculations associated with this cut-off score provides the highest degree of accuracy when evaluating the DAI's analysis of treatment-need versus the NIHB selection of cases for orthodontic treatment. These results are summarized in **Table 4.11**. This showed that a 30.03 DAI cut-off score was the threshold for orthodontic service-need, i.e., cases scores below this threshold indicated no service-need, while scores greater than or equal to 30.03 indicated a progressive service-need.

As illustrated in **Figure 4.14**, matrix table analysis indicated an acceptable (87%) level of assessment accuracy for the DAI in the total case sample, although the false positive (0.50) fraction was unacceptably high, indicating that high orthodontic service-need evaluated by the DAI assessment would have led to unnecessary services. By contrast, matrix table analysis of the permanent dentition subsample (***Figure 4.15***) indicated a greater level of assessment accuracy (94%) relative to that for the total sample; this was also confirmed by the likelihood ratio of a positive (3.00) and negative (0.00) test. Although the false negative fraction of 0.00 indicates an excellent value, the false positive fraction of 0.33 is still too high to be considered an acceptable level of false positive assessments of treatment-need. Furthermore, matrix table analysis for the mixed dentition subsample (***Figure 4.16***) indicated an unacceptable level of assessment accuracy (40%)

relative to that for the total sample. Similarly the 0.67 likelihood ratio of a positive test also reflected the poor ability of the DAI to indicate a positive need for orthodontic service in cases where there was a clear service-need (assessed by NIHB service approval regardless of the population being tested). By contrast, the 0.00 likelihood ratio of a negative test suggested that the DAI is acceptable in the determination of a negative service-need, regardless of the population being tested. As both the false positive (1.00) and negative (0.33) fractions were particularly unacceptable, in particular the false positive reflected a high level of false service-need assessments, the need to modify the DAI index cannot be overstated.

Figure 4.14 - Standard -DAI Assessment of Orthodontic Treatment-need

NIHB APPROVED

DAI APPROVED		Y	N
	Y	29	4
	N	1	4

Y indicates approval
N indicates non-approval

Accuracy = 0.87

Sensitivity = 0.97
False Positive Fraction = 0.5
Specificity = 0.500
False Negative Fraction = 0.03

Likelihood Ratio of a Positive Test = 1.9
Likelihood Ratio of a Negative Test = 0.67

Figure 4.15 - Standard-DAI Assessment of Orthodontic Treatment-need in the Permanent Dentition

DAI APPROVED	NIHB APPROVED: Y	NIHB APPROVED: N
Y	27	2
N	0	4

Y indicates approval
N indicates non-approval

Accuracy = 0.94

Sensitivity = 1.00
False Positive Fraction = 0.3
Specificity = 0.67
False Negative Fraction = 0.00

Likelihood Ratio of a Positive Test = 3.0
Likelihood Ratio of a Negative Test = 0.00

Figure 4.16 - Standard-DAI Assessment of Orthodontic Treatment-need in the Mixed Dentition

DAI APPROVED	NIHB APPROVED: Y	NIHB APPROVED: N
Y	2	2
N	1	0

Y indicates approval
N indicates non-approval

Accuracy = 0.40

Sensitivity = 0.67
False Positive Fraction = 1.0
Specificity = 0.00
False Negative Fraction = 0.33

Likelihood Ratio of a Positive Test = 0.6
Likelihood Ratio of a Negative Test = 0.00

4.4 The Development and Testing of the Modified-DAI

4.4.0 The Development of the Modified-DAI and the Determination of New Treatment-need Cut-off Score

Logistic regression analysis of the DAI components was completed to determine the modifications required for the standard-DAI to provide a more acceptable assessment of orthodontic service-need. As illustrated in **Table 4.12**, the results indicated that the following four components of the original DAI equation were principal determinants of orthodontic treatment-need:

- **Mandibular overjet.**
- **Maxillary overjet.**
- **Vertical anterior overbite.**
- **Anteroposterior molar relationship.**

Moreover, the more appropriate weightings for each of the critical components were also derived from the logistic regression analysis, resulting in the following modified-DAI formula:

9.073877(Md overjet) + 1.618226(Mx overjet) + 10.15565(Vertical overbite) + 1.856006(A-P molar Relationship) = Modified-DAI score

Each case was subsequently re-scored by applying the appropriate component raw group-mean data values to the equation and multiplying each mean component value by the appropriate new weighting. The component scores were subsequently summed to provide a **modified-DAI score** for each case (***see Table 4.13***), which were then used for further matrix table analysis versus the NIHB status of approval.

As demonstrated in **Table 4.14**, this analysis indicated a 9.39 modified-DAI cut-off score was the benchmark for orthodontic service-need, with case scores below this threshold indicating no service-need.

4.4.1 Evaluation of the Modified-DAI to Assess Orthodontic Treatment-need

Based on the total case sample (***Figure 4.17***), the 90% accuracy of this threshold score was slightly higher than that derived from the standard-DAI assessments. In addition, the 3.73 likelihood ratio of a positive test reflected the potential ability of the modified-DAI to indicate a positive service-need in a condition in true need of orthodontic care. The 0.89 likelihood ratio of a negative test was also adequate, whereas both the false positive (0.25) and negative (0.07) fractions, demonstrated improved levels of precision relative to the standard-DAI values. However, the level of the false positive fraction was slightly higher than desired than that desired for the ideal assessment (***see Table 4.10***).

These overall findings were confirmed by repeat analyses of the case subsamples. For instance, analysis of the modified-DAI for assessment of orthodontic treatment-need in the permanent dentition subsample (***Figure 4.18***) provided an 88% accuracy level, although this was slightly lower than that derived from the standard-DAI assessment of the same subsample. The 1.39 likelihood ratio of a positive test also indicated an acceptable ability for the modified-DAI to identify a positive need for orthodontic treatment in conditions of true service-need, although the level was below that derived from the standard-DAI. By contrast, the 0.11 likelihood ratio of a negative test was slightly higher than that of the standard-DAI when reflecting a negative need for orthodontic treatment, regardless of the population being tested. The 0.33 false positive fraction was identical to that of the standard-DAI. Similarly, the 0.07 false negative fraction value was comparable to that calculated for the standard-DAI.

Assessment of orthodontic service-need by the modified-DAI for the mixed dentition subsample is summarized in **Figure 4.19**, where the index was 100% accurate in

the assessment of service-need in the mixed dentition subsample. The likelihood ratio of a positive test equal to infinity also reflected a statistically perfect level of ability for the modified-DAI to identify a positive need for orthodontic treatment in a condition of true service-need. The 0.00 likelihood ratio of a negative test was also identical to the standard-DAI in indicating a negative need for orthodontic treatment, regardless of the population being tested. Similarly, the 0.00 false positive fraction was also equivalent to the ideal values discussed in **Table 4.10** and demonstrates significant improvements relative to the standard-DAI. The 0.00 false negative fraction was also substantially improved involving decisions to avoid the under-assessment of orthodontic treatment-need.

Figure 4.17 - MODIFIED-DAI Assessment of Orthodontic Treatment-need

NIHB APPROVED

DAI APPROVED		Y	N
	Y	*28*	*2*
	N	*2*	*6*

Y indicates approval
N indicates non-approval

Accuracy = 0.90

Sensitivity = 0.93
False Positive Fraction = 0.2
Specificity = 0.75
False Negative Fraction = 0.07

Likelihood Ratio of a Positive Test = 3.7
Likelihood Ratio of a Negative Test = 0.89

Figure 4.18 - MODIFIED-DAI Assessment of Orthodontic Treatment-need in the Permanent Dentition

DAI APPROVED	NIHB APPROVED: Y	NIHB APPROVED: N
Y	25	2
N	2	4

Y indicates approval
N indicates non-approval

Accuracy = 0.88

Sensitivity = 0.93
False Positive Fraction = 0.33
Specificity = 0.67
False Negative Fraction = 0.07

Likelihood Ratio of a Positive Test = 1.39
Likelihood Ratio of a Negative Test = 0.1

Figure 4.19 - MODIFIED-DAI Assessment of Orthodontic Treatment-need in the Mixed Dentition

DAI APPROVED	NIHB APPROVED: Y	NIHB APPROVED: N
Y	3	0
N	0	2

Y indicates approval
N indicates non-approval

Accuracy = 1.00

Sensitivity = 1.00
False Positive Fraction = 0.00
Specificity = 1.00
False Negative Fraction = 0.00

Likelihood Ratio of a Positive Test = Infinity
Likelihood Ratio of a Negative Test = 0.0

4.5 Summary

Caution must be applied to the interpretation of the data derived from this present study, since other determinants impact on the orthodontic service-need, in addition to malocclusion severity, e.g., oral hygiene status, restorative history. In addition, the case samples submitted to investigation were necessarily restricted to one region of the NIHB program, whereas slight modifications of the approval/non-approval status criteria may have been applied in other regions. Therefore, these data are necessarily tentative, so that further evaluations prior to the national acceptance of the modified-DAI as an index of orthodontic service-need.

Nevertheless, the main features derived from this study may be summarized in point form:

- Subjective assessments of orthodontic service-need by practising orthodontic specialists are unacceptably variable to be acceptable in a publicly-funded dental program. The deficiencies were primarily underscored by Orthodontist #16, whose assessments were quite anomalous relative to those from the other Orthodontists. The need to guard against such anomalous assessments underscored the requirement for a more objective categorization system.
- The reliability of the orthodontic severity assessments based on the standard-DAI was confirmed by the consistency between the various assessors. But since these data conflicted with the NIHB approval/non-approval status of the cases, some modification was required to provide more relevant assessments.
- Evaluations of the orthodontic severity based on the modified-DAI, not only proved to be consistent between the assessors, but also the categorizations of service-need closely correlated with their NIHB approval/non-approval status.

The relative merits of the modified-DAI in the categorization of service-need is summarized in **Table 4.15** .

TABLE 4.2 - Orthodontists' Evaluation of Malocclusion Severity

EVALUATOR

CASE NUMBER	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	Mean	SD
1 ·	3	2	2	3	2	4	3	3	3	2	3	3	4	4	2	7	3.13	1.25
2	2	3	3	3	3	4	4	4	3	4	3	2	3	3	3	7	3.38	1.15
3 ·	1	1	1	2	2	1	3	2	2	2	3	2	1	3	2	3	1.94	0.77
4	3	2	2	4	3	3	3	4	3	3	2	2	3	3	3	7	3.13	1.20
5	5	4	4	4	4	4	5	4	5	5	5	4	5	5	5	7	4.68	0.79
6 ·	1	1	2	2	3	2	1	2	2	1	2	1	1	2	2	1	1.63	0.62
7	3	4	5	3	3	4	4	3	4	3	3	3	3	4	3	7	3.69	1.08
8 ·	1	2	1	1	1	2	4	2	2	2	3	1	1	5	2	4	2.13	1.26
9	3	4	5	4	5	5	4	4	4	6	4	4	4	4	4	7	4.00	1.79
• 10 ·	2	2	3	4	2	2	3	4	2	2	2	3	3	3	2	4	2.69	0.79
11	4	3	5	4	4	4	5	3	3	3	5	2	3	3	3	7	3.81	1.22
12 ·	2	1	1	2	2	1	2	2	1	1	2	1	1	2	2	1	1.50	0.52
13	3	4	3	3	3	3	3	4	3	3	3	3	3	4	3	7	3.43	1.03
• 14 ·	1	1	1	3	3	2	3	2	3	2	3	2	1	1	1	2	1.94	0.85
15	5	4	4	6	4	6	4	4	5	5	5	4	5	4	5	7	4.81	0.91
16 ·	1	2	1	2	2	1	3	3	3	3	3	1	2	3	2	1	2.06	0.85
17	4	3	4	5	5	5	5	4	4	5	5	4	4	5	4	7	4.56	0.89
18	4	4	4	3	3	3	3	3	5	3	3	4	4	3	3	7	3.68	1.08
19	3	4	2	3	3	3	3	3	3	4	3	3	2	3	3	7	3.25	1.13
20	7	7	7	6	7	7	7	7	7	7	7	7	7	7	7	7	6.94	0.25
21	6	4	5	5	6	6	5	5	6	5	5	6	6	5	6	7	5.50	0.73
22	2	3	4	3	3	2	3	4	3	3	4	2	3	3	3	7	3.25	1.18
23	5	5	4	4	4	4	5	4	5	5	5	5	5	4	6	7	4.81	0.83
24 •	2	2	3	3	2	2	2	3	4	4	4	2	2	4	2	7	3.00	1.37
25	4	2	3	3	2	2	4	3	2	2	2	3	4	2	2	7	2.81	1.33
26	3	4	3	4	4	3	3	3	2	2	2	4	3	3	2	7	2.93	0.77
27	4	4	5	4	5	5	5	5	5	5	5	4	5	5	4	7	4.81	0.75
28	4	3	3	5	4	3	3	4	3	3	3	5	3	3	4	7	3.63	1.09
29	4	3	4	4	3	3	3	3	4	3	4	3	3	4	4	7	3.69	1.01
30	2	2	3	3	2	3	2	3	2	2	3	3	3	3	3	7	2.88	1.20
• 31	4	4	4	4	4	4	4	4	5	5	4	3	5	4	5	7	4.38	0.89
32	4	3	3	4	3	3	3	4	3	3	3	4	3	3	3	7	3.50	1.03
33	3	3	3	4	3	3	3	3	3	3	4	3	3	3	4	7	3.44	1.03
34	5	4	6	6	6	6	5	4	4	5	5	4	5	5	5	4	4.94	0.77
35	2	2	2	2	4	3	2	3	2	3	2	2	3	2	2	7	2.69	1.30
36	4	4	3	3	4	4	3	4	4	3	3	4	3	4	4	7	3.81	0.98
• 37	2	2	2	2	2	2	2	1	2	2	2	3	2	2	2	3	2.06	0.44
38	3	2	2	2	2	3	3	2	3	3	3	3	3	3	4	3	2.75	0.58

SD range of 0.25 to 1.79
Mean SD = 0.97
Range of Malocclusion Severity = 1.50 - 6.94
Mean Malocclusion Severity Score= 3.45
Median Score = 3.40

Cases Not Approved by MSB for orthodontic treatment = 1,3,6,8,10,12,14,16
Mixed Dentition Cases = 10,14,24,31,37

· = NIHB not approved
• = Mixed dentition cases

TABLE 4.3 Mean Case Score Assessments of the Orthodontist and DAI Evaluators for the Total Sample

		Mean Score and S.D.
Orthodontist	1	3.18 +/- 1.45
	2	3.00 +/- 1.27
	3	3.21 +/- 1.45
	4	3.47 +/- 1.20
	5	3.34 +/- 1.46
	6	3.34 +/- 1.32
	7	3.47 +/- 1.18
	8	3.39 +/- 1.31
	9	3.39 +/- 1.08
	10	3.34 +/- 1.10
	11	3.47 +/- 1.20
	12	3.13 +/- 1.34
	13	3.26 +/- 1.43
	14	3.50 +/- 1.16
	15	3.32 +/- 1.38
	16	5.84 +/- 2.06

S.D. = Standard Deviation

		Mean Score and S.D.
DAI	1	39.00 +/- 8.67
	2	39.13 +/- 8.80
	3	39.32 +/- 8.69
	4	39.29 +/- 8.73
	5	39.55 +/- 8.91
	6	39.82 +/- 8.72

S.D. = Standard Deviation

TABLE 4.4 - Subsample Case Assessments by Orthodontists

Sample Evaluated	Mean Score by 16 Ortho.	Mean Score by 15 Ortho.
A. Total Cases	3.45 +/- 0.97	3.32 +/- 0.64
Approved Cases	3.78 +/- 0.98	3.61 +/- 0.61
Non-Approvrd Cases	2.13 +/- 0.54	2.05 +/- 0.88
B. Total Permanent Dentition	3.58 +/- 0.97	3.42 +/- 0.64
Approved Cases	3.85 +/- 0.99	3.67 +/- 0.61
Non-Approved Cases	2.07 +/- 0.58	2.01 +/- 0.89
C. Total Mixed Dentition	2.81 +/- 0.87	2.69 +/- 0.69
Approved Cases	3.15 +/- 0.90	2.98 +/- 0.61

NB. Mean scores listed with their standard deviations

- ***No statistical calculation was completed for the non-NIHB approved mixed dentition subsample due to the small sample size.***

TABLE 4.6 - Subsample Cases Assessments by the DAI

Sample Evaluated	Mean DAI Scores
A. Total Cases	39.35 +/- 8.75
Approved Cases	40.86 +/- 1.20
Non-Approved Cases	32.29 +/- 6.16
B. Total Permanent Dentition	39.30 +/- 8.94
Approved Cases	41.28 +/- 1.25
Non-Approved Cases	30.73 +/- 5.98
C. Total Mixed Dentition	36.97 +/- 0.64
Approved Cases	36.94 +/- 0.80

NB. Mean DAI scores listed with their standard deviations.

- ***No statistical calculation was completed for the non-NIHB approved mixed dentition subsample due to the small sample size.***

TABLE 4.5 - Standard-DAI Case Scores

EVALUATOR

CASE NUMBER	1	2	3	4	5	6	Mean	SD
1	41	40	43	44	43	42	42.20	1.47
2	35	31	31	31	32	32	32.00	1.55
3	28	29	29	31	31	28	29.30	1.37
4	36	36	35	36	36	35	35.70	0.52
5	50	49	52	50	50	51	50.30	1.03
6	27	27	26	26	26	28	26.70	0.82
7	39	43	42	40	42	42	41.30	1.51
8	31	32	32	31	29	31	31.00	1.09
9	47	46	44	44	45	45	45.20	1.17
10	33	34	33	33	33	33	33.10	0.41
11	42	40	41	41	39	42	40.80	1.17
12	24	25	26	25	26	27	25.50	1.05
13	37	39	38	37	37	39	37.80	0.98
14	41	41	40	41	41	41	40.80	0.41
15	51	53	50	50	54	54	52.00	1.90
16	32	29	29	29	29	30	29.70	1.21
17	42	40	40	41	40	43	41.00	1.26
18	40	39	41	39	41	44	40.80	1.83
19	31	31	31	32	32	31	31.30	0.52
20	68	68	68	68	69	67	68.00	0.63
21	58	57	58	58	58	58	57.80	0.41
22	36	39	39	37	38	39	38.00	1.26
23	51	52	49	51	53	51	51.20	1.33
24	35	34	34	35	36	35	34.80	0.75
25	34	33	34	36	36	34	34.50	1.22
26	34	34	36	35	36	35	35.00	0.89
27	41	43	46	46	45	44	44.20	1.94
28	39	43	40	38	38	43	40.20	2.32
29	40	42	42	41	40	42	41.20	0.98
30	34	33	33	37	35	35	34.50	1.52
31	47	46	47	46	46	48	46.70	0.82
32	41	40	39	39	38	41	39.70	1.21
33	37	38	40	40	40	39	39.00	1.26
34	41	43	44	45	44	42	43.20	1.47
35	40	39	39	38	40	38	33.20	0.89
36	39	40	41	44	44	43	41.80	2.14
37	29	29	30	28	30	30	29.30	0.82
38	31	30	32	30	31	31	30.80	0.75

DAI mean score = 39.21
DAI median score = 39.25
DAI score range = 25.50 to 68.00
SD range of 0.41 to 2.32
Mean SD = 1.10

TABLE 4.7 - Mean DAI-component Scores for Each of the Cases

Average Component Scores

CASE NUMBER	miss. teeth	crowd	space	diast.	Mx ant irreg.	Md an irreg.	Mx OJ	Md OJ	vert. OB	A-P molar
1	2.00	2.00	0.00	0.00	3.80	2.20	4.30	0.00	0.00	1.70
2	0.00	1.17	0.00	0.00	3.67	1.33	2.17	2.00	0.00	0.00
3	0.00	1.00	0.00	0.00	4.33	0.17	5.33	0.00	0.00	0.00
4	1.00	1.50	0.00	0.00	2.50	2.00	3.33	0.00	0.00	1.67
5	1.00	2.00	0.00	0.00	4.50	2.17	6.33	0.00	0.67	0.33
6	0.00	1.80	0.00	0.00	1.80	1.67	3.17	0.00	0.00	0.33
7	0.00	1.17	0.00	0.00	4.30	0.17	4.67	1.83	0.00	2.00
8	0.00	1.83	0.00	0.00	2.80	3.00	5.17	0.00	0.00	0.00
9	1.00	2.00	0.00	0.00	3.80	1.33	6.50	0.00	0.00	2.00
10	0.00	1.83	0.17	0.00	4.17	4.17	4.33	0.00	0.00	1.00
11	0.00	2.00	0.00	0.00	3.33	3.50	8.17	0.00	0.00	0.17
12	0.00	1.67	0.00	0.00	3.00	1.50	3.17	0.00	0.00	0.00
13	0.00	2.00	0.00	0.00	6.17	2.00	5.00	0.00	0.00	1.50
14	2.00	1.80	0.00	0.00	3.67	3.33	3.80	0.00	0.00	0.00
15	0.00	1.33	0.00	0.00	6.67	0.83	7.80	0.00	2.00	2.00
16	0.00	0.67	0.00	0.00	1.17	0.67	4.00	0.00	0.00	2.00
17	0.00	2.00	0.00	0.00	5.17	2.50	6.17	0.00	0.00	2.00
18	0.00	2.00	0.00	0.00	4.33	4.33	4.33	2.00	0.00	0.17
19	0.00	2.00	0.00	0.00	3.33	2.00	4.00	0.00	0.00	1.00
20	2.00	0.83	0.67	0.00	2.17	1.83	0.00	6.17	1.67	2.00
21	0.00	1.00	1.00	0.00	3.67	0.50	6.67	0.00	4.83	2.00
22	0.00	1.33	0.00	0.00	3.67	1.17	7.67	0.00	0.00	1.17
23	0.00	1.17	0.00	0.00	6.33	0.50	3.67	2.83	2.00	1.17
24	0.00	0.83	0.00	0.00	2.33	2.83	4.83	0.00	0.00	2.00
25	0.00	1.00	0.00	0.33	4.50	0.50	5.83	0.00	0.00	1.00
26	0.00	2.00	0.00	0.00	4.33	3.50	3.17	1.17	0.00	0.33
27	0.00	1.83	0.00	0.00	1.83	1.33	0.00	4.00	1.17	1.83
28	0.00	1.83	0.00	0.00	3.50	2.33	4.00	1.00	1.00	1.00
29	0.00	1.83	0.00	0.00	5.30	2.00	6.50	0.00	0.00	2.00
30	0.00	1.30	0.17	0.00	3.50	0.83	0.00	3.17	0.00	1.00
31	2.00	2.00	0.00	0.00	2.33	1.67	4.83	0.00	0.00	2.00
32	0.00	1.67	0.00	1.00	2.67	2.17	2.83	0.00	2.00	1.33
33	1.00	1.83	0.00	0.00	2.83	0.83	6.00	0.00	0.00	0.17
34	0.00	0.00	1.17	1.50	2.50	0.33	8.33	0.00	0.00	1.67
35	0.00	1.50	0.00	0.00	3.67	2.33	7.33	0.00	0.00	1.00
36	0.00	1.67	0.00	0.00	6.33	0.67	1.00	2.83	1.00	1.00
37	0.00	0.50	1.33	0.00	1.50	0.17	2.83	0.00	1.00	1.17
38	0.00	2.00	0.00	0.00	4.33	1.00	0.83	2.17	0.00	0.00

TABLE 4.8 - Group Means and Ranges for Each DAI Componen

DAI Component Data

DAI Componen	Mean Component Value	Range
Number of Missing Teeth	0.03	0.00 - 2.00
Crowding of the Incisal Segments	1.50	0.00 - 2.00
Spacing of the Incisal Segments	0.09	0.00 - 1.33
Maxillary Diastema	0.05	0.00 - 1.50
Largest Mx Anterior Irregularity	3.68	1.17 - 6.67
Largest Md Anterior Irregularity	1.67	0.17 - 4.33
Maxillary Overjet	4.42	0.00 - 8.33
Mandibular Overjet	0.64	0.00 - 6.17
Anterior Vertical Overbite	0.46	0.00 - 4.83
Anteroposterior Molar Relationship	1.05	0.00- 1.83

TABLE 4.9 - Mean DAI-component Scores (Approved vs. Non-approved)

	crowd	Mx ant irreg.	Md ant irreg.	Mx OJ	Md OJ	A-P molar
Permanent Dentition						
Approved	1.52 +/- 0.51	3.93 +/- 1.39	1.59 +/- 1.04	4.51 +/- 2.58	1.04 +/- 1.59	1.20 +/- 0.72
Non-approved	1.66 +/- 0.39	3.15 +/- 0.97	1.71 +/- 1.04	4.23 +/- 1.04	N.C.	0.41 +/- 0.74
Mixed Dentition						
Approved	1.66 +/- 0.39	3.15 +/- 0.97	1.71 +/- 1.04	4.23 +/- 1.04	N.C.	1.72 +/- 0.48
Non-approved	1.82 +/- 0.02	3.92 +/- 0.35	3.75 +/- 0.59	4.07 +/- 0.37	N.C.	0.50 +/- 0.71

N.C. = No Cases

Table 4.11 - Logistic Regression Calculation of Treatment-need Cut-off Values for the Standard-DAI

ln odds of approval = -6.7925 + 0.2262 (DAI average)
$x\sim$ = 9.59 with 1 df, $p < 0.002$

i.e., if 6.7925 - 0.2262 DAI >

Cut-off point = if $p > 0.50$, then "approved"
if $p < 0.50$, then "not approved"

DAI-cut-off point = 30.03 (if DAI < 30.03, probability of approval > 0.50)

Table 4.12 - Final regression analysis indicating the most important DAI components and their relative weighted influence in determining orthodontic treatment-need

VARIABLE	Beta Estimate	Standard Error	Chi-Square Beta = 0	Probability Beta = 0
Intercept	-9.390925	4.584672	4.20	0.0405
Md overjet	9.073877	27.29044	0.11	0.7395
Mx Overjet	1.618226	0.8352367	3.75	0.0527
Vertical Overbite	10.15565	38.97771	0.07	0.7944
A-P molar rel'n	1.856006	0.9969414	3.47	0.0626

Md = Mandibular
Mx = Maxillary
A-P = Anteroposterio

TABLE 4.13 Modified-DAI Case Scores

CASE NUMBER	MODIFIED-DAI CASE SCORES
1	10.11
2	21.66
3	8.62
4	8.49
5	17.66
6	5.74
7	27.87
8	8.37
9	14.23
10	8.86
11	13.53
12	5.13
13	10.87
14	6.15
15	36.64
16	10.18
17	13.70
18	25.47
19	8.33
20	76.66
21	63.56
22	14.58
23	54.10
24	11.53
25	11.29
26	16.36
27	51.58
28	27.56
29	14.23
30	30.62
31	11.53
32	27.36
33	10.02
34	16.58
35	13.72
36	39.31
37	16.91
38	21.03

Modified-DAI mean score = 20.79
Modified-DAI score range = 5.13 to 76.66

Table 4.14 - Logistic Regression Calculation of Treatment-need Cut-off Values for the Modified-DAI

ln odds of approval = -6.7925 + 0.2262 (DAI average)
x^2 = 9.59 with 1 df, $p < 0.002$

i.e., if 6.7925 - 0.2262 DAI > 0

Cut-off point = if $p > 0.50$, then "approved"
if $p < 0.50$, then "not approved"

DAI-cut-off point = 9.39 (if DAI < 9.39, probability of approval > 0.50)

TABLE 4.15 Priorized Case Lists Based on Orthodontists' Analog, Standard and Modified-DAI Scores

Case	Ortho Score	Case	Standard-DAI	Case	Modified-D
20	6.94	20	68.00	20	76.66
21	5.50	21	57.83	21	63.56
34	4.94	15	52.00	23	54.10
27	4.81	23	51.17	27	51.58
23	4.81	5	50.33	36	39.31
15	4.81	31	46.67	15	36.64
5	4.68	9	45.17	30	30.62
17	4.56	27	44.17	7	27.87
31	4.38	34	43.17	28	27.56
9	4.00	1*	42.17	32	27.36
36	3.81	36	41.83	18	25.47
11	3.81	29	41.17	2	21.66
29	3.69	7	41.33	38	21.03
7	3.69	17	41.00	5	17.66
18	3.68	11	40.83	37	16.91
28	3.63	14*	40.83	34	16.58
32	3.50	18	40.67	26	16.36
33	3.44	28	40.17	22	14.58
13	3.43	32	39.67	29	14.23
2	3.38	33	39.00	9	14.23
19	3.25	35	39.00	35	13.72
22	3.25	22	38.00	17	13.70
1*	3.13	13	37.83	11	13.53
4	3.13	4	35.67	24	11.53
24	3.00	26	35.00	31	11.53
26	2.93	24	34.83	25	11.29
30	2.88	25	34.50	13	10.87
25	2.81	30	34.50	16*	10.18
38	2.75	10*	33.17	1*	10.11
10*	2.69	2	32.00	33	10.02
35	2.69	19	31.33	10*	8.86
8*	2.13	8*	31.00	3*	8.62
37	2.06	38	30.83	4	8.49
16*	2.06	16*	29.67	8*	8.37
14*	1.94	37	29.33	19	8.33
3*	1.94	3*	29.33	14*	6.15
6*	1.63	6*	26.67	6*	5.74
12*	1.50	12*	25.50	12*	5.13

* *Indicates Cases Not-Approved by NIHB*

Discussion

Contents

This section is divided into two main area of Discussion:

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DISCUSSION

Section 1 - Macroscopic Discussion of Public-health Funding Allocation Mechanisms.

This study has been focused on the most appropriate allocation of scarce resources for orthodontic services within the NIHB program. As this program is primarily designed to provide to dental services to the people of First Nations Treaty and Inuit communities analogous to those available to other Canadians living in similar locations, there are concerns that the provision of orthodontic services might deplete the resources for "essential" services. These concerns are common to other third party health care programs, i.e., no resources are adequate for everyone to obtain all the health care services they demand (Klein, 1993). Rationing of resources in this sense, is therefore inherent to the dynamics of the system, whether financed by publicly or privately-funded resources (Heginbotham, 1992). Although there is nothing new about health care rationalization, the growing level of academic and political discussion suggests that this topic is progressing upwards on the policy agenda.

Although explicit policies for the provision of orthodontic services are preferable for any form of rationing, they are not the only strategic options. Left to themselves, all third party health care systems will undoubtedly devise rationing arrangements that are largely implicit to those that provide them (Heginbotham, 1992). For instance, the main rationing mechanisms for orthodontic services within the NIHB dental program have relied on the initial gatekeeping role of general dentists, together with the "clinical judgement" (professional autonomy) of both generalists and specialist dentists (orthodontists), buffered by prior approval assessment systems devised by the respective regional dental officers.

These mechanisms have primarily served three functions:

- **Who** should make the rationing decisions for orthodontic services?
- **What** mechanisms should be employed to make and implement such decisions, and to whom should they be explicit?
- **What** criteria should be employed to underpin decisions?

These are not discrete issues, since those that relate to clinical freedom define both the inherent determinants of the decision maker and the mechanisms to discriminate between those who should/should not be provided with orthodontic services. There may also be iterations in the policy issues. For instance, if equity is chosen as the appropriate criterion, then how and by whom it is to be operationalized become central issues. There may also be different levels of decision-making within any rationing system:

- **Macro-mechanisms** associated with resource allocations to the various component services within the NIHB program, e.g. restorative versus orthodontic services or dental versus pharmacy services.
- **Micro-mechanisms** associated with the local or regional allocation of resources for orthodontic services.

These issues are the principal focus of this section, which is primarily related to potential mechanisms for control of the provision of orthodontic services to those eligible for NIHB benefits.

5.0. Decision Makers

Five groups are potential candidates of the decision makers for the provision of orthodontic services within the NIHB dental program:

- Government
- National and/or regional NIHB managers
- The dental profession
- The First Nations Treaty and Inuit communities
- The courts.

5.0.0 Government

There is an obvious sense in which Government is the appropriate decision-making body. Dental service rationing within the NIHB program is fundamentally a political exercise, i.e., it involves the authoritative allocation of values. In the publicly-funded NIHB dental program, trade-offs are inevitable between competing objectives of public expenditures, although there are two important policy choices that remain undetermined by this necessity.

First, the necessity for governments to make decisions about the allocation of publicly-funded resources between such sectors as health, education, infrastructure, sanitation etc., need not extend to decisions about priorities within the health sector. Second, government need not necessarily imply the Federal government, since transfer of NIHB control to Tribal and Band councils may result in changes in this regard. Yet in all discussions on the government's role in rationing, there is an important caveat, i.e., the public (those eligible for NIHB dental benefits) does not necessarily perceive politicians to exercise their legitimate status as decision-makers, due to the low esteem in which politicians are held.

5.0.1 National and/or regional NIHB managers

In the NIHB dental program, Health Canada has recently formed a Dental Care Advisory Committee (DCAC) comprised of a diverse selection of members who represent First Nations and Inuit peoples, the Canadian Dental Association, the Denturist Association of Canada, the Royal College of Dentists of Canada, the Canadian Dental Therapy Association and Dental Academia. The role of this committee is to provide advice and recommendations on:

- Dental treatment and preventative programs/benefits provided to eligible clients;
- Management and delivery of dental programs and benefits by the NIHB;
- Transfer of control and management of dental care programs/benefits to eligible clients;
- Establishment of an appropriate needs-based standard of care;
- Recognition and application of cultural needs and differences.

In general terms, the DCAC has tried to avoid the explicit rationing of particular dental services, although they may provide advice on the allocation of financial resources to broad areas of dental care. Although there would appear to be greater support from the First Nations Treaty and Inuit communities if the DCAC acted as rationing decision makers rather than for politicians. The greatest deficiency stems from the lack of legitimacy which is de facto accorded by patients, the public and the news media to dental professionals by virtue of their direct role in providing dental care. The future viability of rationing decisions by the DCAC may therefore be dependant upon either devising some mechanism of legitimation (e.g., election or extensive public consultation) or, the establishment of clear criteria to underpin their managerial rationing decisions. Yet such a role is hampered by the lack of precise epidemiological data on the orthodontic service-

needs of those eligible for NIHB benefits or the impact of the current level of services on their total orthodontic burden.

5.0.2 The dental profession

The dental profession has been the main player in rationing orthodontic services to those eligible for NIHB benefits, in sofar as deciding what orthodontic services are available and who should receive them. It is clearly possible for policy makers to exploit this public deference to professionals in order to avoid making difficult decisions themselves, although such arrangements are constrained by two sorts of difficulties. The first is pragmatic, in that the co-operation between dentists (generalists and specialists) in highly competitive markets may be difficult to achieve. The second is a difficulty of principle. For instance, if rationing is delegated to dentists, there are concerns for the confidence of the associated criteria, since there is no mechanism for calling them to account for their decisions, i.e., there are no generally accepted criteria to discriminate between those that should/should not be provided with orthodontic services. Clinicians may decide on the basis (for instance) of perceived need or probable service effectiveness, but they may equally employ concealed social judgments or wishful thinking about service effectiveness. The paradox of the respective position of dentists and politicians is therefore clear:

- Politicians constitutionally should make rationing decisions, but do not.
- Dentists do ration the provision of services, but they should not constitutionally make such judgments.

5.0.3 The First Nations Treaty and Inuit communities

A more populist approach to orthodontic service rationing decisions has superficial attractiveness to provide legitimation for decisions whose legitimacy is not otherwise clear. There are, however, a number of deficiencies with this approach. For instance, if government apparently ignores substantial evidence that those eligible for NIHB benefits would like to maintain the previous rate of resource growth allocated to dental care, it would seem inconsistent to concede a public voice in the rationing of such resources as currently allocated. There are also uncertainties whether those eligible for NIHB benefits wish to be involved with such decisions, since generally a number of researchers have noted the consistent desire of the public to delegate difficult decision-making to some other authority (Bowling *et.al.*, 1993). Finally, there is no advance way of knowing the criteria that would underpin rationing decisions derived from populist opinion. It is not impossible that non-populist approaches to public consultation can be devised, however, although such a process would be necessarily unwieldy and time-consuming.

5.0.4 The courts

As a result of the Charter of Rights' legislation, the courts have a potential role in health care rationing, although whether the legal obligation of the Federal Minister of Indian Affairs to provide comprehensive health (including orthodontic) services to those eligible for NIHB benefits could be translated to the particular rights of an individual to orthodontic services has yet to be tested.

5.1 The Mechanisms for Orthodontic Service Rationing

There would seem to be six principal rationing mechanisms which could be used as instruments for policies to ration the provision of orthodontic services:

- Charges
- Primary care gatekeeping
- Waiting lists
- Professional autonomy
- Explicit rules
- Patient information.

5.1.0 Charges

Charges for orthodontic services applied to other jurisdictions include flat-rate payments, percentage costs (co-payments or deductibles), with exceptions determined by specific parameters. The evidence concerning the behavioral impact of charges on patient demands is heavily contested, although it seems implausible to adopt the view that, ceteris paribus, there is no deterrent effect. There are, however, concerns that such charges must closely match patients' ability to pay, which is a major concern for the First Nations Treaty and Inuit communities, i.e., controlling the provision of orthodontic services to those eligible for NIHB benefits by patient charges is not a strategic option. Moreover, this approach ignores the debate of "right or privilege".

5.1.1 Primary care gatekeeping

Access to orthodontic services is generally controlled by general dentists, since they subsequently generate specialist referrals. This gate-keeping function seems to be generally accepted by those eligible for NIHB benefits, although the maintenance of this gatekeeping function relies on their good-will, which can no longer be guaranteed in highly competitive markets. Nevertheless, general dentists must accept some responsibility

in only referring patients with good oral health motivation, and the like, for orthodontic treatment.

5.1.2 Waiting lists

Waiting lists for specialists services seem to perform several functions, not all widely recognized. They serve as a buffer between demand and capacity, allow time for potential further facial growth or permanent tooth eruption, although they may also be useful deterrents to generalist dentists in making referrals, i.e., long waiting period hamper referrals. Moreover, this may no longer be a viable option in highly competitive markets, although waiting periods provide opportunities to ensure orthodontic services are only offered to those who are motivated and have consistently good oral hygiene practices.

5.1.3 Professional autonomy

The professional autonomy of clinicians (specialists and generalists) performs several functions. For instance, it serves to reassure patients that orthodontic service decisions depend on dental rather than managerial criteria and allows professionals to resist managerial interferences in their clinical decisions (Harrison and Pollitt, 1993). In addition, most patients generally accept the generalist's or specialist's word that orthodontic services are/are not appropriate (Aaron and Schwartz, 1993). There are also many political advantages of such "invisible" rationing mechanisms, although they are vulnerable to the withdrawal of co-operation or bias by the profession (Harrison, 1995; Harrison and Pollitt, 1997). Nevertheless, both generalists and orthodontic specialists have a responsibility to ensure patient compliance with orthodontic services, including but not limited to effective oral hygiene practices.

5.1.4 Explicit rules

It is possible to envisage the creation of specific rules about what orthodontic services will or will not be provided by the NIHB dental program. From a policy-making perspective, however, there are concerns in terms of the legitimacy of the decision-making process or the criteria which underpin them, i.e., there are no scientific guidelines to distinguish between those who should/should not be provided with orthodontic services. However, the potential application of indices to discern those who should/ should not be provided with orthodontic services is a defensible strategy when addressing the problems of assessment consistency and reliability .

5.1.5 Patient information

The demand for orthodontic services can be affected by the kind of information made available to patients, although there is little experience in using this information (e.g., education, video-displays) as a systematic policy to control demands. Nevertheless, such information may be helpful in ensuring patients have realistic expectations prior to embarking on a course of orthodontic services.

5.2 The Criteria

There seem to be four broad criteria which might underpin orthodontic service rationing decisions within the NIHB dental program:

- The "rescue" principle
- Effectiveness
- Cost-effectiveness and utility
- Equity

5.2.0 The "rescue" principle

Broadly defined, the "rescue" principle states that the provision of orthodontic services should be confined to those in "trouble", with priority given to those in greatest need. This principle is discernible in many areas of public (e.g., publicly-funded special interest groups) and private life other than health care. It is also the defining feature of civilization. But although such principles are not wrong (Goodwin and Wilenski, 1984), they provide no guidance as to when to stop. The opportunity costs of the rescue principle (how many other patients could have benefited from the resources devoted to orthodontic services) are therefore potentially extremely high. Herein lies a potential anomaly, without scientific criteria to define the severity of orthodontic service-need, the most appropriate provision of 'rescue' services remain arbitrary and therefore controversial.

5.2.1 Effectiveness

If it is at all possible to discern a contemporary received wisdom about desirable rationing criteria, effectiveness would represent it, i.e., what is the point of providing a health care service that does not work. Unfortunately, ostensibly technical formulation may undermine rationing decisions, in that there are no certainties, i.e., what is a reasonable expectation of effectiveness and who is to determine this? Clearly, if orthodontic services have to be discontinued due to poor patient compliance, such a service is ineffective. Similar concerns apply to orthodontic services that lead to excessive tooth root resorption, although the prediction of such anomalous reactions remains controversial.

5.2.2 Cost effectiveness and cost-utility

One way of addressing the question of probabilities and degrees of effectiveness is to set them against service costs, i.e., are the benefits of orthodontic services to those eligible for NIHB benefits compatible with their expenditures? Since at the policy-making

level, rationing decisions entail choices between quite different services for different malocclusions, natural measures of their relative effectiveness are difficult to find. Also policy-makers would have to take a number of further considerations into account when applying such a rule. For instance, data on both the cost and effectiveness of orthodontic services are dynamic over time, so that allowances must be made to accommodate future advances in research and development. In addition, since most policy decisions are taken at the margin (rather than being zero-based), priorizing specific orthodontic services would need to reflect the cost-utilities of adjusting the supply of particular services upwards and downwards from the current levels of services. Moreover, such policies would be based on the assertion that patients already receiving orthodontic services are the ones in whom it is likely to be most effective. But without systematic epidemiological data, this assertion may/may not be valid.

Moreover, the adoption of cost-utility as a policy vehicle for orthodontic service rationing decisions seems to rest upon the answers to two fundamental questions. First, is it desired to maximize total utility derived from orthodontic service expenditures of the NIHB program? Such would be the effect of following the decision rule set out above, an effect that would pay no attention to the distribution of such a utility within a region or tribal band. Second, are policy makers satisfied that it is appropriate to collapse into a single formula the multi-faceted phenomena of quality of life derived from orthodontic services, whilst ignoring the utilities that the resources might derive from other policy decisions, e.g., housing, sanitation etc. (Carr-Hill, 1991; Bartley, 1993). Underlying such uncertainties, include the lack of data on the effectiveness of orthodontic services on patients' self-esteem and other psychological parameters.

5.2.3 Equity

Whereas cost-utility is concerned with achieving the greatest possible (expected) output of orthodontic utilities from particular expenditure levels, equity is more concerned with the distribution of such outputs:

- Equity implies equal orthodontic services to patients with equal orthodontic needs (horizontal equity); and
- Unequal services to patients with unequal needs (vertical equity).

In order to establish an operational definition of equity (i.e., one that is of use to policy makers), it is necessary to separate the two dimensions of the meaning. First, since policy makers cannot in practice be concerned with equity between individuals, the groups to be compared must generally embrace gender or geographic locations. Second, is the policy to seek equity of inputs (resources), of processes (e.g. orthodontic services) or of outcomes, to be measured in terms of orthodontic health status? Since it is well known that orthodontic services aimed at individuals are unlikely to be the sole or even the main contributors of such outcomes (Lalonde, 1994), such an approach might well include a more general attempt to produce a general orthodontic policy for the NIHB program.

An outline of such a potential general policy is as follows:

- Prevent or reduce the morbidity of malocclusions by the preferential institution of interceptive orthodontic services, although such a policy would require explicit guidelines when and what interceptive services are most appropriate for different occlusal conditions;
- Consider all orthodontic services to be effective, choosing from them (in accordance with available financial resources) priorities on the basis of their expected contribution to the equalization (at the lowest practicable level) of

morbidity (this pursues vertical equity);

- Make such prioritized orthodontic services available to all those eligible for NIHB benefits who may be expected to benefit from them;
- Within the above, provide services in their most cost-effective form at the most cost-effective stage, although the provision of both parameters requires further investigation.

Health care (including orthodontic service) rationing is therefore a difficult policy field, both technically, conceptually and politically. Older implicit approaches to rationing, e.g., the exercise of professional autonomy, are more politically comfortable than the explicit type of approach envisaged in this thesis. Yet advocates of implicit rationing (Hoffenberg, 1992) must answer the question whether the return to previous criteria is feasible in a context where not only policy-makers, but professions, are coming increasingly under public scrutiny. The need for guidelines for the provision and maintenance of orthodontic services cannot be overstated, although the appropriate body to control their development and implementation currently remains problematic.

Section 2 - Discussion Involving the Results of the Current Study

To enable a thorough discussion of the Results obtained from this study, the material will be discussed under the following headings:

- ***Orthodontists' Assessment of Malocclusion Severity***
- ***DAI Assessment of Malocclusion Severity***
- ***DAI Assessment of Treatment-need***
- ***Use of the Modified-DAI in Public-funding Assessments***
- ***Limitations of the Current Study***

5.3 Orthodontist's Assessment of Malocclusion Severity

To accept conclusions from the data relative to malocclusion severity assessments, relies on the premise that the Orthodontist's subjective evaluations of malocclusion severity comprise independent validating criteria of the standard-DAI index to discern malocclusion severity. This method has been described by Carlos (1970) as inadequate, since clinical judgment may have no inherent validity. However, as a malocclusion comprises a variation from the accepted "norm" rather than a disease state, no rigid criteria are available to outline the definition of a malocclusion. Until a more "objective" mode of evaluation becomes available, the method of subjective clinician evaluation will predominate despite the potential for biased assessments. Ideally, the level of intra-reliability and inter-examiner agreement must be high, with a low possibility of random chance effecting the subjective opinion values. As was demonstrated by the Intraclass Correlation Coefficient analysis, the reliability of the participating Orthodontists' evaluations of malocclusion severity was high in this study (0.97, $p<0.05$), well above the minimum acceptable limit of 0.80 as suggested by Fleiss (1990). Nevertheless, such statistical data cannot obscure the anomalous evaluations derived from observer #16 in this study.

Freer *et.al.* (1973) examined this issue of intra and inter-examiner reliability and agreement between ten orthodontists. They assessed malocclusion severity levels on the same ninety-eight sets of study models and repeated their assessments one month later. The results indicated that the mean scores derived by the ten examiners for each of the study models between the first and second examination sessions were generally close. In addition, the product-moment correlation coefficients, reflecting the intra-examiner reliability over the two evaluating sessions, were very high among all sets of examiners, ie. the coefficients ranged from 0.71 to 0.93. This indicated that little variation in intra-examiner scoring occurred between the two time periods, although there was a tendency to score slightly lower at the second session, ie. subjective assessments may vary with the experience of the assessor.

5.4 The Ability of the Standard-DAI to Discern Varying Degrees of Malocclusion Severity for the Total Case Sample, Permanent and Mixed Dentition Subsamples

To evaluate the potential application of the standard-DAI to assess varying degrees of malocclusion severity, a sample of pre-treatment orthodontic cases with a wide range of malocclusion severity was assessed by both the standard-DAI and Manitoba Orthodontists. The group data for each mode of assessment was then used for scattergraph comparison on a case-by-case basis (***see Figures 4.11, 4.12, 4.13***).

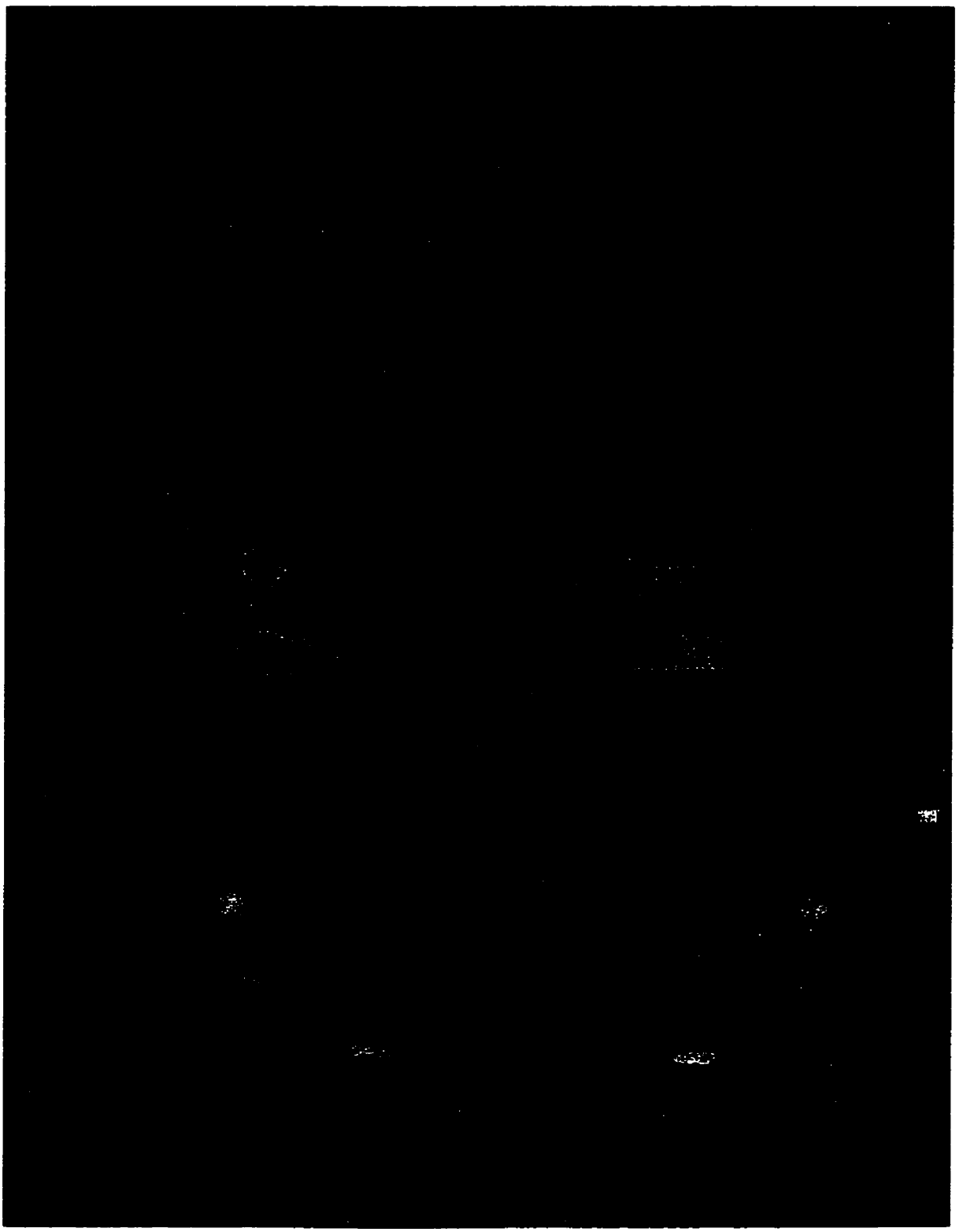
Following scattergraph comparisons and calculations of the Pearson's correlation coefficients for all thirty-eight cases, a high degree of congruence ($r = 0.92$) was found to exist between the Orthodontists' and standard-DAI evaluations of malocclusion severity. These results tended to conflict with the results of Keay *et.al.* (1993) from a similar study, where only a moderate ($r = 0.64$) degree of congruence was identified. One of the important factors that may have impacted on such variances in correlation coefficients between the two studies stem from the difference in inter-examiner agreement levels found

among the Orthodontists' subjective evaluations. The current study indicated high ICC values, whereas a lower degree of inter-examiner agreement was noted in the Keay *et.al.* study. Although the mean case scores were used in both studies, the subjective case assessments for each of the cases in the Keay *et.al.* study exhibited a wide range of values between the four evaluating Orthodontists. This wide assessment range by a small number of evaluators may have skewed the mean case values relative to that derived from the larger evaluator sample, thereby contributing to their lower degree of congruence relative to the DAI case scores.

Analysis of the five cases in the mixed dentition subsample resulted in a moderate degree of congruence ($r = 0.66$) between the standard-DAI and Orthodontists' malocclusion severity assessments, significantly lower than that found with the total case sample. One of the main contributors to the correlation coefficient value of this subsample analysis was Case #14.

In the mixed dentition subsample, case #14 appeared to be the primary cause of the large reduction in correlation coefficient value relative to that for the total sample. Case #14 (***Figure 5.1***) was a fourteen year old six month female exhibiting an Angle Class II moderately crowded dentition with both mandibular primary second molars retained and no succedaneus second premolars. Due to the lack of probable eruption of permanent teeth to replace these primary molars, the DAI was scored as two teeth missing, thereby dramatically increasing the total DAI score to indicate a more severe malocclusion. Although the Orthodontists may identify the agenesis of the permanent premolars as a concern, the presence of the primary molars in a favorable occlusal relationship with radiographically adequate alveolar support most likely reduced their estimation of the malocclusion severity.

Fig 5.1 Case #14 Study Models and Panoramic Radiograph



The ability of the standard-DAI to discern varying degrees of malocclusion severity for the mixed dentition was also evaluated in a study by Keay *et.al.* in 1993. In that study, seventy mixed dentition cases were assessed by both the standard-DAI and the subjective opinions of four Orthodontists, resulting in a Pearson correlation coefficient value of r = 0.62. This moderate value reflected the analogous degrees of congruence as discerned from the present study.

The scattergraph evaluation of the thirty-three case permanent dentition subsample revealed a strong correlation coefficient value (r = 0.94). This reflected a slightly higher level of agreement than those found between the standard-DAI and Orthodontists' evaluations of the total sample. This contrasts with the correlation computed for the permanent dentition subsample in the study by Keay *et.al.* (1993) in which the thirty-five case subsample analyzed provided only a moderate (r = 0.68) level of congruence. In common with the total case sample analysis, the low level of inter-examiner agreement may have primarily contributed to the moderate derived correlation value. This, therefore, underscored the need to replace the subjective assessments of individual assessors by a more objective approach.

5.5 The Ability of the Standard and Modified-DAI to Assess Orthodontic Treatment-need

5.5.0 The Determination of a Treatment-need Cut-off Score

Prior to evaluating the ability of the standard-DAI to discern orthodontic treatment-need, a DAI cut-off score was established to demarcate treatment-need. Using logistic regression analysis of the standard-DAI scores relative to the previously established NIHB bench mark for treatment-need, a 30.03 cut-off score indicated a high degree of accuracy in evaluating the treatment-need.

The methods used to determine treatment-need cut-off scores are fairly standard throughout the dental literature, involving the subjective opinion from a group of dental health 'experts' regarding the severity of a malocclusion and whether the extent of the malocclusion warrants treatment. Historically, the determination for orthodontic treatment-need have been made either as a result of mean group data evaluations (Richmond *et.al.*, 1995; Richmond *et.al.*, 1994), or on a consensus basis among a group of orthodontists (Jenny *et.al.*, 1993). With both methods, no objective criteria were identified as a guide when evaluating the need for orthodontic care. Such ill-defined criteria may have been one of the contributing factors to the large range of intra and inter-examiner agreement noted in the Richmond *et.al.* study (1994), in which the intra-examiner kappa values ranged from 0.54 to 0.97 for the seventy-four examiners. The inter-examiner kappa values ranged from 0.36 to 0.52, indicative of only fair levels of evaluator agreement (Landis and Koch, 1977).

Two methods have been cited in the literature to determine cut-off scores involving the DAI. In a study by Jenny *et.al.* (1993), the determination of orthodontic treatment-need was made from a consensus between two Orthodontists. Once again, no objective criteria were available for guideline purposes. The subsequent consensus agreement for the 1,306 untreated cases was then subjected to cross tabulation with the DAI scores for each case at the 90th, 86th, 80th, 75th, 70th, and 65th percentiles, resulting in a DAI score at the 86th percentile of 36 or greater determined as being handicapping according to the DAI. In another study, a DAI cut-off score of 32.5 was based on a variety of studies evaluating the distribution of severity scores and cumulative frequency distribution of the DAI scores (Keay *et.al.*, 1993), although the actual calculation of the score was not outlined.

The functional need for orthodontic treatment may only be assessed in absolute terms with accurate information regarding the long-term effects of malocclusion. Currently this information is unavailable. However, in the absence of clear evidence, it would seem

reasonable to introduce an index to enable a uniform approach to assess treatment-need. If such an index is used, a cut-off score should be both reliable and valid. As no "disease state" marker currently exists in orthodontics to define treatment-need, a secondary validation process must be incorporated. The methods for determination of a valid cut-off point share on common weak-link; no guideline criteria has been established to define a handicapping malocclusion. The current study has attempted to eliminate this potential problem by using cases previously categorized by a publicly-funded health program, where orthodontic treatment-need was discerned from guideline criteria. By using these NIHB cases, not only is a more objective yardstick used to determine appropriate DAI cut-off scores for treatment-need, but the existing policies at NIHB may also be tested for consistency.

5.5.1 The Ability of the Standard-DAI to Assess Orthodontic Treatment-need on the Total Case Sample, Permanent and Mixed Dentition Subsamples

To test the ability of the standard-DAI to assess orthodontic treatment-need for the total case sample, permanent and mixed dentition subsamples, the 30.03 DAI cut-off score was used as a benchmark for orthodontic treatment-need, based on the 2x2 matrix table analysis of the DAI-determined versus the NIHB-determined need for orthodontic treatment. **Figures 5.2 and 5.3** underscore the extent of the problem in the identification of greatest treatment-need for orthodontic cases submitted to NIHB.

The evaluation of the total case sample indicated that the standard-DAI is moderately accurate in assessing the need for orthodontic treatment, with a moderately high level of treatment-need over-estimation. This level of assessment accuracy is an improvement over the 0.70 value found in the Keay *et.al.* study (1993) based on the assessment of 105 pre-treatment cases. However, the same predilection for the treatment-need over-estimation prevailed. This tendency for treatment over-estimation was also found in a study by Caisley (1995), evaluating a sample of Angle Class II division 1 pre-

treatment cases. As shown in **Figure 5.4**, Case #17 (DAI score = 41.00) was approved and Case #16 (DAI score = 29.70) not approved when the DAI cut-off score of 30.03 was used as the minimum treatment-need criteria.

The evaluation of the thirty-three cases in the permanent dentition subsample revealed a greater degree of assessment accuracy than that found in the total case sample and was an improvement over the 0.74 value found in the Keay *et.al.* study (1993) involving the treatment-need assessment of a thirty-five case permanent dentition subsample. Although the over-estimation of treatment-need was found in the permanent dentition subsample relative to the total sample, the level of 0.33 would still be deemed unacceptably high. However, the results from this study were still lower than those found in the Keay *et.al.* study (1993).

Matrix table analysis of the five cases in the mixed dentition subsample indicated a low degree of assessment accuracy relative to that found in the total case sample, and the 0.67 level found in the Keay *et.al.* study (1993) involving the treatment-need assessment of a seventy case mixed dentition subsample. In particular, the 1.00 level of false positive fraction indicated an extremely high incidence of treatment over-estimation, and was slightly higher than the value found in the Keay *et.al.* study (1993). **Figure 5.5** illustrates NIHB-approved cases for the permanent (Case #20) and mixed (Case #31) dentition subsamples.

A possible reason for the poor assessment accuracy and false positive fraction values found in the mixed dentition subsample from the current study may lie in the standard-DAI assessments of missing teeth. As was previously discussed in **Section 5.4**, Case #14 exhibited both mandibular primary molars in good occlusion, with no succedaneus second premolars present. The standard-DAI would score two teeth as missing resulting in a total case score that surpasses the minimum of 30.03 for treatment approval. The NIHB criteria most likely interpreted the malocclusion as not a severe enough handicap, thereby denying orthodontic treatment. Of interest is the finding that re-

scoring of the case as having no teeth missing results in a case score below 30.03, reflecting the NIHB evaluation of non-approval for treatment. Although this deficiency in the standard-DAI assessment is inherent to the index, the interpretation of such a clinical situation may reflect the scoring of that component. As an example, an experienced Orthodontist may score the lack of succedaneous teeth in the situation outlined as relatively insignificant. However, a general practitioner or dental auxillary may unwittingly score the situation as more serious, reflecting the current score exhibited. This degree of interpretation is not acceptable by the standards by the Shaw *et.al.* (1991) in the criteria for an ideal index and therefore presents a problem with the standard-DAI in it's current form.

Figure 5.2 TheTotal Case Sample Illustrating the Difficulty in Identifying the Greatest Treatment-need.

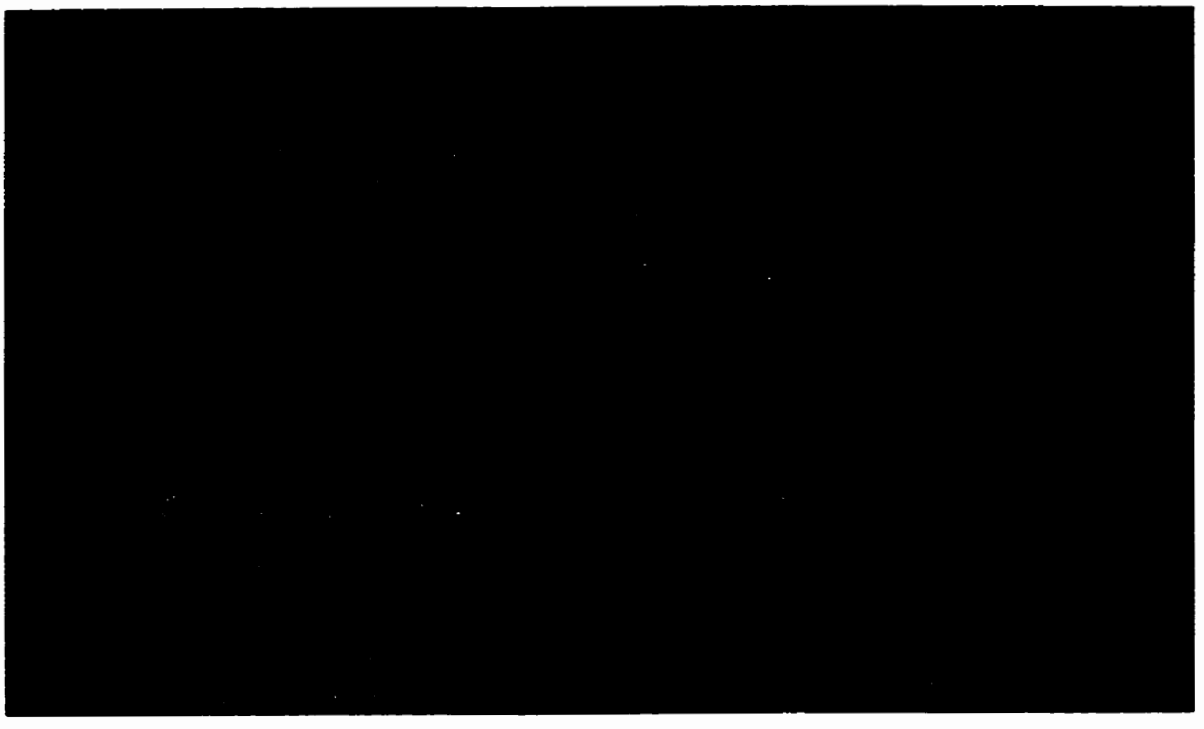


Figure 5.3 The Total Case Sample Categorizes via NIHB-approval Status

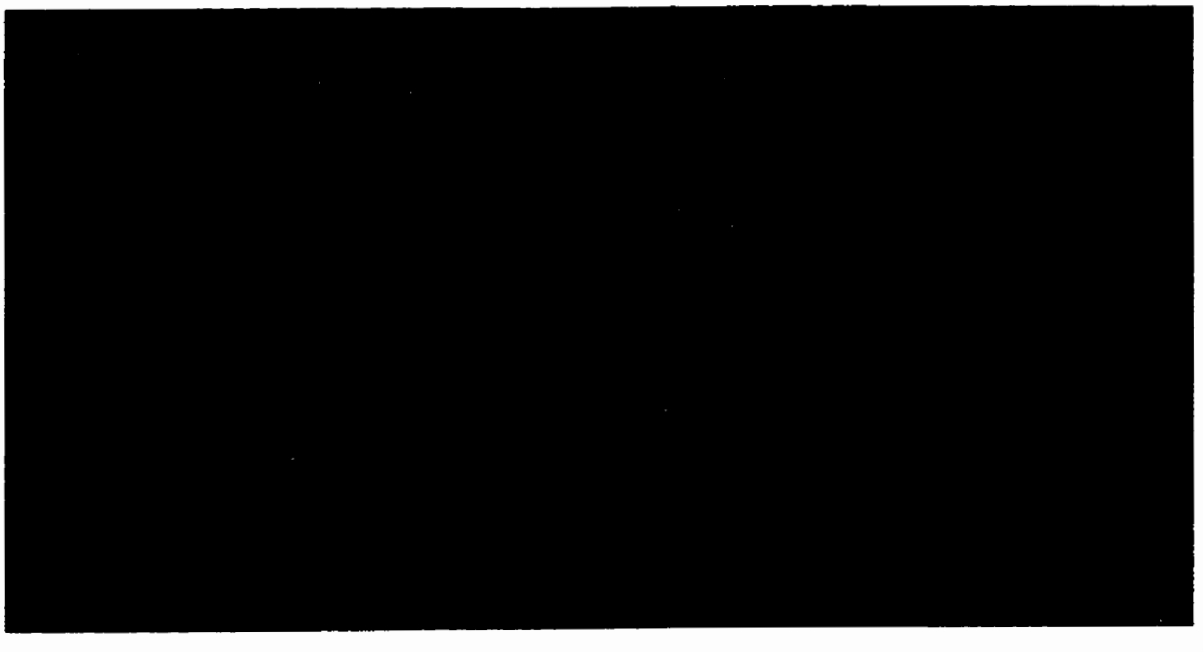


Figure 5.4 Illustrates a Case Approved (Case #17) and Not-approved (Case #16) via DAI Cut-off Score of 30.03.

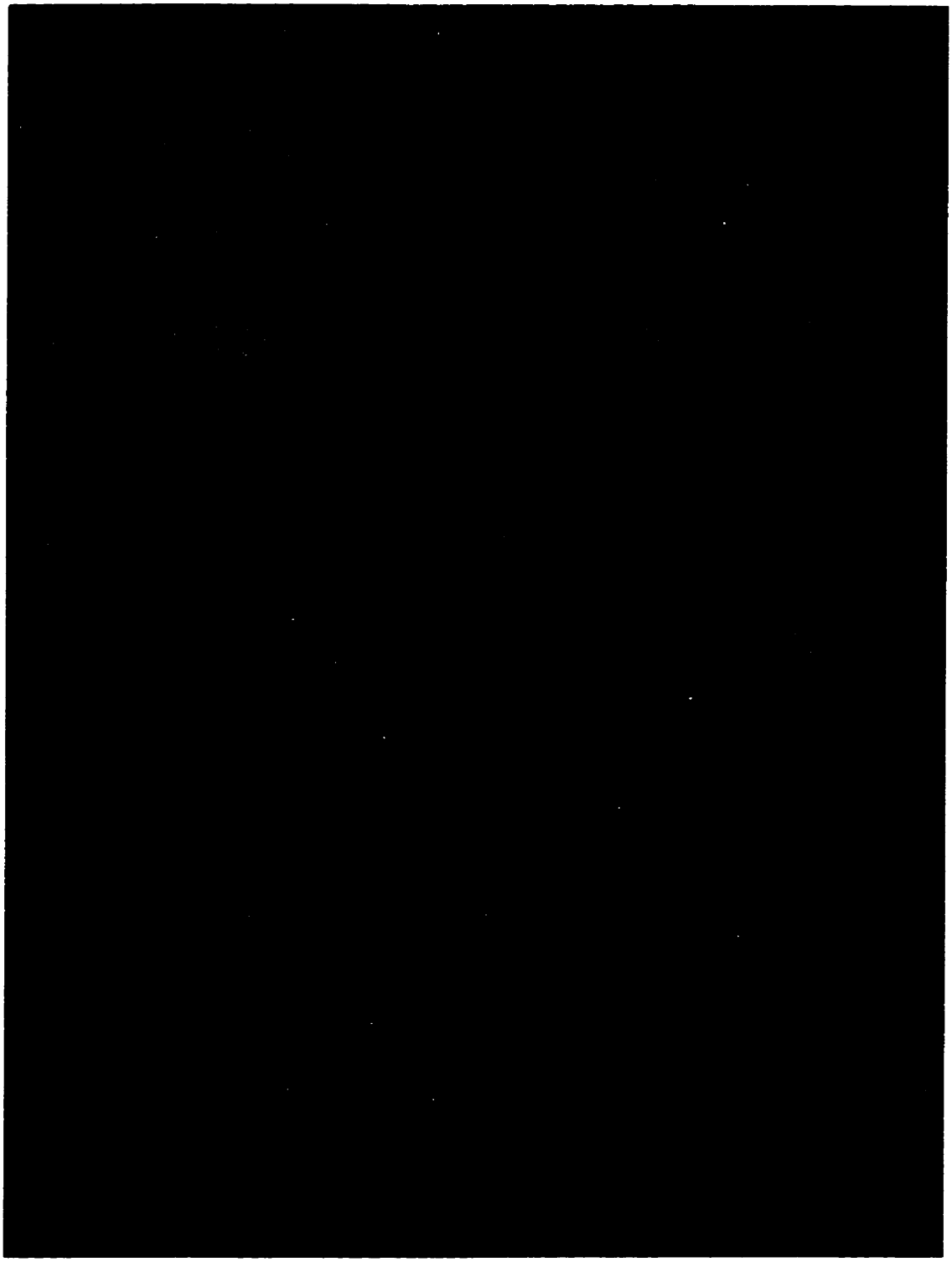
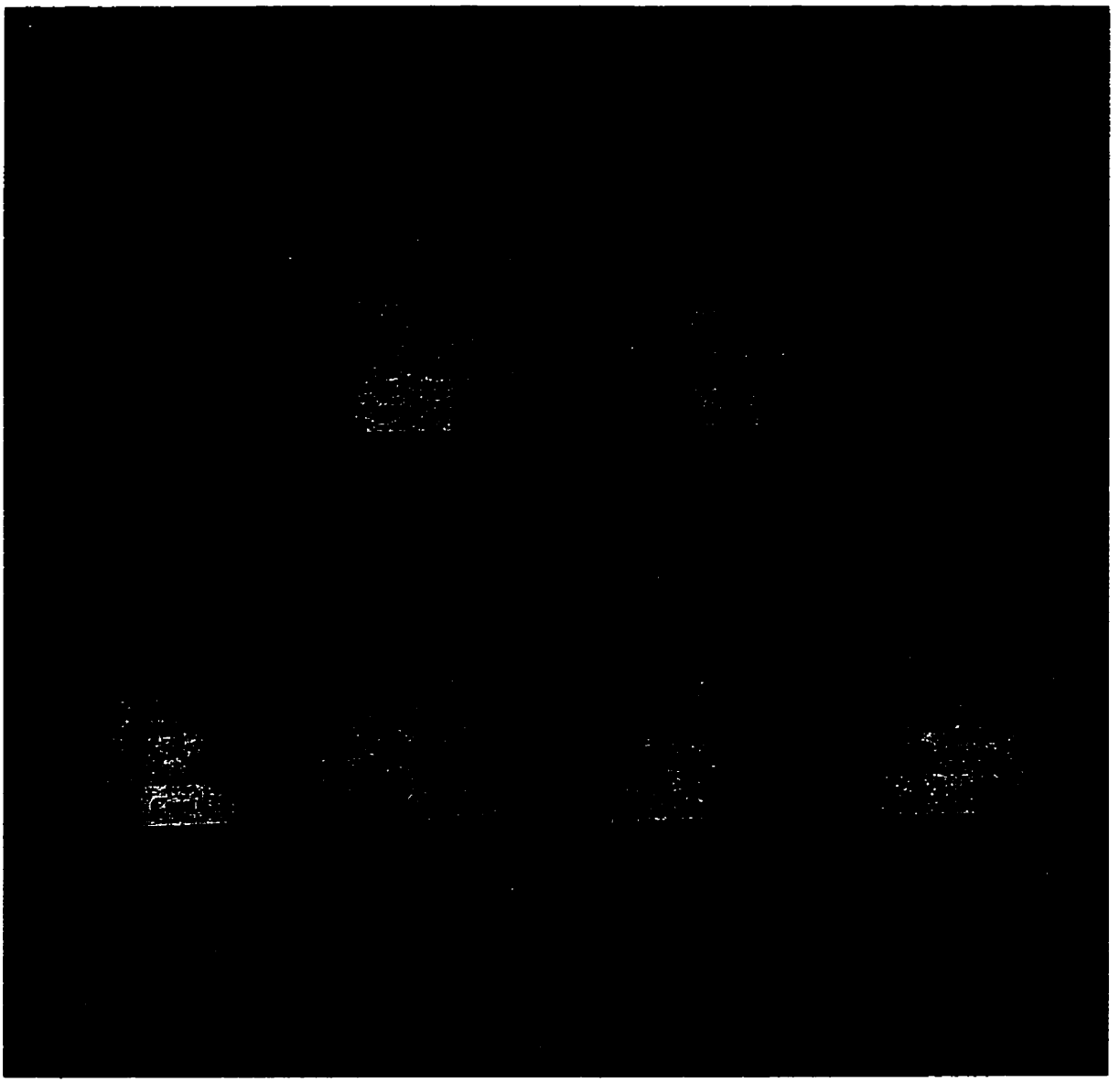


Figure 5.5 Illustrates NIHB-approved Cases for the Permanent (Case #20) and Mixed (Case #31) Dentition Subsamples.



5.5.2 The Ability of the Modified-DAI to Assess Orthodontic Treatment-need on the Total Case Sample, Permanent and Mixed Dentition Subsamples

To determine if any of the standard-DAI components were critical in determining orthodontic treatment-need, logistic regression analysis of the standard-DAI components was completed. Four critical components from the standard-DAI equation were found to be most important; mandibular overjet, maxillary overjet, vertical anterior overbite and anteroposterior molar relationship. This modified-DAI was subsequently applied to the raw data scores of the appropriate components and the newly derived weightings applied, with the matrix table analysis of the thirty-eight cases scored with the modified-DAI revealed some encouraging findings.

The assessment accuracy of the total, permanent and mixed dentition groups increased to the levels of 0.90, 0.88 and 1.00 respectively. Of equal importance, was the level of false positive fraction decrease to 0.25 and 0.33 for the total and permanent groups. These levels, although not ideal, represent significant improvements. Of significance is the 0.00 level of false positive fraction exhibited in the mixed dentition group. This area of improvement, in addition to the greatly increased level of assessment accuracy, provided a drastic improvement of the modified-DAI over the standard-DAI in the assessment of orthodontic treatment-need. The most likely contributor to this improvement is the elimination of the missing teeth component from the standard-DAI, as was discussed in **Section 5.2.1**.

Of interest are the four components of the modified-DAI regression equation and the diversity between their relative numerical weighting deemed most important in discerning orthodontic treatment-need; mandibular overjet (9.073877), maxillary overjet (1.618226), vertical anterior overbite (10.15565) and anteroposterior molar relationship (1.856006) (**Table 4.12, Section 4.4.0**). The weighting emphasis placed on both the mandibular overjet and vertical openbite components would suggest that minor (e.g., 1+ millimeter) sagittal mandibular excess or anterior overbite deficiency are of sufficient

influence to provide a modified-DAI score in excess of the minimum 9.39 cut-off score (**Table 4.14**) warranting service-need. The calculation of these numerical weightings was possibly influenced by the representative malocclusion sub-types used in this investigation, the NIHB approval/non-approval status used as the dependent variable in the determination of the regression equation, or a combination of the two.

5.6 Use of the Modified-DAI for Publicly-funded Treatment-need Assessment

Initial assessments involving the modified-DAI as an instrument to evaluate treatment-need in the publicly-funded health sector is encouraging. However, several factors should be considered prior to it's more general application.

All of the current indices, including the standard and modified-DAI, are primarily based on the evaluation of dental relationships. Pertinent information such as facial esthetics, patient expectations, periodontal status and psychological factors are not included. Facial esthetics, although somewhat subjective, have been identified as important factors in the psycho-social development of an individual (Albino and Tedesco,1991; Burstone, 1958). The standard-DAI attempts to connect the public's perception of dental esthetic acceptability with the occlusal components of an index via a regression equation. However, this link did not evaluate the actual perioral soft tissue structures. Unfortunately, the ability to objectively measure soft tissue deviations is likely to be imprecise and problematic. Due to a wide variation in response, it becomes very difficult to estimate the psychological impact a malocclusion has on an individual. Some individuals adapt and function in a social setting quite well despite severe physical aberrations, while others are greatly distressed by even slight tooth crowding (Cohen and Jago, 1988). Although treatment-need indices may objectively assess variation from an acceptable

occlusal norm, the impact of the anatomical severity of malocclusion may not be directly proportional to the psychological distress of patients (Otuyemi and Jones, 1995).

One of the concerns for any publicly-funded health program is the fiscal constraints currently levied against these organizations. The issues of cost and population treatment-need must be carefully weighed prior to determining treatment cut-off levels. If the NIHB decides to use an index, such as the modified-DAI, as in instrument to decide treatment-need, several factors should be closely scrutinized. The cut-off levels for treatment-need determined in this study, reflect a small subsample of the entire native population eligible for NIHB benefits. Although this study revealed a close correlation between the existing NIHB and modified-DAI treatment-need decision levels, the association does not necessarily indicate appropriate decision levels. Studies have found that Native Indians are as equally aware of poor dental esthetics as other ethnic groups (Cons *et.al.*, 1990). In addition, a study by Jenny *et.al.* in 1991 utilized the standard-DAI in evaluating community levels of malocclusion severity. When taken from the evaluation of 497 Native American Indians and 1337 Caucasian Americans, these findings revealed that the Native Americans consistently yielded higher standard-DAI scores indicating poorer dental esthetics and a greater need for orthodontic treatment. These differences in treatment-need should, in theory, be adjusted for the Native population, with an appropriate index cut-off score for treatment approval. Of interest is how significantly different relatively small changes in service-need cut-off scores can affect approval levels (***see Figures 5.6, 5.7***). By lowering the required modified-DAI cut-off score to 7.00, the total number of cases approved under this criteria increases to thirty-five from the previous level of thirty. By comparison, increasing the cut-off score to 15.00 significantly decreases the total cases approved by the modified-DAI to seventeen.

Of course, all of these factors must be weighed in conjunction with the ever-diminishing available resources. One possible solution involves the use of decision analysis, currently employed to an increasing extent throughout the medical field (Mavreas

and Melsen, 1995). The process of decision analysis is not synonymous with the act of clinical decision making, but can and should provide a means for testing, improving and comparing judgements that are now based on clinical intuition. By incorporating the use of such an analysis, current levels of treatment benefit to costs incurred could be determined with the resulting data indicating a possibly more effective use of funding. These findings may in turn dictate treatment-need levels and subsequently adjust index treatment cut-off scores at the appropriate levels.

Figure 5.6 - MODIFIED-DAI Assessment of Orthodontic Treatment-need Using a Cut-off Score = 7.00

DAI APPROVED	NIHB APPROVED: Y	NIHB APPROVED: N
Y	*30*	*6*
N	*0*	*3*

Y *indicates approval*
N *indicates non-approval*

Accuracy = 0.87

Sensitivity = 1.00
False Positive Fraction = 0.63
Specificity = 0.38
False Negative Fraction = 0.00

Likelihood Ratio of a Positive Test = 1.60
Likelihood Ratio of a Negative Test = 0.0

Figure 5.7 - MODIFIED-DAI Assessment of Orthodontic Treatment-need Using a Cut-off Score = 15.00

DAI APPROVED	NIHB APPROVED: Y	NIHB APPROVED: N
Y	*17*	*0*
N	*13*	*8*

Y *indicates approval*
N *indicates non-approval*

Accuracy = 0.66

Sensitivity = 0.57
False Positive Fraction = 0.00
Specificity = 1.00
False Negative Fraction = 0.43

Likelihood Ratio of a Positive Test = Infinity
Likelihood Ratio of a Negative Test = 0.4

5.7 Limitations of the Current Study

Although this investigation has centered on the potential application of the modified-DAI to evaluate the need for orthodontic services, there were inherent weaknesses. The most serious deficiency stemmed from the small sample size, whereas 364 cases would have been required to obtain data at a 5% statistical confidence level. Although ideal, such a sample size was not feasible for two reasons: The first relates to the number of Orthodontists willing to participate as evaluators i.e., a logistical compromise was needed to obtain the highest number of Manitoba Orthodontists that represented the professional community, while respecting the personal time of their voluntary services. Secondly, financial considerations constrained the number of pre-treatment orthodontic records that could be feasibly duplicated.

Although the case sample used in this study reflected a wide range of malocclusion severity, the number of cases within each type of malocclusion classification was necessarily limited. This, in conjunction with the statistical determination of the modified-DAI, may have resulted in the large disparity between the component weightings noted in the modified index, although subsequent data derived from another investigation showed this to have only a minor impact.

A further concern stemmed from the use of only Manitoba Orthodontists to evaluate these cases. Although these evaluations reflected the opinions of a large portion of the professional specialty community in one geographical region, they may not extend to other Orthodontic colleagues in various other areas of the country. Finally, the ability of the standard and modified-DAIs to assess orthodontic treatment-need was made relative to the pre-determined evaluations by NIHB for Manitoba and the North West Territories. Although the criteria for treatment-approval is universal for all areas of Canada, the interpretation of the criteria may vary between the various inter-provincial NIHB centers. Therefore, the treatment-need status of the sample cases used in this study may vary from

one provincial NIHB office to the next. This factor could possibly reflect itself in the statistical ability of the standard and modified-DAIs to assess treatment-need.

These deficiencies must therefore be addressed by evaluations from a much broader range of observers and significant extensions to the sample size. Nevertheless, data from the current study indicated:

- The modified-DAI provided a flexible objective method to discern who should/ should not be provided with orthodontic services funded by the NIHB program.

- The index is not only simple to use, but also provides much greater evaluative consistency than the subjective opinions of experienced Orthodontists.

- The modified-DAI may be useful as an initial screening tool in discerning NIHB-approval, allowing other more involved issues (e.g., functional) to be considered before adjudicating the case.

Summary and Future Investigations

SUMMARY AND FUTURE INVESTIGATIONS

This project was designed to test the ability of the DAI to objectively categorize and prioritize the orthodontic treatment-need of patients from publicly-funded resources. A two-stage assessment process was used to test the standard-DAI; both involved the assessment of thirty-eight randomly selected pre-treatment records previously submitted for publicly-funded orthodontic treatment approval. The initial selection criteria included a wide range of malocclusions in subjects without psychological or social complications. The sample comprised thirty cases approved and eight cases not approved for orthodontic treatment. In addition, thirty-three of the cases exhibited a permanent dentition while five cases exhibited a mixed dentition.

The first stage involved the individual but structured case assessments by 75% of the Manitoba Orthodontists, scored on a pre-determined visual analog system with the mean case scores calculated. In the second stage, six Graduate Orthodontic students from the University of Manitoba scored the same pre-treatment cases using the standard-DAI. The mean scores were then used for comparison with the Orthodontists' assessments. Both the Orthodontists and the Graduate students then re-scored a subset of five original cases one month later to evaluate the accuracy of the assessments.

The ability of the standard-DAI to discern varying degrees of malocclusion severity was evaluated from comparison of the Orthodontists' assessment and standard-DAI score for each case. A high Pearson's correlation coefficient ($r = 0.92$) was noted between the Orthodontists' and standard-DAI assessment of the total case sample evaluated, indicating a strong ability of the standard-DAI to discern varying malocclusion severities. To test the ability of the standard-DAI to assess treatment-need, logistic regression analysis of the standard-DAI scores was used to obtain the cut-off score of 30.03 to discriminate the approved from the non-approved cases. Using the determined cut-off score, matrix table analysis of the standard-DAI versus NIHB determination of

treatment-need was calculated for the total case sample, as well as the permanent and mixed dentition subsamples. Results indicated that the standard-DAI exhibits a high degree of accuracy in determining orthodontic treatment-need for the total sample and permanent dentition subsamples, but at the expense of over-estimation. Analysis of the mixed dentition subsample indicated a low degree accuracy assessment with an extremely high degree of service-need over-estimation.

Logistic regression analysis of the standard-DAI indicated that four components were critical in evaluating orthodontic treatment-need; **mandibular overjet, maxillary overjet, vertical anterior overbite and the anteroposterior molar relationship**. The four components were re-weighted and then applied to the raw data results with a subsequent new cut-off score of 9.39 being determined. The subsequent matrix table analysis revealed that the modified-DAI improved the accuracy of the treatment-need results and reduced the prevalence of treatment-need over-estimation. This was particularly note-worthy in the mixed dentition subsample, where statistically ideal matrix table calculations were determined.

The results of this study have provided a small glimpse into the effectiveness an index has in discerning malocclusion severity and detecting the need for orthodontic treatment. However, further investigations need to be completed prior to instituting the modified-DAI as an instrument of orthodontic treatment-need evaluation for cases submitted for public-funding.

To ensure the modified-DAI exhibits no major weaknesses, the following testing is suggested:

- Evaluation of a larger sample of pre-treatment orthodontic cases encompassing representation of all malocclusion sub-types, thereby providing greater statistical confidence in the results obtained and confirmation of the modified-DAI component weightings.

- The use of only Manitoba Orthodontists in assessing malocclusion severity was noted as a limiting factor in this study. Gaining assessments from a larger representative group of Orthodontists throughout the rest of Canada would be useful in evaluating the universality of the modified-DAI.

- Gaining regional NIHB evaluation representation when evaluating the modified-DAI would provide two important pieces of information. First, the ability of the modified-DAI to assess the need for treatment would be determined. Secondly, the consistency of regional NIHB evaluations may also be reflected in such findings.

Health and Welfare Canada
Santé et Bien-être social Canada

ORTHODONTICS
MEDICAL SERVICES BRANCH
MANITOBA REGION
EFFECTIVE MARCH 1, 1990

MSB will consider supporting the cost of orthodontic treatment for Registered Indians if the following conditions apply:

1. the malocclusion is severe and results in a significant limitation in function;
2. all preliminary dental treatment (surgical, periodontal, restorative) has been completed;
3. the patient's oral hygiene has been consistently good;
4. the patient has been caries-free for a minimum period of six months;
5. the patient and the parents/guardians understand the nature of the orthodontic treatment to be undertaken and are expected to comply with its requirements;
6. the treatment must be performed at this time; and
7. the patient is less than 18 years of age at the time of the case assessment.

Pre-authorization is required for:

(a) orthodontic consultation and diagnostic records; and

(b) orthodontic treatment

1. comprehensive
2. limited

An MSB-Blue Cross Dental Form is used for obtaining pre-authorization of benefits and can be forwarded with accompanying diagnostic patients records to:

Regional Dental Officer
Manitoba Region
Medical Services Branch
Health and Welfare Canada
500 – 303 Main Street
WINNIPEG, Manitoba
R3C 0H4

Appendix B

THE DEVELOPMENT OF AN OBJECTIVE ORTHODONTIC TREATMENT-NEED INDEX

THE ASSESSMENT OF MALOCCLUSION SEVERITY

***Rater Identification Number*_____**

Please examine each set of pre-treatment orthodontic records and circle the rating that most closely matches your assessment of malocclusion severity for each case.

Case Number	**Malocclusion Severity** *(Mild*					*Very Severe)*	
1	**1**	**2**	**3**	**4**	**5**	**6**	**7**
2	**1**	**2**	**3**	**4**	**5**	**6**	**7**
3	**1**	**2**	**3**	**4**	**5**	**6**	**7**
4	**1**	**2**	**3**	**4**	**5**	**6**	**7**
5	**1**	**2**	**3**	**4**	**5**	**6**	**7**
6	**1**	**2**	**3**	**4**	**5**	**6**	**7**
7	**1**	**2**	**3**	**4**	**5**	**6**	**7**
8	**1**	**2**	**3**	**4**	**5**	**6**	**7**
9	**1**	**2**	**3**	**4**	**5**	**6**	**7**
10	**1**	**2**	**3**	**4**	**5**	**6**	**7**
11	**1**	**2**	**3**	**4**	**5**	**6**	**7**
12	**1**	**2**	**3**	**4**	**5**	**6**	**7**
13	**1**	**2**	**3**	**4**	**5**	**6**	**7**
14	**1**	**2**	**3**	**4**	**5**	**6**	**7**
15	**1**	**2**	**3**	**4**	**5**	**6**	**7**
16	**1**	**2**	**3**	**4**	**5**	**6**	**7**

Case Number	Malocclusion Severity						
	(Mild						*Very Severe)*
17	1	2	3	4	5	6	7
18	1	2	3	4	5	6	7
19	1	2	3	4	5	6	7
20	1	2	3	4	5	6	7
21	1	2	3	4	5	6	7
22	1	2	3	4	5	6	7
23	1	2	3	4	5	6	7
24	1	2	3	4	5	6	7
25	1	2	3	4	5	6	7
26	1	2	3	4	5	6	7
27	1	2	3	4	5	6	7
28	1	2	3	4	5	6	7
29	1	2	3	4	5	6	7
30	1	2	3	4	5	6	7
31	1	2	3	4	5	6	7
32	1	2	3	4	5	6	7
33	1	2	3	4	5	6	7
34	1	2	3	4	5	6	7
35	1	2	3	4	5	6	7
36	1	2	3	4	5	6	7
37	1	2	3	4	5	6	7
38	1	2	3	4	5	6	7

Appendix C

THE DEVELOPMENT OF AN OBJECTIVE ORTHODONTIC TREATMENT-NEED INDEX

PRIORITIZING THE OCCLUSAL, FUNCTIONAL AND ESTHETIC COMPONENTS IN ASSESSING MALOCCLUSION SEVERITY

Rater Identification Number _____

Please examine the following list of occlusal, functional and esthetic components, and ***numerically prioritize*** (eg. ***1*** = ***most*** important, ***16*** = ***least*** important) each component's importance when ***you*** evaluate the severity of ***any*** given malocclusion.

Component	Numerical Priority
Overjet	_____
Relationship of dental midlines	_____
Buccal segment occlusion (vertical, transverse and antero-posterior)	_____
Upper and lower lip prominence relative to Burstone's lip profile line (Subnasale to soft tissue Pogonion)	_____
Vertical facial thirds	_____
Maxillary and Mandibular anterior segment irregularity (crowding/ spacing)	_____
Nasolabial angle	_____
Relationship of dental midlines to facial midline	_____
Throat length : Lower Anterior Face Height Ratio	_____
Overbite	_____
Soft tissue Facial angle (the internal angle formed between a line connecting soft tissue Nasion with soft tissue Pogonion, and Frankfort Horizontal)	_____

Appendix C (continued)

Interlabial gap at rest _____

Amount of Upper Incisor revealed on smiling _____

Centric relation - Centric occlusion discrepancy of greater than 2 mm _____

Frontal facial asymmetry _____

Buccal segment crowding/ spacing _____

In addition, please indicate if there are *any* components of a malocclusion that you feel have been omitted from the provided list:

_____
_____
_____

Please examine the following list of major malocclusion components and numerically prioritize (eg. *1* = *most* important, *3* = *least* important) each component's importance when *you* evaluate the severity of *any* given malocclusion.

Occlusal _____

Functional _____
Esthetic _____

Appendix D

THE DEVELOPMENT OF AN OBJECTIVE ORTHODONTIC TREATMENT-NEED INDEX

QUESTIONNAIRE ON EVALUATOR'S PROFESSIONAL PROFILE

The responses obtained from this questionnaire will be used to provide a sense of the sphere of orthodontic practice and the experience of the participants.

You are asked to respond as accurately as possible to the questions provided. Your answers should reflect your time in both ***private practice and in a teaching/supervision*** role. If you do not wish to respond to a question, you may elect not to answer that question.

All responses will remain confidential.

Rater Identification Number _____

Year Graduated From Dental School:_____
Dental School Attended:_____

Year Graduated From Orthodontic Program:_____
Orthodontic School Attended:_____

Percentage Of Patient Sub-groups You Treat:

_____ **Children (< 10 Years)** _____ **Adolescents (10-16 Years)**
_____ **Adults (> 16 Years)** _____ **Surgical Patients (Any Age)**

Number Of Patient-Care Hours Provided Per Week:_____

Approximate Number Of New Patient Case-Starts Last Year:_____

Appendix E

Case # _____	value	wt.	component score
1) Missing incisor, canine and premolar Maxillary and Mandibuular Enter total #		6	
2) Crowding in the incisal segments 0= no crowding 1= 1 segment crowded 2= 2 segments crowded		1	
3) Spacing in the incisal segments 0= no spacing 1= 1 segment spaced 2= 2 segments spaced		1	
4) Diastema in mm		3	
5) Largest anterior irregularity... Maxilla in mm.		1	
6) Largest anterior irregularity... Mandible in mm.		1	
7) Anterior Maxillary overjet in mm.		2	
8) Anterior Mandibular overjet in mm.		4	
9) Vertical anterior openbite in mm.		4	
10) Antero-posterior molar relation Normal= 0 1/2 cusp= 1 Full cusp= 2		3	
11) CONSTANT	////////	13	13
12) TOTAL SCORE	////////	////////	

Cons et.al., 1986

REFERENCES

Aaron, H.J.; Schwartz, W.B. (1984): The Painful Prescription: Rationing Hospital Care, Washington DC: Brookings Institution.

Albino, J.E.; Lewis, E.A. and Slakter, M.J. (1978): Examiner Reliability for Two Methods of Assessing Malocclusion, Angle Orthod 48: 297-302.

Albino, J.E.and Tedesco, L.A. (1991): Esthetic Need for Orthodontic Treatment. In: Current Controversies in Orthodontics, Melsen B (Ed), Quintessence, Chicago, 1991.

Andrews, L.F. (1972): The Six Keys to Normal Occlusion, Am J Orthod 62: 296-309.

Angle, E.H. (1899): Classification of Malocclusion, Dent Cosmos 41: 248-264.

Annual Government of Canada Report (1996).

Ansai, T.; Miyazaki, H.; Katoh, Y.; Yamashita, Y.; Takehara, T.; Jenny, J. and Cons, N.C. (1993): Prevalence of Malocclusion in High School Students in Japan According to the Dental Aesthetic Index, Community Dental Oral Epidemiol 21: 303-305.

Ash, M.M. (1995): Philopsophy of Occlusion: Past and Present, Dent Clin of North Amer 39(2): 233-255.

Ast, D.B.; Carlos, J.P. and Cons, N.C. (1965): The Prevalence and Characteristics of Malocclusion Among Senior High School Students in Upstate New York, Am J Orthod 51: 437-445.

Bahiraei, D. (1995): The Validation of Peer Assessment Rating Index by Western Pennsylvania Orthodontists [Abst], Am J Orthod Dentofac Orthop 107: 227.

Ballard C.F. and Wayman J.B. (1964): A Report on a Survey of the Orthodontic Requirements of 310 Apprentices, Trans Br Soc St Orthod 86: 81-86.

Bartley, M. (1993): Editorial, Crit Public Health 4: 3-6.

Baume, L.J.; Horowitz, H.S.; Summers, C.J.; Backer, D.O.; Brown, W.A.B; Carlos, J.P.; Freer, T.J.; Harvold, E.P.; Moorees, C.F.A.; Salzmann, J.A.; Scmuth, G.; Solow, B. and Taatz, H. (1973): A Method of Examining Occlusal Traits Developed by the FDI Commission on Classification and Statistics for Oral Conditions (COCST OC), Int Dent J 23: 530-537.

Bedford, W.R. and Davey, K.W. (1993): Indian and Inuit Dental Care in Canada: The Past, the Present and the Future, J Can Dent Assoc 59: 126-132.

Bennett, K.; Torrance, G. and Tugwell, P. (1991): Methodological Challenges in the Development of Utility Measures of Health Related Quality of Life in Rheumatoid Arthritis, Controlled Clin Trials 12: 1185-1285.

Berg, R. (1979): Post-retention Analysis of Treatment Problems and Failures in 264 Consecutively Treated Cases, Eur J Orthod 1: 55-68.

Bjork, A.; Krebs, A. and Solow, B. (1964): A Method for Epidemiological Registration of Malocclusion, Act Odontol Scand 22: 27-41.

Bowling, A.; Jacobson, B.; and Southgate, L. (1993): Explorations in Consultation of the Public and Health Professionals on Priority Setting in an Inner London Health District, Soc Sci Med 37: 851-857.

Brook, P.H. and Shaw, W.C. (1989): The Development of an Orthodontic Treatment Priority Index, Eur J Ortho 11: 309-320.

Brzroukov, V.; Freer, T.J.; Helm, S.; Kalamkarov, H.; Sardoinfirri, J. and Solow, B. (1979): Basic Methods for Recording Malocclusion Traits, Bull World Health Organ 57: 955-961.

Buchanan, I.B.; Shaw, W.C.; Richmond, S.; O'Brien, K.D. and Andrews, M. (1993): A Comparison of the Reliability and Validity of the PAR Index and Summers Occlusal Index, Eur J Orthod 15: 27-31.

Burden O.J. (1995): The Ranking of Dental Aesthetics, Br J Orthod 22(3): 259-261.

Burstone, C.J. (1958): The Integumental Profile, Am J Orthod 44: 1-24.

Burton, V.J.; Rob, M.I.; Craig, G.G. and Lawson, J.S. (1984): Changes in the Caries Experience of 12-Year-old Sydney School Children Between 1963 and 1982, Med J Aust 140(7): 405-407.

Caisley, S.M. (1995): Quantifying Malocclusion: An Investigation of Two Malocclusion Indicies Applied to an Aboriginal Sample, Thesis.

Carlos, J.P. (1970): Evaluation of Indices of Malocclusion, Int Dent J 20: 606-617.

Carr, W.K. (1977): Predetermination and Alternative Course of Treatment Cost Control or Cost Switching with Increased Cost to Patient (Editorial), J Indiana Dent Assoc 56(2): 12-13.

Carr-Hill, R.A. (1921): Allocating Resources to Healthcare: Is QALY a Technical Solution to a Potential Problem?, Int J Health Serv 21: 351-363.

Cohen, L.K. and Jago, J.D. (1988): Toward the Formulation of Sociodental Indicators, Int J Health Services 6: 681-698.

Cons, N.C.; Jenny, J.; Kohout, F.J. and Jakobsen, J. (1994): Comparing Ethnic Group-specific DAI Equations With the Standard DAI, Int Dent J 44: 153-158.

Cons, N.C.; Jenny, J. and Kohout, F.J. (1986): DAI: The Dental Aesthetic Index, College of Dentistry, University of Iowa, Iowa City, IA.

Cons, N.C.; Jenny, J.; Kohout, F.J. Freer, T.J. and Eismann, D. (1983): Perceptions of Occlusal Conditions in Australia, the German Democratic Republic and the United States of America, Int Dent J 33: 200-206.

Cons, N.C.; Jenny, J.; Kohout, F.J. and Jakobsen, J. (1994): Comparing Ethnic Group-specific DAI Equations With the Standard DAI, Int Dent J 44: 153-158.

Cons, N.C.; Jenny, J.; Kohout, F.J. and Jakobsen, J. (1990): Perceptions About Orthodontics on Remote Indian Reservations [Abst], J Dent Res 69: 314.

Cons, N.C.; Jenny, J.; Kohout, F.J.; Songpaisan, Y. and Jotikastira, D. (1989): Utility of the Dental Aesthetic Index in Industrialized and Developing Countries, J Pub Health Dent 49: 163-166.

Cons, N.C.; Mruthyunjay, Y.C. and Pollard, S.T. (1978): Distribution of Occlusal Traits in a Sample of 1,337 Children Aged 15-18 Residing in Upstate New York, Int Dent J 28: 154-164.

Cooney, P.V.; Hassard, T.H. and Spanger, U.A. (1995): Predetermination as a Cost-containment Mechanism in a Social Allowance Dental Program in Manitoba, J Public Health Dent 55(3): 177-180.

Cooney, P.V. and Lavelle, C.L.B. (1996): Do Regional Differences Preclude a National Dental Insurance Program? A Strategic Analysis, J Community Dent 11: 13-20.

Cooney, P.V.; Leake, J.L. and Williams, J.I. (1986): Quality Control Mechanisms in Dental Insurance Schemes in Ontario, J Can Dent Assoc 52(5): 419-424.

Davies, T.M.; Shaw, W.C.; Worthington, H.V.; Addy, M.; Dummer, P. and Kingdon, A. (1991): The Effect of Orthodontic Treatment on Plaque and Gingivitis, Am J Orthod Dentofac Orthop 99(2): 155-161.

DeGuzman, L.; Bahiraei, B.S.; Vig, K.W.L.; Vig, P.S.; Weyant, R.J. and O'Brien, K. (1995): The Validation of the Peer Assessment Rating Index for Malocclusion Severity and Treatment Difficulty, Am J Orthod Dentofac Orthop 107: 172-176.

Douglas, C.W. and Furino, A. (1990): Balancing Dental Service Requirements and Supplies: Epidemiological and Demographic Evidence, JADA 121: 587-592.

Draker, H.L. (1967): American Association of Orthodontists Approval of the Assessment Record form and the Definition of Handicapping Malocclusion, J Am Dent Assoc 75: 1441-1442.

Draker, H.L. (1960): Handicapping Labio-lingual Deviations: A Proposed Index for Public Health Purposes, Am J Orthod 46: 295-305.

Eismann, D. (1979): Reliable Assessment of Morphological Changes Resulting from Orthodontic Treatment, Eur J Orthod 2(1): 19-25.

Elderton, R.J. and Clark J.D. (1983): Orthodontic Treatment in the General Dental Service Assessed by the Occlusal Index, Br J Orthod 10: 178-186.

Evans, R. and Shaw, W.C. (1987): Preliminary Evaluation of an Illustrated Scale for Rating Dental Attractiveness, Eur J Orthod 9: 314-318.

Fields, H.W.; Vann, W.F. and Vig, K.W.L. (1982): Reliability of Soft Tissue Profile Analysis in Children, Angle Orthod 52: 159-165.

Fisk, R.O. (1960): When Malocclusion Concerns the Public, Can Dent Assoc J 26: 397-412.

Fleiss, J.L. (1990): Statistical Management of Data in Clinical Research, Crit Rev Oral Biol Med 1: 55-66.

Fleiss, J.L.; Slakter, M.J.; Fishman, S.L.; Park, M.H. and Chilton, N.W. (1979): Inter-Examiner Reliability in Caries Trials, J Dent Res 58: 604-609.

Fletcher, C.M. (1963): Some Problems of Diagnostic Standardization Using Clinical Methods, with Special Reference to Chronic Bronchitis, Quar J Med 32: 33-49.

Foote, D.K. and Stoffman, D. (1996): Boom Bust and Echo; How to Profit from the Coming Demographic Shift, Toronto: Macfarlane Walter and Ross.

Foster, T.D. and Menezes, D.M. (1976): The Assessment of Occlusal Features for Public Health Planning Purposes, Am J Orthod Dentofac Orthop 69: 83-90.

Freer, T.G.; Grewe, J.M. and Little, R.M. (1973): Agreement Among the Subjective Severity Assessments of Ten Orthodontists, Angle Orthod 43: 185-190.

Friedman, J.W. (1975): PSROs in Dentistry, Am J Public Health 65(12):1298-1303.

Getzen, T.E. and Poullier, J.P. (1992): International Health Spending Forecasts: Concepts and Evaluation, Soc Sci Med 34(9): 1057-1068.

Ghafari, J.; Locke, S. and Bentley, J. (1989): Evaluation of the Treatment Priority Index, Am J Orthod Dentofac Orthop 96: 382-389.

Goodwin, R.E. and Wilenski, P. (1984): Beyond Efficiency; The Logical Underpinnings of Administrative Principles, Public Admin Rev 6: 512-517.

Gottleib, E.L. (1975): Grading Your Orthodontic Treatment, J Chi Orthod 9: 155-161.

Grainger, R.M. (1967): Orthodontic Treatment Priority Index, Public Health Services Publication No. 1000 - Series 2, No. 25, Washington, D.C.: Government Printing Office.

Grainger, R.M. (1961): Burlington Orthodontic Research Progress Report, Series #6, University of Toronto, Division of Dental Research: 9-11.

Gravely, J.F. and Johnson, D.B. (1974): Angle's Classification of Malocclusion: An Assessment of Reliability, Br J Orthod 1: 79-86.

Gray, A.S. and Demirjian, A. (1977): Indexing Occlusion for Dental Public Health Programs, Am J Orthod Dentofac Orthop 72: 191-197.

Greene, J.C. and Vermillion, J.R. (1964): The Simplified Oral Hygiene Index, J Am Dent Assoc 68: 7-13.

Grewe, J.M. and Hagan, D.V. (1972): Malocclusion Indices: A Comparative Evaluation, Am J Orthod 61: 286-294.

Ham, C. (1995): Synthesis: What Can We Learn From International Experience?, Brit Med Bull 51(4): 819-830.

Harrison, S. (1995): Clinical Autonomy and Planned Markets: The British Case. In: Saltman RB, von Otter C, eds. Implementing Planned Markets in Healthcare: Balancing Social and Economic Responsibility, Buckingham, Open Univeristy Press.

Harrison, R.L. and Davis, D.W. (1996): Dental Malocclusion in Native Children of British Columbia, Community Dent Oral Epidemiol 24: 217-221.

Harrison, S. and Pollitt, C. (1994): Controlling Health Professionals: The Future Work and Organization in the NHS, Buckingham Open University Press.

Heginbotham, C. (1992): Rationing, BMJ 304: 496-499.

Hellman, M. (1921): Variation in Occlusion, Dent Cosmos 63: 608-619.

Helm, S. (1968): Malocclusion in Danish Children with Adolescent Dentition: An Epidemiologic Study, Am J Orthod 54: 352-366.

Helm, S. and Petersen, P.E.(1989): Causal Relationship Between Malocclusion and Caries, Acta Odontol Scand 47(4): 217-221.

Hermanson, J.W. and Grewe, J.M. (1970): Examiner Variability of Several Malocclusion Indices, Angle Orthod 40: 219-225.

Hoffenberg, R. (1992): Letter to the Editor, BMJ 304: 182.

Horup, N.; Melsen, B. and Terp, S. (1987): Relationship Between Malocclusion and Maintenance of Teeth, Community Dent Oral Epidemiol 15(2): 74-78.

Jenny, J. and Cons, N.C. (1996): Comparing and Contrasting Two Orthodontic Indices, the Index of Orthodontic Treatment Need and the Dental Aesthetic Index, Am J Orthod Dentofac Orthop 110: 410-416.

Jenny, J and Cons, N.C. (1993): Establishing Severity Levels on the DAI Scale [Abst], J Dent Res 72: 363.

Jenny, J.; Cons, N.C.; Kohout, F.J and Frazier, P.J. (1980): Test of a Method to Determine Socially Acceptable Occlusal Conditions, Community Dent Oral Epidemiol 8: 424-433.

Jenny, J.; Cons, N.C.; Kohout, F.J. and Jakobsen, J. (1992): Predicting Handicapping Malocclusion Using the DAI [Abst], J Dent Res 71: 236.

Jenny, J.; Cons, N.C.; Kohout, F.J. and Jakobsen, J. (1991): Differences in Need for Orthodontic Treatment Between Native Americans and the General Population Based on DAI Scores, J Public Health Dent 51(4): 234-238.

Katz, M.I. (1992): Angle Classification Revisited I: Is Current Useage Reliable? Am J Orthod Dentofac Orthop 102: 277-284.

Keay, P.A.; Freer, T.J. and Basford, K.E. (1993): Orthodontic Treatment Need and the Dental Aesthetic Index, Aust Orthod J 13: 4-7.

Kenealy, P.; Frude, N and Shaw, W. (1989): An Evaluation of the Psychological and Social Effects of Malocclusion: Some Implications for Dental Policy Making, Soc Sci Med 28(6): 583-591.

Kizhaber, J.A, (1993): Prioritising Health Services in an Era of Limits: The Oregon Experience, BMJ 307(6900): 373-377.

Klein, R.E. (1992): Dimensions of Rationing: Who Should do What?, BMJ 307: 309-311.

Klein, H.; Palmer, C.E. and Knutson, J.W. (1938): Studies on Dental Caries I: Dental Status and Dental Needs of Elementary School Children, Public Health Rep 53: 751-765.

Lalonde, M. (1974): A New Perspective on the Health of Canadians: A Working Document, Ottawa: Information Canada.

Landis, J.R. and Koch, G.G. (1977): The Measurement of Observer Agreement for Categorical Data, Biometrics 33: 159-174.

Lavelle, C.L.B. (1976): A Study of Multiracial Malocclusions, Community Dent Oral Epidemiol 4: 38-41.

Leake, J.L. (1992): Oral Health Survey of Canada's Aboriginal Children, Dept. Community Dentistry, Univeristy of Toronto (Ontario): 10-16.

Lewis, E.A.; Albino, J.E.; Cunat, J.J. and Tedesco, L.A. (1982): Reliability and Validity of Clinical Assessments of Malocclusion, Am J. Orthod 81: 473-477.

Linder-Aronson, S. (1974): Orthodontic in Swedish Public Dental Health System, Trans Eur Orthod Soc: 233-240.

Loe, H, and Silness, J., (1963): Periodontal Disease in Pregnancy I. Prevelance and Severity, Acta Odont Scand 21: 533-551.

Lunn, H.; Richmond, S. and Mitropoulos, C. (1994): The Use of the Index of Orthodontic Treatment Need (IOTN) as a Public Health Tool: A Pilot Study, Community Dent Health 10: 111-121.

Magnusson, T.E. (1976): An Epidemiologic Study of Occlusion Anomalies in Relation to Development of the Dentition Among Icelandic Children, Community Dent Oral Epidemiol 4: 121-128.

Massler, M. and Frankel, J.M. (1951): Prevelance of Malocclusion in Children Aged 14 to 18 Years, Am J Orthod 37: 751-768.

Mathews, D.; Banting D. and Bohay R. (1995): The Use of Diagnostic Tests to Aid Clinical Diagnosis, J Can Dent Assoc 61: 785-791.

Mavreas, D. and Melsen, B. (1995): Financial Consequences of Reduced Treatment Availability in a Publicly-funded Orthodontic Service. A Decision Analysis Problem, Br J Orthod 22: 47-51.

Milnes, A.R. (1996): Description and Epidemiology of Nursing Caries, J Public Health 56: 38-50.

Mohl, N.; Zarb, G.; Carlsson, G. and Rugh, J. (1988): A Textbook of Occlusion 2nd Ed, Chicago: Quintessence Pub. Co.

Moyers, R.E. (1963): Handbook of Orthodontics for the Student and General Practitioner, ed. 2, Chicago, Year Book Publishers, Inc.

Musgrove, P. (1993): Investing in Health: The 1993 World Development Report of the World Bank, Bull Pan Am Health Organ 27(3): 284-286.

O'Brien, K.D.; Shaw, W.C. and Roberts, C.T. (1993): The Use of Occlusal Indices in Assessing the Provision of Orthodontic Treatment by the Hospital Orthodontic Service of England and Wales, Br J Orthod 20: 25-35.

Otuyemi O.D. and Jones S.P. (1995): Methods of Assessing and Grading Malocclusion: A Review, Aust Orthod J 14: 21-27.

Pelton, W.J. and Elsasser, W.A. (1953): Studies of Dentofacial Morphology, J A D A 46: 648-657.

Pickering, E.A. and Vig, P.S. (1975): The Occlusal Index Used to Assess Orthodontic Treatment Results, Br J Orthod 2: 47-51.

Picton, D.C. (1986): Basis for the Use of Topical and Systemic Fluoride in Caries Prevention, J R Soc Med 79(14): 18-21.

Popovich, F. and Thompson, G.W. (1971): A Longitudinal Comparison of the Orthodontic Treatment Priority Index and the Subjective Appraisal of the Orthodontists, J Public Health Dent 31: 2-8.

Posselt, U. (1952): Studies in the Mobility of the Human Mandible, Acta Odontol Scand 10(suppl 10): 1-160.

Poulton, D.R. and Aaronson, S.A. (1961): The Relationship Between Occlusion and Periodontal Status, Am J Orthod 47: 690-699.

Proffit, W.R. and Ackerman, J.L. (1973): Rating the Characteristics of Malocclusion: A Systematic Approach for Planning Treatment, Am J Orthod, 64: 258-269.

Proshek, J.M.; Jenny, J.; Cons, N.C; Summers, C.J. and Mruthyunjaya, Y.C. (1979): A Factor Analysis of Traits Measured by COSTOC-MOT to Identify Occlusal Trait Combinations, Community Dent Oral Epidemiol 7: 274-282.

Pullinger, A.G.; Seligman, D.A. and Gornbeim, J.A. (1993): A Multiple Logistic Regression Analysis of the Risk and Relative Odds of Temporomandibular Disorders as a Function of Common Occlusal Factors, J Dent Research 72: 968.

Ramfjord, S.P. and Ash, M.M. (1983): Significance of Occlusion in the Etiology and Treatment of Early, Moderate and Advanced Periodontitis, J Periodontol 52(9): 511-517.

Richmond, S. (1990): A Critical Evaluation of Orthodontic Treatment in the General Dental Services of England and Wales. Doctoral dissertation, University of Manchester, Manchester, England.

Richmond, S. and Andrews, M. (1993): Orthodontic Treatment Standards in Norway, Eur J Orthod 15: 7-15.

Richmond, S.; Roberts, C.T. and Andrews, M. (1994b): Use of the Index of Orthodontic Treatment Need (IOTN) in Assessing the Need for Orthodontic Treatment Pre - and Post-appliance Therapy, Br J Orthod 21: 175-184.

Richmond, S.; Shaw, W.C.; O'Brien, K.D.; Buchanan, I.B.; Stephens, C.D.; Andrews, M. and Roberts, C.T. (1995b): The Relationship Between the Index of Treatment Need and Concesus Opinion of A Panel of 74 Dentists, Br Dent J 178: 370-374.

Richmond, S.; Shaw, W.C.; Roberts, C.T. and Andrews, M. (1992a): The Development of the Par Index (Peer Assessment Rating): Reliability and Validity, Eur J Orthod 14: 125-139.

Richmond, S.; Shaw, W.C.; Roberts, C.T. and Andrews, M. (1992b): The Par Index (Peer Assessment Rating): Methods to Determine Outcome of Orthodontic Treatment in Terms of Improvement and Standards, Eur J Orthod 14: 180-187.

Richmond, S.; Shaw, W.C. and Stephens, C.D. (1992c): Orthodontics in the General Dental Services of England and Wales: The Provision of Treatment, Br Dent J 172: 150-152.

Rinchuse, D.J. and Rinchuse, D.J. (1989): Ambiguities of Angle's Classification, Angle Orthod 59: 295-298.

Rocky, B.N. (1988): Practice Profile, J Can Dent Assoc 54(11): 817-819.

Russell, A.L. (1956): A System of Scoring for Prevalence Surveys of Periodontal Disease, J Dent Res 35: 350-359.

Salzmann, J.A. (1969): Orthodontics in Practice and Perspective, Am J Orthod 55: 556-565.

Salzmann, J.A. (1968): Handicapping Malocclusion Assessment to Establish Treatment Priority, Am J Orthod 54: 749-769.

Scivier, G.A.; Menenzes, D.M. and Parker, C.D. (1974): A Pilot Study to Assess the Validity of the Orthodontic Treatment Priority Index in English School Children, Community Dent Oral Epidemiol 2: 246-252.

Shaw, W.C. (1981): Factors Influencing the Desire for Orthodontic Treatment, Eur J Orthod 3: 151-162.

Shaw, W.C.; Addy, M. and Ray, C. (1980): Dental and Social Effects of Malocclusion and Effectiveness of Orthodontic Treatment: A Review. Comm Dent Oral Epid 8: 36-45.

Shaw, W.C.; O'Brien, K.D.; Richmond, S. and Brook, P. (1991): Quality Control in Orthodontics: Risk/Benefit Considerations, Br Dent J 170: 33-37.

Shaw, W.C.; Rees, G.; Dawe, M. and Charles, C.R. (1985): The Influence of Dentofacial Appearance on the Social Attractiveness of Young Adults, Am J Orthod 87: 21-26.

Shaw, W.C.; Richmond, S. and O'Brien, K.D. (1995): The Use of Occlusal Indices: A European Perspective, Am Orthod Dentofac Orthop 107: 1-10.

Shaw, W.C.; Richmond, S.; O'Brien, K.D.; Brook, P.; and Stephen, C.D. (1991): Quality Control in Orthodontics: Indices of Treatment Need and Treatment Standards, Br Dent J 170: 107-112.

So, L.L.Y. and Tang, E.L.K. (1993): A Comparative Study Using the Occlusal Index and the Index of Orthodontic Treatment Need, Angle Orthod 63: 57-66.

Spencer, A.J.; Allister, J.H. and Brennan, D.S. (1992): Utility of the Dental Aesthetic Index as an Orthodontic Screening Tool in Australia. Adelaide: University of Adelaide.

Summers, C.J. (1971): A System for Identifying and Scoring Occlusal Disorders, Am J Orthod 59: 552-567.

Tang, E.L.K. (1994): The Prevalence of Malocclusion Amongst Hong Kong Male Dental Students, Br J Orthod 21: 37-63.

Tang, E.L.K. and Wei, S.H.Y. (1993): Recording and Measuring Malocclusion : A Review of the Literature, Am J Orthod Dentofac Orthop 103: 344-351.

Turner, S.A.M. (1990): Occlusal Indices Revisited, Br J Orthod 17: 197-203.

Turner, S.A.M. (1983): The Feasibility and Validity of Orthodontic Screening of Children in Their Tenth Year, Br J Orthod 10: 147-153.

U.S Department of Health and Human Services (1989). Oral Health of United States Children: 1986-87. National and Regional Findings. Washington, D.C.: U.S. Government Printing Office, NIH publication no. 89-2247.

U.S. Public Health Service, National Center for Health Statistics (1981). The Prevalence of Dental Caries in United States Children, 1979-1980: The National Dental Prevalence Survey. Washington, D.C.: U.S. Government Printing Office, NIH publication no. 82-2245.

U.S. Department of Health, Education and Welfare (1972). Decayed, Missing and Filled Teeth Among Children. Washington, D.C.: U.S. Government Printing Office.

Van Kirk, L.K. and Pennell, E.H. (1959): Assessment of Malocclusion in Population Groups, Am J Orthod 45: 752-758.

Wang, G.; Hagg, U. and Ling, J. (1994): Need for Orthodontic Treatment in 12 Year Old Chinese Children [Abst], Community Dent Health 11: 474.

Woolass, S.E. and Shaw, W.C. (1987): Validity and Reproducibility of Rating Dental Attractiveness from Study Casts, Br J Orthod 14: 187-190.

World Health Organization (1966): An International Methodology for Epidemiological Studies of Oral Disease, Manual No. 5, Epidemiological Studies of Periodontal Diseases, First Draft, Geneva.

Zammit, M.P. (1995): Malocclusion in Labrador Inuit Youth: A Psychological, Dental and Cephalometric Evaluation, Arctic Medical Research 54: 32-4.

The University of Manitoba
Faculty of Dentistry

COMMITTEE ON RESEARCH INVOLVING HUMAN SUBJECTS

Date: August 23, 1996

Committee Reference EC46/96P

Name of investigator: Dr. K. Danyluk

Your project entitled: The Development of an Objective Orthodontic Treatment-Need Index,

revised on August 21, 1996, has been approved by the Committee.

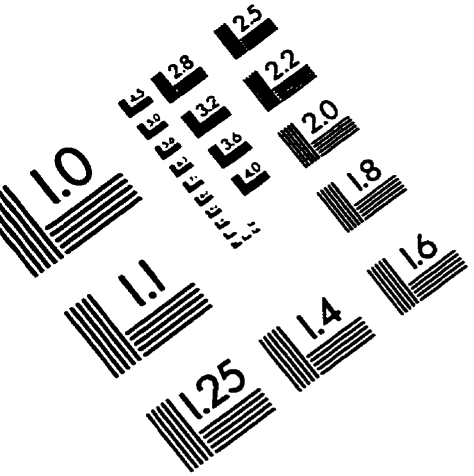
PLEASE NOTE

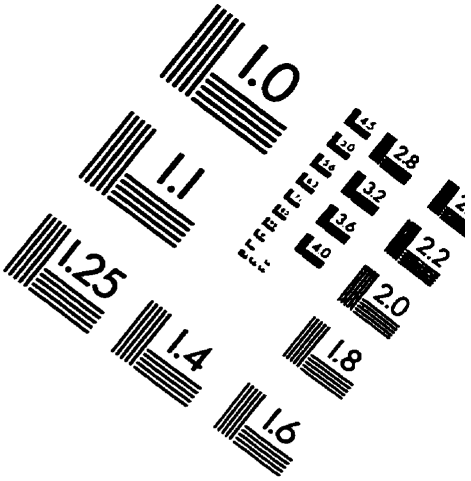
Any significant changes in the approved protocol must be reported to the Chair of the committee for the Committee's consideration and decision, prior to the implementation of the changes in the protocol.

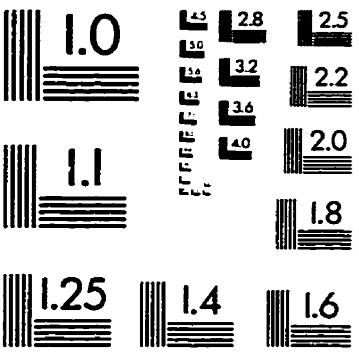
Yours sincerely,

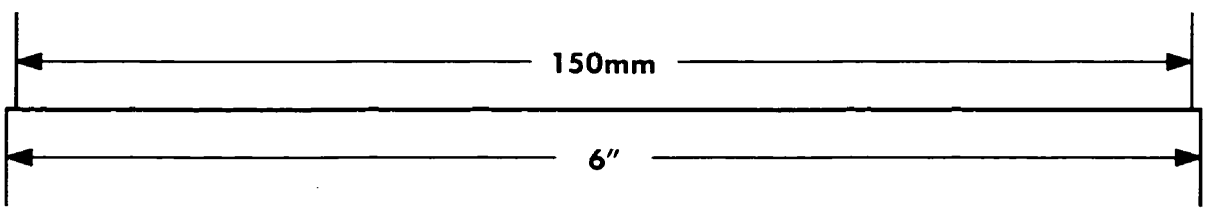
Colin Dawes B.Sc., B.D.S., Ph.D.
Chair, Committee on Research
Involving Human Subjects

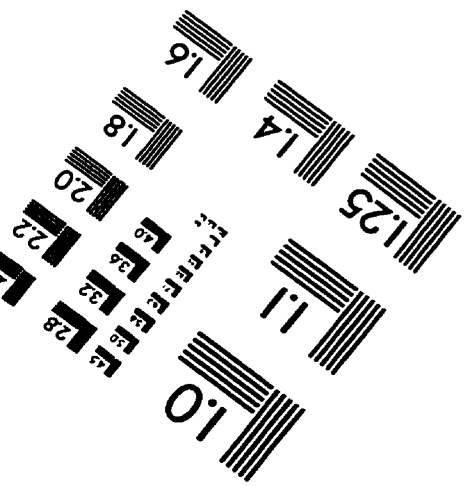
IMAGE EVALUATION TEST TARGET (QA-3)

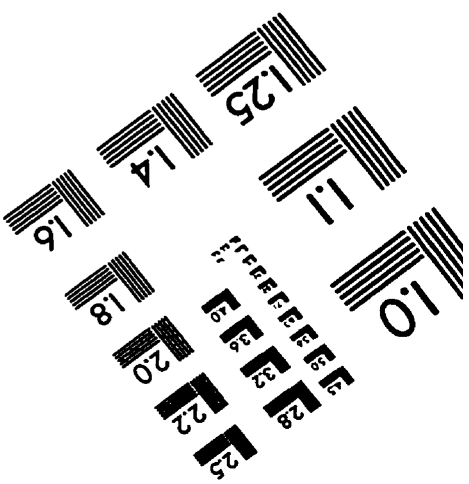












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