QUANTIFYING MALOCCLUSION: AN INVESTIGATION OF TWO MALOCCLUSION INDICES APPLIED TO AN ABORIGINAL PATIENT SAMPLE

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By

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Mathematics 0280
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LANGUAGE, LITERATURE AND LINGUISTICS

Language
- General 0679
- Ancient 0289
- Linguistics 0290
- Modern 0291

Literature
- General 0401
- Classical 0294
- Comparative 0295
- Medieval 0297
- Modern 0298
- African 0316
- American 0591
- Asian 0305
- Canadian (English) 0352
- Canadian (French) 0355
- English 0593
- Germanic 0311
- Latin American 0312
- Middle Eastern 0315
- Romance 0313
- Slavic and East European 0314

PHILOSOPHY, RELIGION AND THEOLOGY

Philosophy 0422
Religion
- General 0318
- Biblical Studies 0321
- Clergy 0319
- History of 0320
- Philosophy of 0322

Theology 0469

SOCIAL SCIENCES

American Studies 0323
Anthropology
- Archaeology 0324
- Cultural 0326
- Physical 0327

Business Administration
- General 0310
- Accounting 0272
- Banking 0770
- Management 0454
- Marketing 0338

Canadian Studies 0385
Economics
- General 0501
- Agricultural 0503
- Commerce-Business 0505
- Finance 0508
- History 0509
- Labor 0510
- Theory 0511

Folklore 0358
Geography 0366
Gerontology 0351
History
- General 0578
- Ancient 0579
- Medieval 0581
- Modern 0582
- Black 0328
- African 0331
- Asia, Australia and Oceania 0332
- Canadian 0334
- European 0335
- Latin American 0336
- Middle Eastern 0333
- United States 0337

History of Science 0585
Law 0398
Political Science
- General 0615
- International Law and Relations 0616
- Public Administration 0617

Recreation 0814
Social Work 0452
Sociology
- General 0626
- Criminology and Penology 0627
- Demography 0938
- Ethnic and Racial Studies 0631
- Individual and Family Studies 0628
- Industrial and Labor Relations 0629
- Public and Social Welfare 0630
- Social Structure and Development 0700
- Theory and Methods 0344

Transportation 0709
Urban and Regional Planning 0999
Women's Studies 0453

THE SCIENCES AND ENGINEERING

BIOLOGICAL SCIENCES

Agriculture
- General 0473
- Agronomy 0285
- Animal Culture and Nutrition 0475
- Animal Pathology 0476
- Food Science and Technology 0359
- Forestry and Wildlife 0478
- Plant Culture 0479
- Plant Pathology 0480
- Plant Physiology 0817
- Range Management 0777
- Wood Technology 0746

Biology
- General 0306
- Anatomy 0287
- Biostatistics 0308
- Botany 0309
- Cell 0379
- Ecology 0329
- Entomology 0353
- Genetics 0369
- Limnology 0793
- Microbiology 0410
- Molecular 0307
- Neuroscience 0317
- Oceanography 0416
- Physiology 0433
- Radiation 0821
- Veterinary Science 0778
- Zoology 0472

Biophysics
- General 0786
- Medical 0760

EARTH SCIENCES

Biogeochemistry 0425
Geochemistry 0996
Geodesy 0370
Geology 0372
Geophysics 0373
Hydrology 0388
Mineralogy 0411
Paleobotany 0345
Paleoecology 0426
Paleontology 0418
Paleozoology 0985
Palynology 0427
Physical Geography 0368
Physical Oceanography 0415

HEALTH AND ENVIRONMENTAL SCIENCES

Environmental Sciences 0768
Health Sciences
- General 0566
- Audiology 0300
- Chemotherapy 0992
- Dentistry 0567
- Education 0350
- Hospital Management 0769
- Human Development 0758
- Immunology 0982
- Medicine and Surgery 0564
- Mental Health 0347
- Nursing 0569
- Nutrition 0570
- Obstetrics and Gynecology 0380
- Occupational Health and Therapy 0354
- Ophthalmology 0381
- Pathology 0571
- Pharmacology 0419
- Pharmacy 0572
- Physical Therapy 0382
- Public Health 0573
- Radiology 0574
- Recreation 0575
- Speech Pathology 0460
- Toxicology 0383

Home Economics 0386

PHYSICAL SCIENCES

Pure Sciences

Chemistry
- General 0485
- Agricultural 0749
- Analytical 0486
- Biochemistry 0487
- Inorganic 0488
- Nuclear 0738
- Organic 0490
- Pharmaceutical 0491
- Physical 0494
- Polymer 0495
- Radiation 0754

Mathematics 0405
Physics
- General 0605
- Acoustics 0986
- Astronomy and Astrophysics 0606
- Atmospheric Science 0608
- Atomic 0748
- Electronics and Electricity 0607
- Elementary Particles and High Energy 0798
- Fluid and Plasma 0759
- Molecular 0609
- Nuclear 0610
- Optics 0752
- Radiation 0756
- Solid State 0611

Statistics 0463

Applied Sciences

Applied Mechanics 0346
Computer Science 0984
Engineering
- General 0537
- Aerospace 0538
- Agricultural 0539
- Automotive 0540
- Biomedical 0541
- Chemical 0542
- Civil 0543
- Electronics and Electrical 0544
- Heat and Thermodynamics 0348
- Hydraulic 0545
- Industrial 0546
- Marine 0547
- Materials Science 0794
- Mechanical 0548
- Metallurgy 0743
- Mining 0551
- Nuclear 0552
- Packaging 0549
- Petroleum 0765
- Sanitary and Municipal 0554
- System Science 0790

Geotechnology 0428
Operations Research 0796
Plastics Technology 0795
Textile Technology 0994

PSYCHOLOGY

General 0621
Behavioral 0384
Clinical 0622
Developmental 0620
Experimental 0623
Industrial 0624
Personality 0625
Physiological 0989
Psychobiology 0349
Psychometrics 0632
Social 0451

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TABLE OF CONTENTS

(Table of Contents, Cont'd)

Abstract

In common with other countries, Canada can no longer afford current levels of government-funded health and dental care. Federal and provincial dental budgets are being significantly curtailed; other third-party payment systems are actively promoting cost-containment and quality assurance. Unless dentistry adopts proactive responses to such changes, external regulatory systems will undoubtedly be imposed on the profession, especially for orthodontic and other elective services. Objective systems to categorize malocclusion severity and prioritize orthodontic service needs as well as treatment difficulty are therefore mandatory to ensure the equitable distribution of such funding. Faced with similar fiscal constraints, many European countries have adopted various occlusal indices for these purposes. However, they have yet to be widely accepted or tested on the North American continent.

The purpose of this study was to investigate the ability of two malocclusion indices, the Dental Aesthetic Index (DAI) and the Peer Assessment Rating (PAR index), to determine stratified levels of malocclusion severity and treatment difficulty. A representative sample of twenty-one pre-treatment study models from Aboriginal patients with various Class II malocclusions were solicited from the records of orthodontists in Winnipeg (Manitoba) and Thunder Bay (Ontario). These casts were scored by fifty-one examiners, comprised of five experienced orthodontists, seventeen general dentists and twenty-nine hygienists, using the DAI and PAR index. As well, the 'expert' orthodontists rated the 'perceived difficulty of treatment' for each case. The data were analyzed with

univariate and multivariate statistical analyses. Results showed no significant difference among the three examining groups ($p > 0.05$). Both indices were able to determine/predict malocclusion severity levels, based on results from discriminant function analysis ($p < 0.05$). Consensus subjective opinion was substantial with respect to treatment difficulty (Cohen's Kappa=0.79), although results from further discriminant analysis were inconclusive ($p > 0.05$). The ability of both indices to determine/predict treatment difficulty indicated that malocclusion severity and treatment difficulty are related but distinct entities.

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List of Tables

(List of Tables - cont'd)

List of Figures

(List of Figures - cont'd)

Introduction

The urgent need to evaluate malocclusion indices is evident, as underscored by the existing literature, which will be reviewed under the following topics:

1. Health Care Reform
2. Historical Development of Malocclusion Indices
3. Recent Malocclusion Indices
    - Index of Orthodontic Treatment Need
    - Peer Assessment Rating Index
    - Dental Aesthetic Index

1. Health Care Reform

In the 1994 *State of the Union Address*, health care reform was placed at the top of the domestic policy agenda (Weil, 1994; Clark, 1990). Although the proposals, which would have altered health care organization, finance and delivery were eventually quashed, private market forces continue to transform the United States health care system (Damiano *et al.*, 1992; Capilouto, 1995). This transformation, driven by profit-seeking corporations, health insurers, cost-conscious governments and fundamental economic forces has resulted in the emergence of managed care programs, increased competition among health care providers and reduced costs (Grembowski *et al.*, 1991; Douglas, 1995).

Health care in Canada has also come under scrutiny, with comments and debates being found in scholarly publications (Evans, 1992), the media (Rachliss and Kushner,

1992) and abroad (Shugars *et al.*, 1991). Attention has focused on Canada's publicly financed system of health care benefits. Unfortunately, the costs of dental care are rarely included in these discussions. Unlike medicine, which is publicly funded in Canada, direct public financing of dental services is not universal and varies from provision of services for the Aboriginal peoples to diverse programs contributing toward dental care for children, the indigent and elderly (Leake *et al.*, 1993).

Within Canada, there are approximately 450,000 Aboriginal people eligible for public funded dental care under the *Non-Insured Health Benefits Program* of the Medical Services Branch of the federal government (Bedford and Davey, 1993). Although orthodontic treatment is included, certain pre-requisites and restrictions apply, as indicated in Appendix A. Governments, encumbered by an increasing debt load can no longer keep pace with the increasing demand and costs of dental and health care. In the health field, numerous cost-cutting measures have been implemented. Budgets for dental care, including orthodontics, have been significantly curtailed (Wenn, 1994). Faced with similar fiscal constraints, many European countries have adopted some form of managed care, using malocclusion indices to determine occlusal severity and prioritized treatment needs (Cooper, 1994). Given these limitations, treatment difficulty becomes another variable of concern for allocation of funds (De Guzman *et al.*, 1995).

Economic forces are driving health care reform. Their potential impact on provision of orthodontic (dental) care to insured groups necessitates the evaluation of current techniques used to determine malocclusion severity and allotment of funds for the remuneration of services rendered.

2. Historical Development of Malocclusion Indices

Oral health data are crucial to determine the treatment needs and manpower supply for a population. In this era of fiscal constraint and accountability, the urgency of such data cannot be overstated. Numerous indices have been devised to facilitate such evaluations, for example the Community Periodontal Index of Treatment Need (Ainamo *et al.*, 1982; Page and Morrison, 1994), but their reliability and validity remain central issues. Such concerns apply specifically to indices developed to evaluate and measure malocclusion severity, as well as prioritize treatment needs and determine quality of care (Richmond and Andrews, 1993; Shaw *et al.*, 1995).

Malocclusion is not a single disease entity. Its complexity hampers objective assessments (Foster and Menezes, 1976). A logical solution is to compare any malocclusion to some "gold standard" or "ideal occlusion", although even this simplistic evaluation proves difficult (Berg, 1991). Numerous authors, using various parameters, have attempted to define "ideal standards of occlusion" with no consensus being reached (Hellman, 1921; Andrews, 1972; Ramfjord and Ash, 1983; Mohl *et al.*, 1988). These models are, however, too complex for routine assessments. To accommodate this dilemma, malocclusion can be subdivided into a number of components and then measured to simplify their assessment (Carlos and Ast, 1966). This "index" approach, endorsed by the World Health Organization (1966) resulted in criteria specific to the definition of occlusal indices (Appendix B). Concerns were expressed for an appropriate model that was not specific to epidemiologic studies (Salzmann, 1968, 1969; Summers, 1971). Subsequently, Shaw *et al.*, (1991) defined the properties listed in Table 1.2.1 as those required for an ideal malocclusion index.

Table 1.2.1 Properties of an Ideal Occlusal Index (Shaw *et al.*, 1991)

1. reliable in use
2. valid
3. sensitive to the needs of the patient
4. acceptable to both the public and profession
5. administratively simple to learn and use
6. sensitive throughout the scale
7. amenable to statistical analysis
8. require a minimum of judgement
9. able to detect a shift in group conditions

The earliest indices developed to record malocclusion were qualitative, descriptive and devised mainly for epidemiologic purposes. Table 1.2.2 summarizes notable indices, authors and malocclusion assessment criteria.

Based on antero-posterior tooth relationships, Angle's (1899) definition of malocclusion types is widely accepted by the dental profession, despite numerous criticisms (Jago, 1974; Gravely and Johnson, 1974; Katz *et al.*, 1990). For example, several authors have noted that Angle disregards tooth relationships relative to facial profile and evaluates three-dimensional malocclusions as two-dimensional deviations (Case, 1905; Dewey, 1915; Hellman, 1920). The Angle classification system, therefore, appears unsuitable to determine malocclusion severity, treatment priority and effectiveness, even though it remains the primary method of orthodontist communication (Ackerman and Proffit, 1969; Katz, 1992a). Other investigators subsequently developed more precise classification systems to address these deficiencies (Stallard, 1932; McCall, 1944; Sclare, 1945; Fisk, 1960). None has become widely accepted.

Alternative classification systems were devised to accommodate three-dimensional arch shape as well as differential skeletal and dental discrepancies (Proffit and Ackerman, 1973). Unfortunately, they merely provide morphologic descriptions or are too complex for use as an epidemiologic tool (Björk *et al.*, 1964). A simplified version has, however, been devised by the Federation Dentaire Internationale (FDI) Commission on Classification and Statistics for Oral Conditions (COCSTOC) (Baume *et al.*, 1973). From 1973 to 1976, this technique was modified by the World Health Organization (WHO), leading to the final version being published as the WHO/FDI *Basic Method for Recording Malocclusion* (Brzroukov *et al.*, 1979). Comprised of three general measurement categories: dental, intra-arch and inter-arch, it has mainly been used to estimate populational orthodontic treatment requirements (Solow and Helm, 1968; Helm 1968; Ingervall, 1974; Lavelle, 1976; Magnusson, 1976).

With the evolution of qualitative methods to record malocclusion, researchers arbitrarily chose and evaluated symptoms in an all-or-none manner relying on single morphologic variables (Stallard, 1932; McCall, 1944; Sclare, 1945; Helm, 1968). In contrast, Fisk (1960) attempted to define specific malocclusion attributes using frequency distribution patterns, whereas Björk and the FDI developed carefully defined criteria (Baume

Table 1.2.2 Qualitative Methods for Recording Malocclusion

Angle (1899)	Classification of molar relationship devised as a prescription for treatment.
Stallard (1932)	The general dental status, including some malocclusion symptoms, was recorded. No definition of the various symptoms was specified.
McCall (1944)	Malocclusion symptoms recorded include: molar relationship, posterior crossbite, anterior crowding, rotated incisors, excessive overbite, labial or lingual version, tooth displacement, constriction of arches. No definition of these symptoms was specified. Symptoms were recorded in "all-or-none" manner.
Sclare (1945)	Specific malocclusion symptoms were recorded, which include Angle's crowding, superior protrusion with incisor crowding, superior constriction without incisor crowding, labial prominence of canines, lingually placed incisors, rotated incisors, crossbite, open bite and close bite. No definition of these symptoms was specified. Symptoms were recorded in an "all-or-none" manner.
Fisk (1960)	Dental age was used for grouping patients: Three planes of space were considered: 1. Anterior posterior relationship: Angle's classification, anterior crossbite, overjet (mm), negative overjet (mm). 2. Transverse relationship: Posterior crossbite (maxillary teeth biting buccally or lingually). 3. Vertical relationship: open bite (mm), overbite (mm). Additional measurements include labiolingual spread (Draker, 1960), spacing, therapeutic extractions, post-natal defects, congenital defects, mutilation, congenital absence, supernumerary teeth.
Björk, Krebs, and Solow (1964)	Objective registration of malocclusion symptoms based on detailed definitions. Data obtained could be analyzed by computers. Three parts: 1. Anomalies in the dentition: Tooth anomalies, abnormal eruption, malalignment of individual teeth. 2. Occlusional anomalies: Deviations in the positional relationship between the upper and lower dental arches in the sagittal, vertical, and transverse planes. 3. Deviation in space conditions: Spacing or crowding.
Proffit and Ackerman (1973)	5-step procedure of assessing malocclusion (no definite criteria for assessment was given): 1. Alignment: ideal, crowding, spacing, mutilated. 2. Profile: mandibular prominence, mandibular recession, lip profile relative to nose and chin (convex, straight, concave). 3. Crossbite: relationship of the dental arches in the transverse plane, as indicated by buccolingual relationship of posterior teeth. 4. Angle classification: relationship of the dental arches in the sagittal plane. 5. Bite depth: relationship of the dental arches in the vertical plane, as indicated by the presence or absence of anterior open bite, anterior deep bite, posterior open bite, and posterior collapse bite.

(Table 1.2.2 - Cont'd)

WHO/FDI (1979)	Five Major groups of items were recorded with (well-defined recording criteria): 1. Gross anomalies. 2. Dentition: absent teeth, supernumerary, malformed incisor, ectopic eruption. 3. Space conditions: diastema, crowding, spacing. 4. Occlusion: a. Incisal segment: maxillary overjet, mandibular overjet, crossbite, overbite, open bite, midline shift. b. Lateral segment: anteroposterior relations, open bite, posterior crossbite. 5. Orthodontic treatment need judged subjectively: not necessary, doubtful, necessary, urgent.

(adapted from Tang and Wei, 1993)

et al., 1973). As none of these methods provided reliable assays, quantitative techniques (Table 1.2.3) were developed to address the deficiencies.

Early attempts to establish quantitative techniques to measure malocclusion were limited in scope, evaluating teeth as "in correct occlusion or maloccluded" (Massler and Frankel, 1951) or measuring tooth displacement on a 0 to 2 scale (Van Kirk and Pennel, 1959). Subsequently, the Handicapping Labiolingual Deviation Index (Draker, 1960, 1967) defined nine oral conditions. These were scored and weighted differentially, with higher scores reflecting a more severe malocclusion. Unfortunately, this index could not distinguish "handicapping" from "non-handicapping" malocclusions based on the clinical judgements of orthodontists as the "gold standard" (Carlos, 1970). Draker (1970), however, argued that "such an evaluation constitutes an error... because it treats objective measurements and subjective judgements as manifestations of the same substance" (p. 147). Fletcher (1963) states that clinical judgement is fallible and orthodontic specialists are often inconsistent when independently rating casts as either "handicapping" or "non-handicapping".

The Occlusal Feature Index (Poulton and Aaronson, 1961), based on only four occlusal features (Table 1.2.3) is considered incomplete due to the exclusion of several important traits, whereas the Eastman Aesthetic Index, although derived from eleven measured occlusal variables, did not gain wide acceptance (Howitt *et al.*, 1967; see Table 1.2.3). In 1965, the American Association of Orthodontists (AAO) and the Council on Orthodontic Health Care (COHC) defined criteria for establishing a "handicapping malocclusion index". As a result, the specifics on the Treatment Priority Index (TPI) were

Table 1.2.3 - Quantitative Methods for Recording Malocclusion

Massler and Frankel (1951)	Count the number of teeth displaced or rotated. Assessment of tooth displacement and rotation is qualitative --- all or none.
Malalignment Index Vankirk and Pennell (1959)	Tooth displacement and rotation were measured. Tooth rotation defined quantitatively: < 1.5 mm or > 1.5 mm. Tooth rotation defined quantitatively: < 45° or > 45°.
Handicapping Labiolingual Deviation Index (HLDI) Draker (1960)	Measurements include cleft palate (all or none), traumatic deviations (all or none), overjet (mm), overbite (mm), mandibular protrusion (mm), anterior open bite (mm), and labiolingual spread (a measurement of tooth displacement in mm).
Occlusal Feature Index (OFI) Poutlon and Aaronson (1967)	Measurements include lower anterior crowding, cuspal interdigitation, vertical overbite, and horizontal overjet. Occlusal features measured and scored according to defined criteria.
Eastman Esthetic Index (EEI) Howitt, Stricker, Henderson (1967)	Eleven weighted and defined occlusal measurements: (1) overjet, (2) reverse overjet, (3) overbite, (4) open bite, (5) number of teeth crowded out of the arch, (6) largest labiolingual deviation of one tooth from the arch, (7) number of rotated teeth, (8) severity of the rotations, (9) mandibular incisor alignment, (10) diastemas, (11) anterior fractures. Patient's subjective evaluation of their own oral and facial appearance.
Treatment Priority Index (TPI) Grainger (1967)	Eleven weighted and defined measurements: (1) upper anterior segment overjet, (2) lower anterior segment overjet, (3) over bite of upper anterior over lower anterior, (4) anterior open bite, (5) congenital absence of incisors, (6) distal molar relation, (8) posterior crossbite (maximally teeth buccal to normal), (10) tooth displacement, (11) gross anomalies. Seven malocclusion syndromes were defined: (1) maxillary expansion syndrome, (2) overbite, (3) retrognathism, (4) open bite, (5) prognatism, (6) maxillary collapse syndrome, (7) congenitally missing incisor.
Handicapping Malocclusion Assessment Record (HMAR) Salzmann (1968)	Weighted measurements consisting of three parts: 1. Intra-arch deviation - missing teeth, crowding, rotation, spacing. 2. Interarch deviation - overjet, overbite, crossbite, open bite, mesiodistal deviation. 3. Six handicapping dentofacial deformities: (1) facial and oral clefts, (2) lower lip palatal to maxillary incisors, (3) occlusal interference, (4) functional jaw limitation (5) facial asymmetry, (6) speech impairment. This part can only be assessed on live patients.

(Table 1.2.3 - Cont'd)

Occlusal Index (OI) **Summers (1971)**	Nine weighted and defined measurements: (1) molar relation, (2) overbite, (3) overjet, (4) posterior crossbite, (5) posterior open bite, (6) tooth displacement, (7) midline relations, (8) maxillary median diastema, (9) congenitally maxillary incisors. Seven malocclusion syndromes and two divisions defined: Division I: 1. Overjet and open bite. 2. Distal molar relation, overjet, overbite, posterior crossbite, midline diastema, and midline deviation. 3. Congenitally missing maxillary incisors. 4. Tooth displacement (actual and potential). 5. Posterior open bite. Division II: 6. Mesial molar relation, overjet, overbite, posterior crossbite, midline diastema, and midline deviation. 7. Mesial molar relation, mixed dentition analysis (potential tooth displacement), and tooth displacement. Different scoring schemes and forms for different stages of dental development: decidous dentition, mixed dentition, and permanent dentition.

(adapted from Tang and Wei, 1993)

published, following modifications to the Malocclusion Severity Index developed by Grainger (1967). Based on the most common malocclusion types, six prerequisites were used to determine a handicapping malocclusion: (1) unacceptable aesthetics, (2) significant reduction in masticatory function, (3) a traumatic condition which predisposes to tissue destruction (periodontal disease or caries), (4) speech impairment, (5) lack of occlusal stability and (6) gross or traumatic defects (e.g. cleft palate). On the basis of these parameters, defined characteristics were recorded on a 1 to 10 scale. The reliability of the TPI has been confirmed by numerous investigators (Popovitch and Thompson, 1971; Scivier *et al.*, 1974; Albino *et al.*, 1978; Lewis *et al.*, 1982), although lack of a mixed dentition analysis was a concern (Turner, 1983, 1990). Also the values recorded in the mixed dentition stage could not predict the severity of malocclusion manifested in the permanent dentition (Ghafari *et al.*, 1989). Nevertheless, the TPI is a useful epidemiologic tool for assessing malocclusion severity (Carlos, 1970; Kelly and Harvey, 1977).

The Handicapping Malocclusion Assessment Record (HMAR) was endorsed by the AAO and AAD as a tool for assessing the severity of handicapping malocclusion (Salzmann, 1968). Although designed to identify occlusal conditions which interfere with oral health or general well being, its validity and reliability have been subjected to scant investigation (Allen, 1970; Caveney, 1976). Such criticisms cannot be applied to the Occlusal Index (OI) (Summers, 1971). Although based on Grainger's TPI, it accommodates different age groups and dental development incorporating nine specific measured and weighted traits (Table 1.2.3).

A number of investigators have compared the relative validity, intra- and interreliability of various malocclusion indices (Tang and Wei, 1993). For instance, insignificant inter-examiner variability at the 1% level has been reported for the OI and TPI (Hermanson and Grewe, 1970), while the HMAR, OI and TPI are all highly reproducible (Grewe and Hagan, 1972; Summers, 1972). However, no index has proved superior to others when compared to the gold "clinical judgement" standard, although the OI appears to correlate best with clinical standards determined by subjective orthodontic assessment (Turner, 1990).

The OI has been the index of choice in recent studies, even though it cannot account for early permanent molar loss (Pickering and Vig, 1974) or subjective tooth displacement scores (Gray and Demirjian, 1977; Turner, 1983; Elderton and Clark, 1984). The OI also tends to underestimate orthodontic treatment needs (Tang, 1994) and penalize cases with disto- or mesio-occlusion (Buchanan *et al.*, 1993). Despite reservations, the OI offers acceptable reliability and validity relative to other indices, although several recent initiatives have been introduced to overcome these deficiencies.

3. Recent Malocclusion Indices

A resurgence of interest in developing valid and reliable malocclusion assessments has occurred in several countries due to changing economic climates. Although several indices have been developed, none as yet has been accepted universally.

Index of Orthodontic Treatment Need (IOTN)

The Index of Orthodontic Treatment Need is based on the belief that the main benefits of orthodontic treatment are related to improved aesthetics, increased social-psychological well-being and dental health (Shaw *et al.*, 1980; Shaw, 1980). This index ranks malocclusion in terms of the significance of various occlusal traits for an individual's dental health and perceived aesthetic impairment, with the intention of identifying those persons most likely to benefit from orthodontic treatment (Shaw *et al.*, 1995). The index incorporates a dental health component (DHC) and an aesthetic component (AC), with the DHC defined by five grades --- grade 1 reflecting "no treatment need" and grade 5 indicating "great treatment need". The AC of the IOTN consists of a 10-point scale derived from a series of 10 photographs rated for attractiveness by laypersons. Both examiner and patient independently select an appropriate value for overall dental attractiveness which is closest to one of the photographs. The derived value gives an indication of perceived treatment needs on the basis of aesthetic impairment and, by inference, any socio-psychological need for treatment (Evans and Shaw, 1987).

Initial evaluation of the IOTN on a random 222 sample aged 11 to 12 years indicated inter- and intra-examiner agreement was "substantial to almost perfect" with Kappa values of 0.78 to 0.84 for the dental health component. The correlation coefficient for the aesthetic component was quite high between the orthodontists (0.71 to 0.87) but extremely variable when compared to the patients' perceptions (0.29 to 0.73). This was attributed to the fact that a layperson, in the absence of a side view, may not notice, or find a large overjet particularly displeasing (Brook and Shaw, 1989). Shaw *et al.* (1991) gauged the extent to which the index reflected common professional opinion using a panel of 74 professionals. The reproducibility of the index was "almost perfect" with a Kappa score of 0.83 for the DHC and "substantial" agreement was indicated for the AC (Kappa = 0.72).

The IOTN has been evaluated in institutionalized situations (O'Brien *et al.*, 1993) and as a public health tool for assessing treatment needs in large population groups (So and Tang, 1993; Lunn *et al.*, 1994; Wang *et al.*, 1994). Results indicate that modifications are required to determine treatment requirements (Richmond *et al.*, 1994b). Although the IOTN score is significantly correlated with children's and parents' orthodontic concerns, results from patients with a low awareness of their own oral appearance are significantly less (Birkeland *et al.*, 1994). Information gained from the IOTN in a clinical situation does not differ significantly from that obtained from diagnostic models, however, there was poor agreement for the aesthetic component scored from photographs, when compared with scores recorded clinically or from models (Buchanan *et al.*, 1993).

Although not tested extensively, the IOTN appears to offer a reproducible technique for evaluating the dental and aesthetic components of malocclusion, but validity of the index tends to be quite variable (Richmond *et al.*, 1995b). Green and O'Brien (1994) offered a cautionary note with respect to the IOTN: after suggestions that orthodontic treatment should only be provided to patients whose malocclusion is allocated a certain IOTN score, it then changes from being an ordered classification of treatment need to a diagnostic tool. If the IOTN is used to restrict orthodontic treatment allocation, the inherent error of the measurement needs to be investigated.

Dental Aesthetic Index (DAI)

The DAI is an orthodontic index based on public perceptions of dental aesthetics in the USA. It is a regression equation linking the relative social acceptability of dental appearance to the objective, physical measurements of ten occlusal traits (Cons and Jenny, 1994). Each measurement is multiplied by a specific weight (regression coefficient), the products are summed and then added to a constant to give an individual DAI score. The detailed conventions and procedures for scoring the DAI, as described in the *Guidelines for Using the DAI* (Jenny and Cons., 1988) is provided in Appendix C.

In 1979, the State of the Art Workshop on *Psychological Aspects of Craniofacial Malformations* called for research on methods to quantify psychosocial information and development of methods to identify the interrelationship between craniofacial morphology and psychosocial evolution. This announcement provided the impetus for the research leading to the development and publication of the Dental Aesthetic Index (Jenny and Proshek, 1986: Cons *et al.*, 1986; Jenny and Cons, 1988). On the basis of a representative sample of 1,413 subjects from a population of half a million adolescents (15-18 years), Ast and co-workers (1965) determined that 95% of this group had some degree of malocclusion.

From this archive of models, Cons *et al* (1978) selected 1,337 casts which were assessed and measured as suggested by the FDI's COCSTOC (Baume *et al.*, 1973). Percentage distributions were calculated for all the occlusal traits associated with malocclusion. Proshek and co-workers (1979) subsequently identified 18 occlusal patterns and combinations of traits. Again from this sample of 1,337 models, two random samples of 100 casts were identified and an instrument to measure public perceptions of the social acceptability of occlusal conditions was constructed (Jenny *et al.*, 1980). The development of the *Social Acceptability Scale of Occlusal Conditions* (SASOC) included presenting photographs of the representative subsample of 200 dental casts to a sample of students (n=880) and their parents (n=403) as well as 66 orthodontists. Responses to the photographic stimuli were measured via a set of semantic differential items, e.g.

desirable/undesirable; good/bad; happy/sad; dirty/clean; beautiful/ugly. Stylized masks in the shape of lips surrounded the teeth in the photograph eliminating non-essential parts of the cast and neutralizing effects of racial and soft tissue features. Each stimulus presented a frontal view as well as right and left lateral views of the teeth in occlusion. Following exposure to the photographic stimuli, data from the three groups (student, parent, expert) was assessed using a variety of statistical tests (Cronback's Alpha, Spearman's and Pearson's correlation). The authors concluded that the SASOC scores did in fact reflect general appearance norms that were widely held throughout North American society (Jenny *et al.*, 1983). Subsequently, mean scores from these stimuli for social acceptability were linked by factor analysis and stepwise regression procedures to the occlusal trait measurements for each of the 100 study casts. The resulting regression equation yielded ten occlusal measurements with corresponding weights (regression coefficients). These subsequently became the Dental Aesthetic Index I.

To validate this index, a parallel procedure was performed using the second sample of 100 casts. The results were subjected to a double cross-validation procedure. The statistical analyses produced a refined regression equation, which became the Standard DAI (See schematic diagram in Appendix D for development of the DAI). A DAI score is obtained by measuring defined occlusal traits and inserting the measurements into the DAI equation. Placing the DAI score along a continuum (0=most socially acceptable to 100=least acceptable) determines acceptability with respect to dental appearance --- the further a DAI score falls from an acceptable norm, the more likely the malocclusion may contribute to psychological or social dysfunction.

It has been suggested that different societies vary in their preference for dento-facial characteristics and might be expected to view dental aesthetics differently than the general United States population (Tedesco *et al.,* 1983). Several studies using the previously described methodology and photographic stimuli determined that perceptions of social acceptability of occlusal conditions in other cultures and countries are similar to Native American US students (Cons *et al.,* 1983, 1989). Appendix E presents the correlation values from these studies as well as the data from later investigations of ethnic groups in Latvia, Japan, China and several other Asian populations (Ansai *et al.,* 1993).

The data generated from such diverse groups, both culturally and geographically, suggest norms for dental aesthetics in other populations are sufficiently analogous for use of the DAI without modification (Cons *et al.,* 1994). Based on the assessment of 1,337 models, combinations of occlusal traits that yielded high DAI scores have been found by orthodontists to be in greater need for orthodontic treatment (Cons *et al.,* 1991). Using Angle's classification, 95% of this sample had some degree of malocclusion with a mean DAI score of 28.16; whereas the orthodontists judged only 14% to have a handicapping malocclusion with a mean DAI score of 38.49, thus providing a numerical indication of the contrasting definitions of malocclusion. Katz (1992a,b) also provided evidence of the inability of orthodontists to arrive at a consensus on malocclusion when using Angles' principles. In a practical sense, the use of Angles' classification may result in treatment needs being overestimated --- a fact which could be of particular interest in a public funded orthodontic program with limited financial resources (Rinchuse and Rinchuse, 1989).

For a malocclusion index to be effective it must be able to distinguish subjects with the highest scores and priority for treatment, from those with lower scores and less urgent need for treatment. Therefore, a meaningful cut-off point along the index scale should be determined (Salzmann, 1968; Baume *et al.*, 1973; Estioko *et al.*, 1994). Using the subjective opinion of two orthodontists, a clinical determination was made on the previously used models regarding the presence or absence of a handicapping malocclusion. A consensus decision determined that 14% of the sample had handicapping malocclusions in need of treatment, corresponding to a score of 36 with the DAI (Jenny *et al.*, 1992)

Subsequently, cut-off points were determined identifying less severe categories of malocclusion. Based on consensus clinical judgement, DAI scores less than 25 indicate minor anomalies; scores 26 to 30 indicate a definite malocclusion; scores from 32 to 35 have a severe malocclusion; and scores 36 or higher have the most severe or handicapping malocclusions (Jenny and Cons, 1993). Although these severity levels have been identified, there is little evidence of its applicability in the literature (Keay *et al.*, 1993).

The DAI has been described as an orthodontic index which is grounded in socially defined aesthetic norms, responding to the need for inclusion of psychological factors in the assessment of malocclusion (Cons *et al.*, 1994). It has been incorporated into the *Oral Data Collection Instrument* used by the WHO. There is international interest in its use as a screening tool for eligibility of subsidized orthodontic care and Indian Health Services (U.S.A.) has also shown an interest in its ability to assess unmet needs and prioritize treatment (Jenny *et al.*, 1991, 1993).

Although the DAI shows promise as an occlusal index, it is not without faults, e.g. original and follow-up evaluations were based on a population sample that had only permanent dentition. Further investigation is also required in the area of determining cut-off points on the DAI scale as well as the possibility that the DAI may over or underestimate treatment need before it can be used carte blanche by administrators of publicly funded orthodontic programs to ensure impartial allocation of treatment and monies.

Peer Assessment Rating Index (PAR index)

In an attempt to overcome the deficiencies of previous indices, Richmond *et al* (1992a, b) developed the Peer Assessment Rating to measure malocclusion severity and treatment success. The concept is to assign a score to the various occlusal traits which make up a malocclusion, as defined by the PAR index, i.e. maxillary and mandibular anterior alignment, buccal occlusion, overjet, overbite and midline discrepancy. A score of zero indicates perfect alignment with increasing scores, rarely beyond 50, pointing toward increasing levels of malocclusion severity. Shaw, *et al* (1991) have refined these measurements, with PAR scores of less than 10 indicating a malocclusion that deviates slightly from normal, scores of 11 to 20 have a moderate malocclusion, with scores greater than 20 having substantial malocclusion. A description and detailed conventions of the PAR index, as described by Richmond *et al* (1992a), are provided in Appendix F.

Development of the index included a number of orthodontists, *British Orthodontic Standards Working Party*, evaluating over 200 dental casts, representing a wide spectrum of malocclusions. Group consensus determined the individual features which would be assessed to obtain an estimate of the degree of malalignment expressed in any given occlusion. The reliability of the PAR index was tested using four calibrated examiners evaluating a stratified subsample of 38 cases. The Intraclass Correlation Coefficient of

Reliability showed excellent intra- and inter-examiner reliability, R>0.95 and R=0.91 respectively (Fleiss *et al.,* 1979).

Validation of the PAR index utilized the subjective consensus opinion of numerous experts compared against the objective measurements of the index. A panel of 74 dentists evaluated and reached a consensus opinion on the degree of malocclusion severity presented by 272 cases. Statistical manipulation determined malocclusion component weights reflecting British orthodontic opinion. Subsequent analysis indicated associations between orthodontic opinions and PAR scores to be high ($r = 0.85$, $p < .001$) as was intra- and inter-examiner reliability for the weighted index ($r = 0.93$). However, a poor level of agreement existed between examiners for subjective assessments of deviations from normal, indicating the difficulties associated with orthodontic judgement and determination of malocclusion severity (Richmond *et al.*, 1992a).

Application of the PAR index to both pre-treatment and post-treatment study casts has been used to determine improvement and standard of treatment (Richmond *et al.*, 1992c). Expression of the degree of improvement resulting from treatment is related to a numerical change in the weighted PAR score and consensus orthodontic opinion (Richmond *et al.,* 1992b). Using the PAR index and a nine-point scale from "markedly worse" to "slightly improved" occlusions, inter-examiner agreement was only moderate.

Using the PAR index, several studies assessing the results of treatment in England, Wales and Norway have indicated that treatment standards were high, in terms of dento-occlusal change, but effectiveness of treatment was influenced by education, experience and choice of appliance (Richmond *et al.,* 1992b; O'Brien *et al.,* 1993; Richmond and Andrews, 1993). Furthermore, other studies investigating treatment effects of removable appliances determined less than adequate results occurred (Gravely, 1989; Shaw *et al.*, 1991; Richmond *et al.*, 1993a). Kerr and Buchanan (1993) suggest removable appliances could result in "improved" or "greatly improved" cases, if predetermined criteria are used in case selection. Richmond (1993) has suggested the PAR index for "performance feedback" to improve quality of care, similar to the clinical audit in medicine (Grol *et al.*, 1985; Burke and Wilson, 1994). Fox (1993) suggests the PAR index is useful in reviewing one's own patients to provide valuable information for further personal development. Other investigations found that the PAR index can be used to evaluate treatment results as well as long term, post-retention changes (Otuyemi and Jones, 1995; O'Brien *et al.*, 1995).

The PAR index is an occlusal index developed to measure malocclusion severity and effectiveness of treatment. It has undergone extensive evaluation in Europe and has been adopted for use by a number of dental agencies and hospitals. However, its validity is based on consensus opinion of British dentists, perhaps limiting its use in North America. De Guzman et al (1995) investigated the validity of the PAR index with respect to American orthodontic opinion. Weightings were subsequently derived for the PAR index, making it possible to calculate PAR scores reflecting malocclusion severity based on North American orthodontic opinion and providing a "starting point" for the assessment of malocclusion severity and orthodontic treatment standards in North America utilizing an occlusal index.

Current Study

As shown by this literature review, the DAI and PAR index are the most acceptable indices to quantify malocclusion. The present study was therefore undertaken to evaluate their application to a range of Angle Class II, Division I malocclusions. This information is critical. Whereas such indices are widely accepted in Europe, they have yet to gain wide acceptance in North America (Shaw *et al.*, 1995). Although the AAO does not officially recognize any malocclusion index, nineteen states use various indices as determinants for publicly funded orthodontic treatment (Bowers, 1991). Obviously, some form of a reliable, objective technique for allocating orthodontic treatment is crucial. For instance, the provision of orthodontic services in publicly funded programs is becoming a concern with increased demand and treatment needs as well as limited financial resources (Freer and Olive, 1976; Spencer and Lewis, 1988). For example, 25% of Aboriginal children between the ages of 6 and 12 years exhibit a malocclusion directly associated with reported dissatisfaction with appearance (Leake, 1992). Third-party insurance corporations have also expressed concerns about rising costs and quality of care (Antkowiak and Kuthy, 1993). The assessment of malocclusion severity, treatment need and difficulty is necessary to ensure fairness and equity in establishing eligibility and remuneration for treatment. Unfortunately, this study indicates the need for further development before objective assessments of treatment need and difficulty can be evaluated objectively from study models.

Materials and Methods

This study was based on twenty-one carefully selected pre-treatment orthodontic casts evaluated by fifty-one examiners from three different groups. Their malocclusion severity was assessed using both the DAI and PAR indices. In addition, potential treatment difficulties were determined by a three-point subjective scale. The prime objective of this study is to evaluate techniques to discriminate malocclusion severity as well as levels of treatment difficulty based on orthodontic study models. In order to facilitate appreciation of this study, details of the indices are included in Appendices C and F.

The Sample of Study Casts and Examiners

Study Casts:

A large number of pre-treatment study casts were solicited from orthodontists in Winnipeg (Manitoba) and Thunder Bay (Ontario). A sample of 21 sets of diagnostic study models was then obtained by the application of the following selection criteria: (i) Aboriginal patients, (ii) Class II Division I molar and incisal malocclusion and (iii) models with good surface detail and no apparent distortion. The resulting sample included eleven females (age range: 9Y 8M to 17y 3M) and ten males (age range: 10Y 2M to 17Y 8M). All had been approved for comprehensive orthodontic treatment by the Medical Services Branches in their respective jurisdictions.

The original study casts were duplicated by fabricating silicone rubber pressure moulds made from 2.0 mm mouthguard material* using a Biostar® machine†. They were

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* Great Lakes Ortho Ltd.
Tonawanda, N.Y.

subsequently trimmed to orthodontic specifications. Identification numbers were assigned to each cast by an independent observer using a random numbers table (Dawson-Saunders and Trapp, 1994).

Examiners:

Fifty-one examiners agreed to participate in this investigation. They comprised three groups, depending on their qualifications:

Group 1 - "expert group" - five orthodontists who graduated from the University of Manitoba, Graduate Orthodontic Program.

Group 2 - "auxiliary group" - twenty nine senior hygiene students in their final months of training at the School of Dental Hygiene, University of Manitoba.

Group 3 - "general dentist group" - seventeen general practitioners GP's with 1 to 20 years in practice.

Scoring of the Casts with the PAR Index and DAI

Prior to the scoring of the casts, each participant was supplied with an "Instructional Manual" and protocol for scoring the casts using the DAI and PAR index (see Appendix G). On a separate occasion, demonstrations, practise sessions and further instructions were provided for the participants. Each group scored their casts under standardized conditions, but on separate occasions, allowing the chief investigator to be available for questions and interpretation during the actual scoring procedure.

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† series 11. 1977-1987.
Great Lakes Ortho Products Inc.
Buffalo, N.Y.

Ranking of the Casts

Following the scoring of the casts with the occlusal indices, the "expert group" was asked to give a subjective opinion on each cast with respect to its degree of treatment difficulty. Choices of easy (1), moderately difficult (2) or difficult (3) were recorded on a three point numerical scale (Appendix G).

Data Analysis

The data was collected and analyzed using a SPSS * computer program for Windows†. After appropriate tests of data validity and consistency (homogeneity of variance), univariate and multivariate statistical techniques were applied to test the null hypotheses:

i) there is no difference between examiner groups

ii) neither the PAR index nor DAI is able to determine malocclusion severity

iii) neither the PAR index nor DAI is able to determine treatment difficulty

The analyses comprised the following:

1. The intra-examiner reliability was evaluated using a paired t-test; inter-examiner reliability was assessed with ANOVA.

2. The mean scores, standard deviations and standard errors for each variable

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† SPSS Inc.
Chicago, Il.

in the PAR index and DAI were calculated for each individual Group and compared using a one way ANOVA.

3. The total mean scores and standard deviations were calculated for the PAR index and DAI for each individual Group. These data were then subjected to univariate and multivariate homogeneity of variance tests and MANOVA

4. The ability of the PAR and DAI to determine malocclusion severity was analyzed with stepwise discriminant function analyses.

5. Intra- and inter-examiner reliability with respect to subjective opinion of treatment difficulty was assessed with Cohen's Kappa statistic.

6. The associations between objective assessments of malocclusion severity and the subjective treatment difficulties were analyzed with stepwise discriminant function analyses.

Results

The aim of this section is to assess the efficacy of the DAI and PAR index with respect to determination and prediction of malocclusion severity as well as treatment difficulty. In an effort to provide a coherent presentation of the results, they are listed as a series of subsections with all tables and figures following:

- □ Examiner reliability
- □ Determination of scores for the variables
- □ Determination of scores for the casts
- □ Determination of malocclusion severity
- □ Determination of treatment difficulty

Examiner Reliability

The differences between the duplicate scores for the DAI and PAR index were calculated for each of the three Groups of examiners. A paired t-test applied to each group found no significant difference between measurements ($p > 0.05$). Analysis of variance based on repeat scores by 6 different group examiners, selected at random also showed no significant inter-examiner variability ($p > 0.05$). The reproducibility of measurements for the DAI and PAR index was therefore assessed as satisfactory based on statistical analyses of the differences between replicated scores.

Determination of Scores for Variables

The means, standard deviations and standard errors calculated for each variable in the DAI and PAR index are listed in Tables 3.1 and 3.2. Generally, these data showed marked variability. This is evidenced by the size of the respective standard deviations relative to the means. Nevertheless, no apparent difference in scoring patterns could be detected between the three Groups, i.e. the means and standard deviations were quite similar, particularly with the DAI scores. Although Group 1 (experts) appeared to rate cases higher PAR indices, analysis of variance indicated no significant differences ($p > 0.05$) between Groups 1, 2 and 3 for either the PAR or DAI variables. These trends (Figures 3.1 through 3.6) show a tendency for Group 1 (expert) to score cases slightly higher values using the PAR index, followed by Group 3 (G.P.) and Group 2 (auxiliary). This pattern is repeated with the DAI variable "overjet measurement", but not with the "buccal occlusion" variable. Therefore, there is no particular pattern which differentiates the scoring of the 3 individual groups of examiners. This is confirmed by univariate analyses of the PAR and DAI variances, which showed no significant differences between the observations recorded by the examiners in Group 1, Group 2 or Group 3.

Determination of PAR and DAI Scores for Casts

The means, standard deviations and 95% confidence intervals calculated for the DAI and PAR index, for each Group (expert, auxiliary and G.P), are listed in Table 3.3. Histograms of the PAR and DAI scores for each Group (Figures 3.7 through 3.14) demonstrate scores which approximate normal (Gaussian) distributions. These data, and examination of scatterplots representing examiner scores for the DAI and PAR index parameters, justified the participation of all examiners, i.e., no outliers (examiners) were excluded from any Group. Some values for the DAI and PAR index appear to stand out from the rest of the sample, although expert statistical consultation indicated no further data manipulation was required prior to their continued analysis.

After subjecting both the DAI and PAR index scores to univariate homogeneity of variance tests, no significant differences among the three Groups were evident ($p = 0.16 - 0.14$). Furthermore, multivariate tests of homogeneity confirmed these trends ($p > 0.05$). Multivariate analysis of variance indicated no significant differences among Group 1, Group 2 and Group 3 with $p > 0.001$ and a Wilk's Lambda calculation of 0.45.

These analyses therefore determined that there were no significant differences existed between the 3 Groups with respect to the DAI and PAR index scores. Consequently, the data from the three groups were subsequently pooled prior to their stepwise multiple regression and discriminant function analyses.

Determination of Malocclusion Severity

The DAI and PAR index threshold scores used to classify malocclusion severity are presented in Table 3.4. Iin accord with PAR index protocol, right and left buccal occlusion variables were combined prior to analysis.

Table 3.4 **PAR and DAI scores for malocclusion severity levels as defined by Shaw *et al.* (1991); Jenny and Cons (1993).**

	Malocclusion Severity Levels		
	Mild	**Moderate**	**Severe**
PAR Score	≤ 15	16 to 24	≥ 25
DAI Score	≤ 25	26 to 34	≥ 35

Based on previous ANOVA results, the PAR index and DAI scores from the individual Groups were pooled and subsequently subjected to (i) stepwise multiple regression and (ii) discriminant function analyses.

Results of the multiple regression analyses for the DAI are shown in Table 3.5 and results for the PAR index are shown in Table 3.8. Variables with significant influence on malocclusion severity are indicated (*), as well as the multiple correlation coefficient ($R^2 = 0.57$ (DAI) and 0.56 (PAR)). Both R^2 values indicate moderately good relationships between the individual variables and malocclusion severity for both indices.

Subsequently, the data were scrutinized using discriminant function analyses which confirm the results of the multiple regression analyses. The optimal variables for determining malocclusion severity were derived from mathematical equations (functions) for both the DAI and PAR indices (Tables 3.6 and 3.9. Variables which were not significant discriminators were eliminated from the equation and do not appear in subsequent tables. The results of the discriminant function analysis showed both indices were capable of distinguishing mild, moderate and severe malocclusions as indicated by the three distinct groupings within the scatterplots (Figures 3.15 and 3.16).

Furthermore, results of the classification analysis (Tables 3.7 and 3.10) indicate that 93.27% and 96.65% of the cases (mild, moderate, severe) were correctly grouped by the DAI and PAR indices respectively. However, 56.50% of the mild cases were incorrectly predicted/placed into the moderate category using the DAI. As reviewed in the Discussion, the trend is toward a liberal rather than conservative esetimate of malocclusion severity. A chi-square test calculated on these tables confirmed the appropriateness of case placement/categorization ($p < 0.05$).

Determination of Treatment Difficulty

Treatment difficulty was assessed by the "expert" Group as easy, moderately difficult or difficult, based on subjective opinion, and given a numerical score from 1 (easy) to 3 (difficult). Cohen's Kappa statistic indicated that intra- and inter-examiner agreement varied from moderate to substantial. This has previously been noted by Landis and Koch (1977), and illustrated in Tables 3.11 and 3.12. Interestingly, all examiners with the exception of examiner number 5 exhibited substantial inter-examiner agreement. This fact is difficult to explain. One might speculate, however, that it is due to any one of the factors reviewed in the Discussion.

Pooled DAI and PAR index scores for treatment difficulty were then individually subjected to (i) stepwise multiple regression and (ii) discriminant function analyses. Results of the multiple regression analyses for the DAI are shown in Table 3.13 and results for the PAR index are shown in Table 3.16. Variables with significant influence on treatment difficulty are indicated (*), as well as the multiple correlation coefficient (R^2 - 0.32 (DAI) and 0.22 (PAR)). These R^2 values indicate that only fair relationships exist between the individual DAI variables and the global treatment difficulty assessment. In contrast, a poor relationship exists between PAR variables and the global treatment difficulty assessment.

Subsequently, the data were scrutinized using discriminant function analysis. These analyses confirmed the previous results of the multiple regression analyses. Of note, is the fact that the variable, largest mandibular irregularity, does not appear in Tables 3.13 and 3.14 as it was eliminated from both the regression analysis and discriminant analysis. Thus indicating its non-contribution as a predictor/discriminator of treatment difficult. The optimal variables for determining treatment difficulty derived from mathematical equations (functions) for both the DAI and PAR index (Tables 3.14 and 3.17) showed that the DAI is better able to "discriminate" levels of treatment difficulty as indicated by the cluster effect shown in Figure 3.17, whereas the PAR index is not as discriminating, evidenced by the "shot-gun" effect seen in Figure 3.18.

Furthermore, results of the classification analyses (Tables 3.15 and 3.18) indicated that 82.8% of the cases are correctly classified with respect to treatment difficulty when using the DAI variables, whereas only 70.4% of the cases are correctly categorized with the PAR index variables. Of note with the PAR index is that 48.8% of the difficult cases have been assessed as moderately difficult whereas 63.0% of the easy cases were categorized as moderately difficult. A chi-square test calculated on these tables confirms the appropriateness of case placement/categorization ($p < 0.05$).

Summary of Results

The main findings of this study can therefore be summarized in point form:

- intra- and inter-examiner reliability for both indices was assessed as satisfactory after statistical analysis of repeat scores.

- univariate and multivariate analysis of variance showed no significant differences between examiner Groups.

- based on the pooled data, discriminant function analyses showed that both the DAI and PAR index were able to discriminate between mild, moderate and severe malocclusions.

- intra- and inter-examiner agreement with respect to subjective opinion of treatment difficulty was assessed as moderate to substantial following application of Cohen's Kappa statistic.

Table 3.1 - Means and standard deviations of DAI component variables
Group1 = experts; Group 2 = auxiliaries; Group 3 = GP's.

	Group 1		Group 2		Group 3	
DAI Variables	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**
missing teeth	0.62	1.43	0.63	1.34	0.62	1.43
crowding	1.56	0.69	1.53	0.72	1.66	0.76
spacing	0.15	0.46	0.32	0.61	0.19	0.51
diastema	0.12	0.38	0.24	0.63	0.28	0.61
largest maxillary anterior irregularity	3.40	1.62	3.83	1.82	3.36	1.70
largest mandibular anterior irregularity	2.36	1.64	2.48	1.61	2.21	1.62
buccal occlusion	1.43	0.75	1.23	0.81	1.15	0.84
overjet	6.87	2.52	6.40	2.27	6.87	2.45
open bite	0.05	0.26	0.06	0.71	0.24	0.85

*** measurements as per DAI protocol, Appendix C**

Table 3.2 - Means and standard deviations of PAR component variables
Group 1 = experts; Group 2 = auxiliaries; Group 3 = GP's.

	Group 1		Group 2		Group 3	
PAR Variables	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**	**Mean**	**St. Dev.**
maxillary anterior segment	5.10	3.03	5.85	3.25	6.10	3.72
mandibular anterior segment	3.40	2.63	4.15	3.30	4.04	3.67
right buccal occlusion	1.43	0.75	1.23	0.81	1.15	0.84
left buccal occlusion	1.22	0.82	1.04	0.85	1.05	0.83
overjet	2.31	1.07	2.02	1.08	2.19	1.18
open bite	0.08	0.33	0.04	0.30	0.08	0.33
overbite	1.35	0.82	1.16	0.79	1.11	0.79
centre line	0.55	0.65	0.34	0.50	0.42	0.55

*** Measurements as per PAR protocol, Appendix F.**

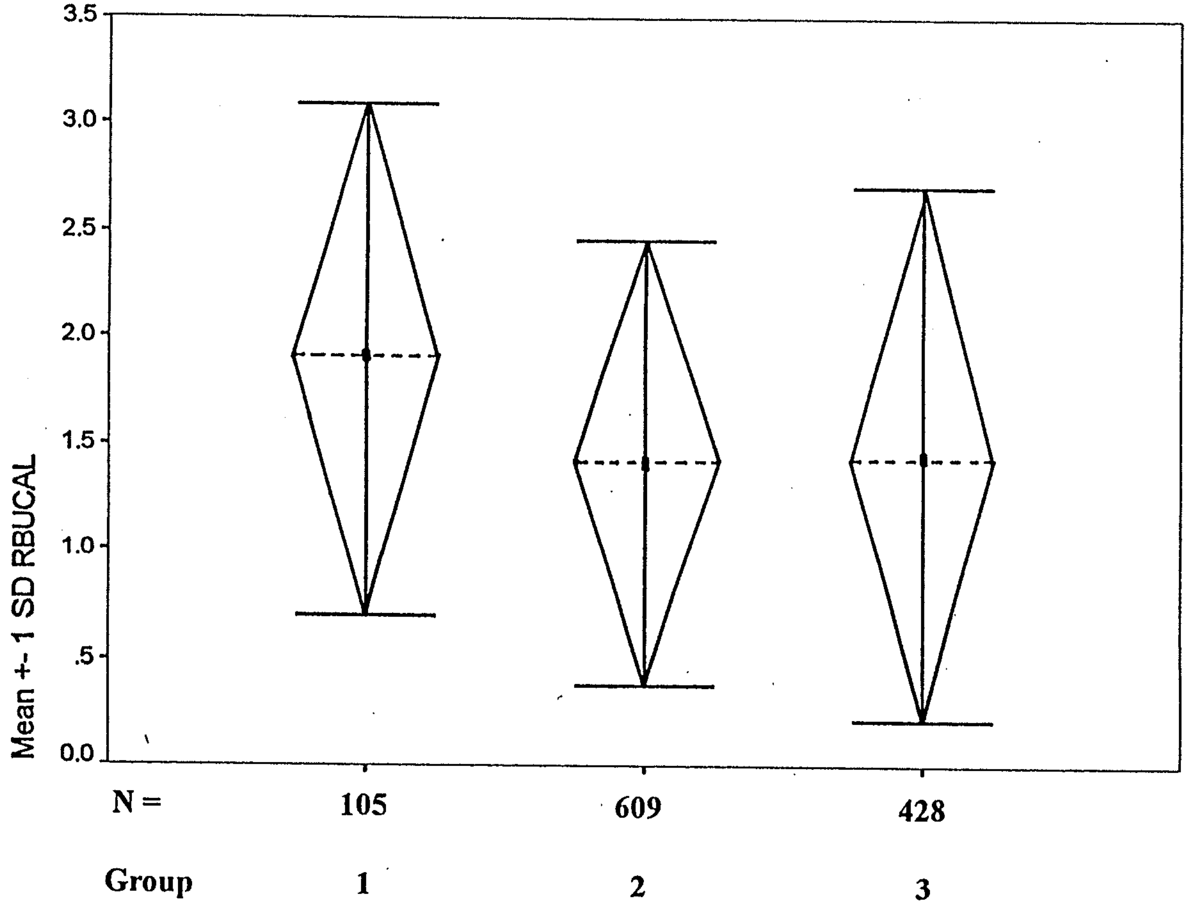


Figure 3.1 - DAI Buccal Occlusion ± 1 Standard Deviation
Group 1 = expert; Group 2 = auxiliary; Group 3 = GP's
N = Group variable measurements

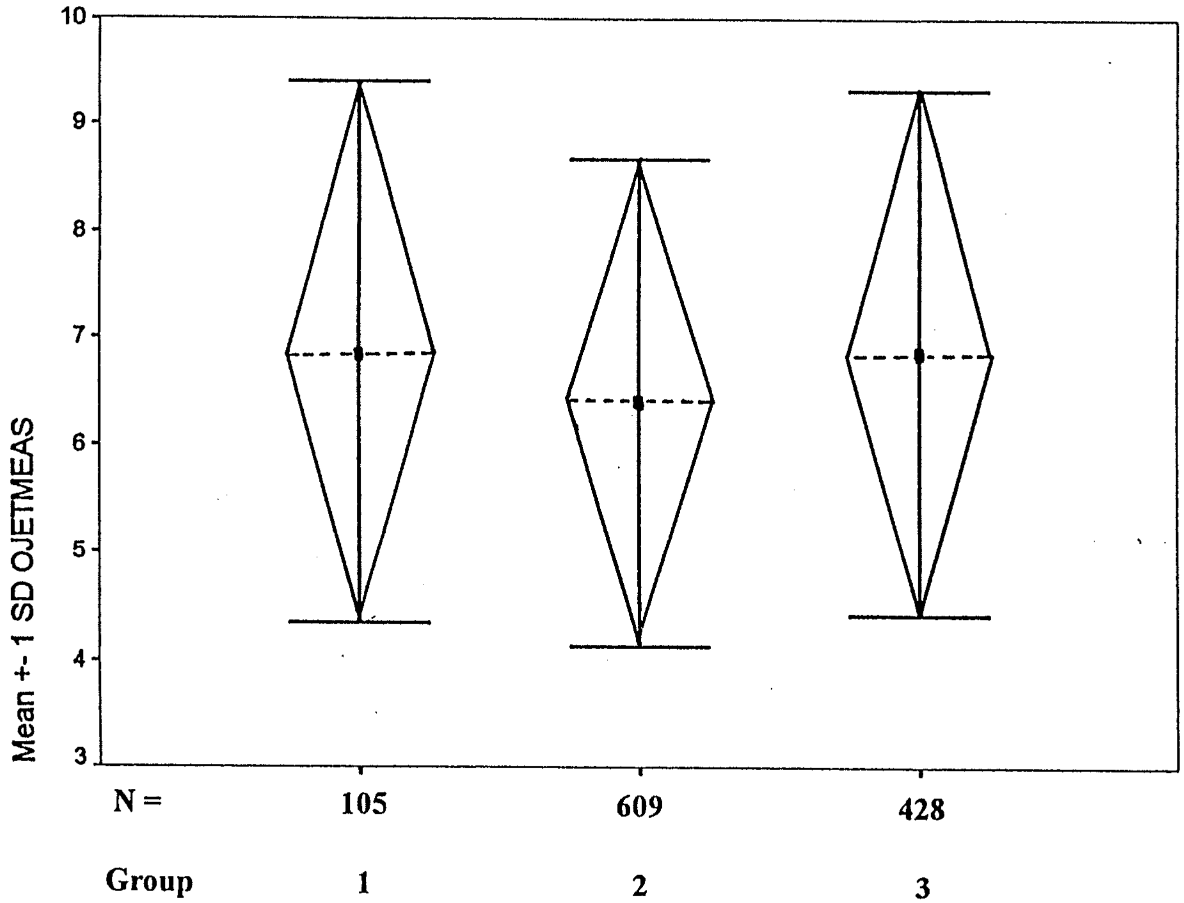


Figure 3.2 - DAI Overjet Measure ± 1 Standard Deviation
Group 1 = expert; Group 2 = auxiliary; Group 3 = GP's
N = Group variable measurements

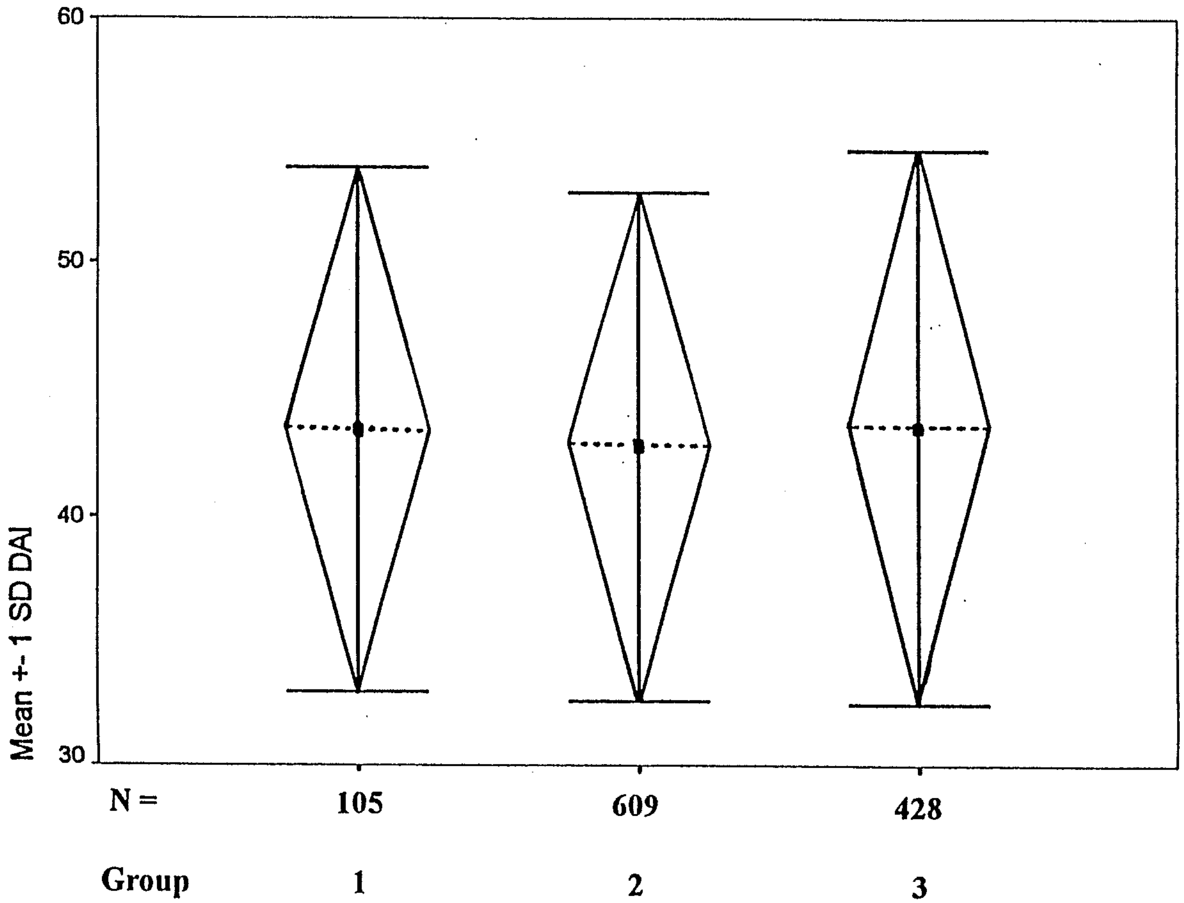


Figure 3.3 - DAI Pooled Group Mean ± 1 Standard Deviation
Group 1 = expert; Group 2 = auxiliary; Group 3 = GP's
N = Group variable measurements

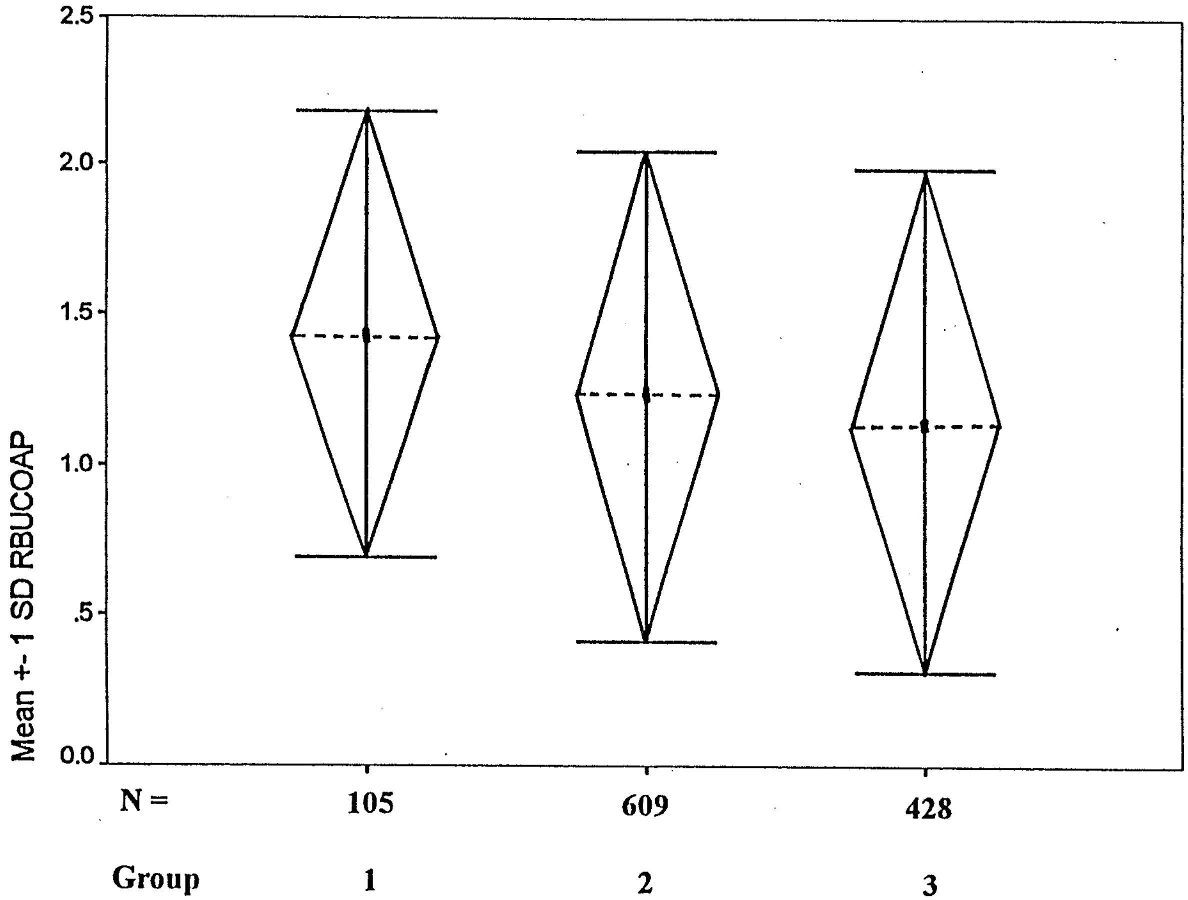


Figure 3.4 - PAR Buccal Occlusion ± 1 Standard Deviation
Group 1 = expert; Group 2 = auxiliary; Group 3 = GP's
N = Group variable measurements

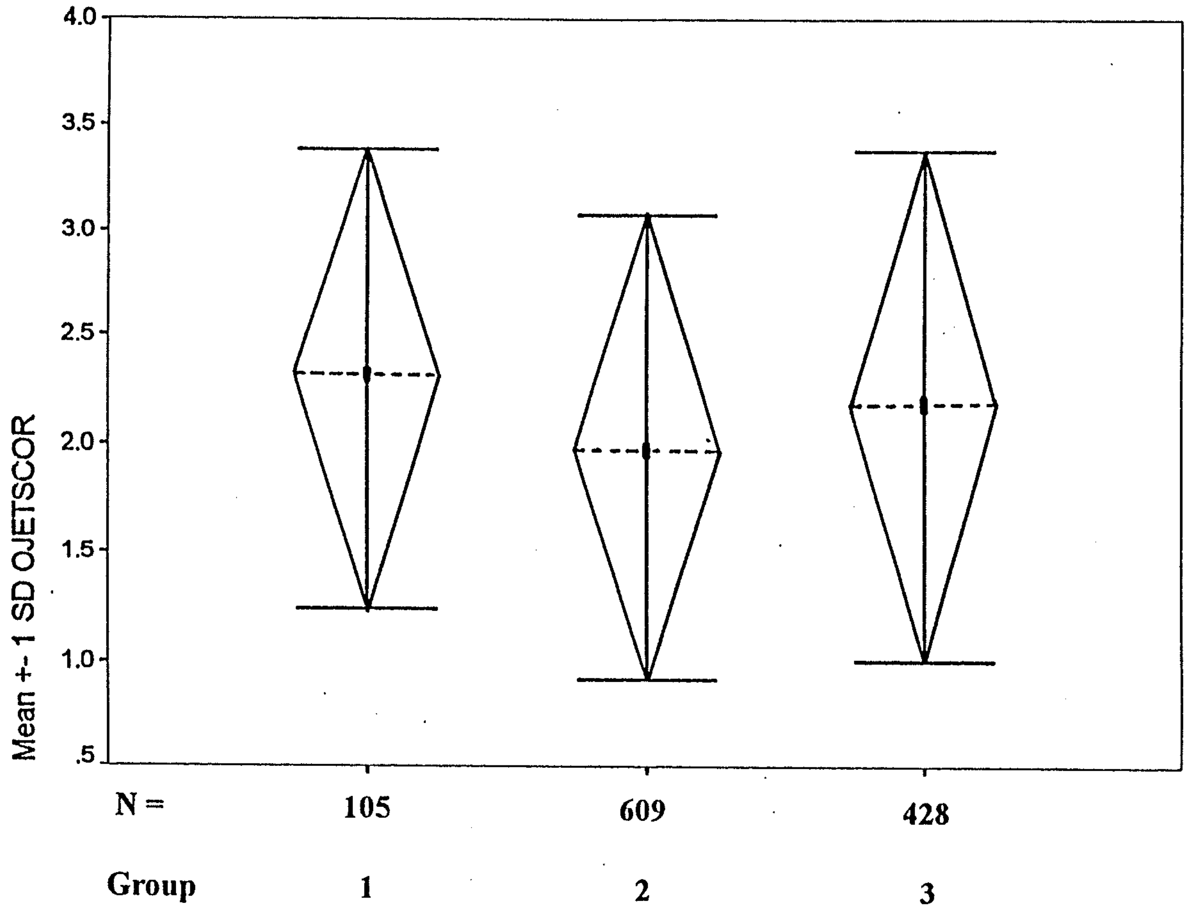


Figure 3.5 - PAR Overjet Score ± 1 Standard Deviation
Group 1 = expert; Group 2 = auxiliary; Group 3 = GP's
N = Group variable measurements

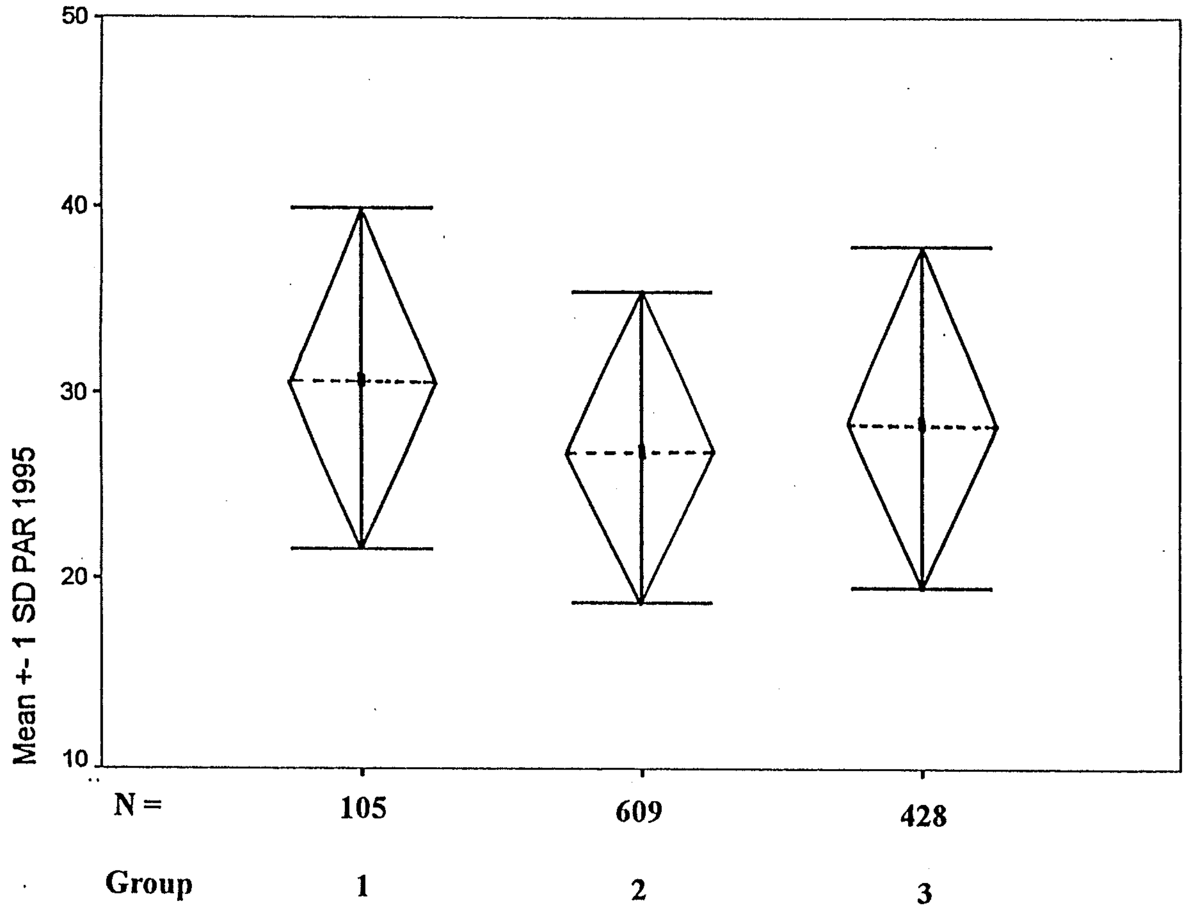
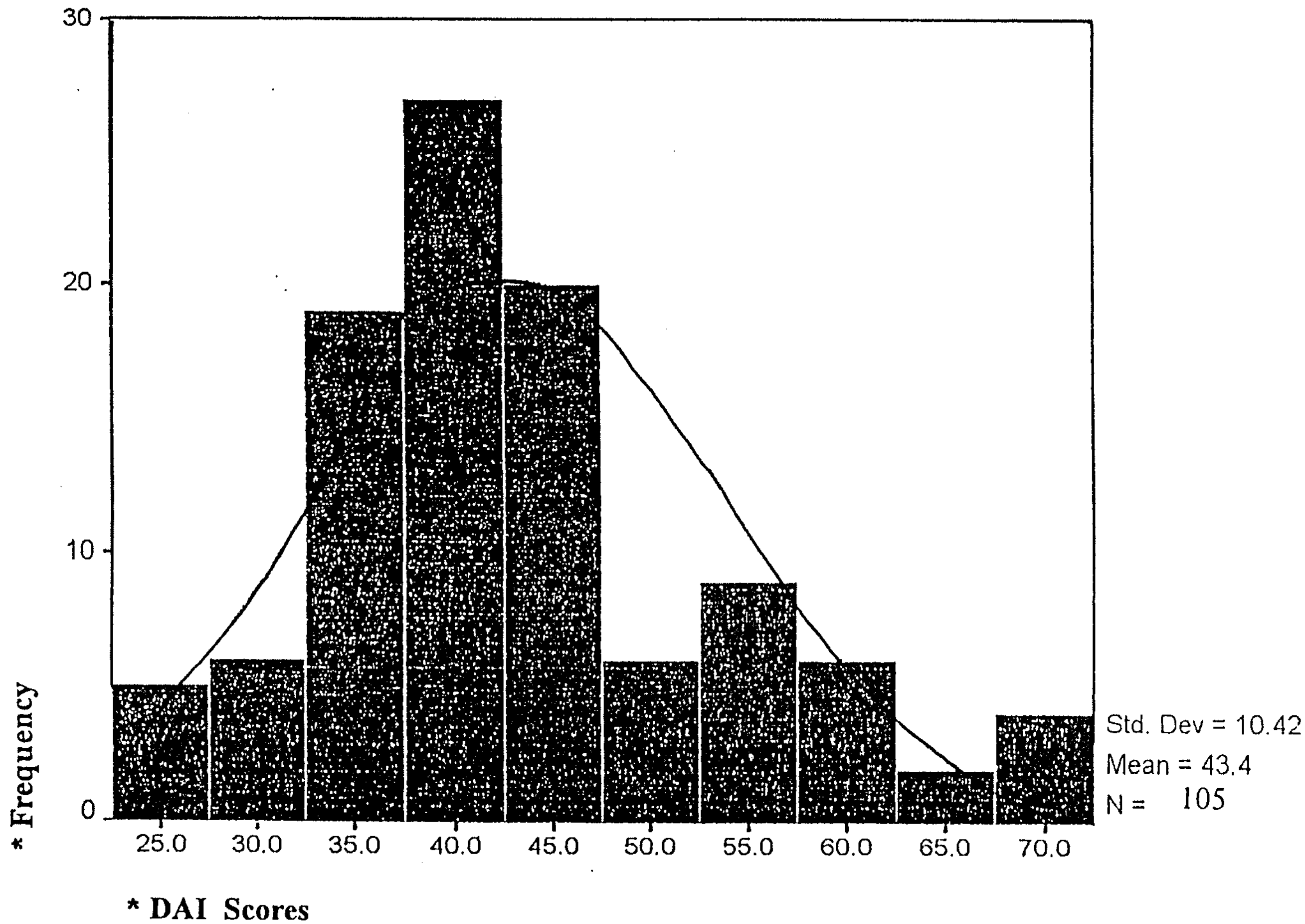
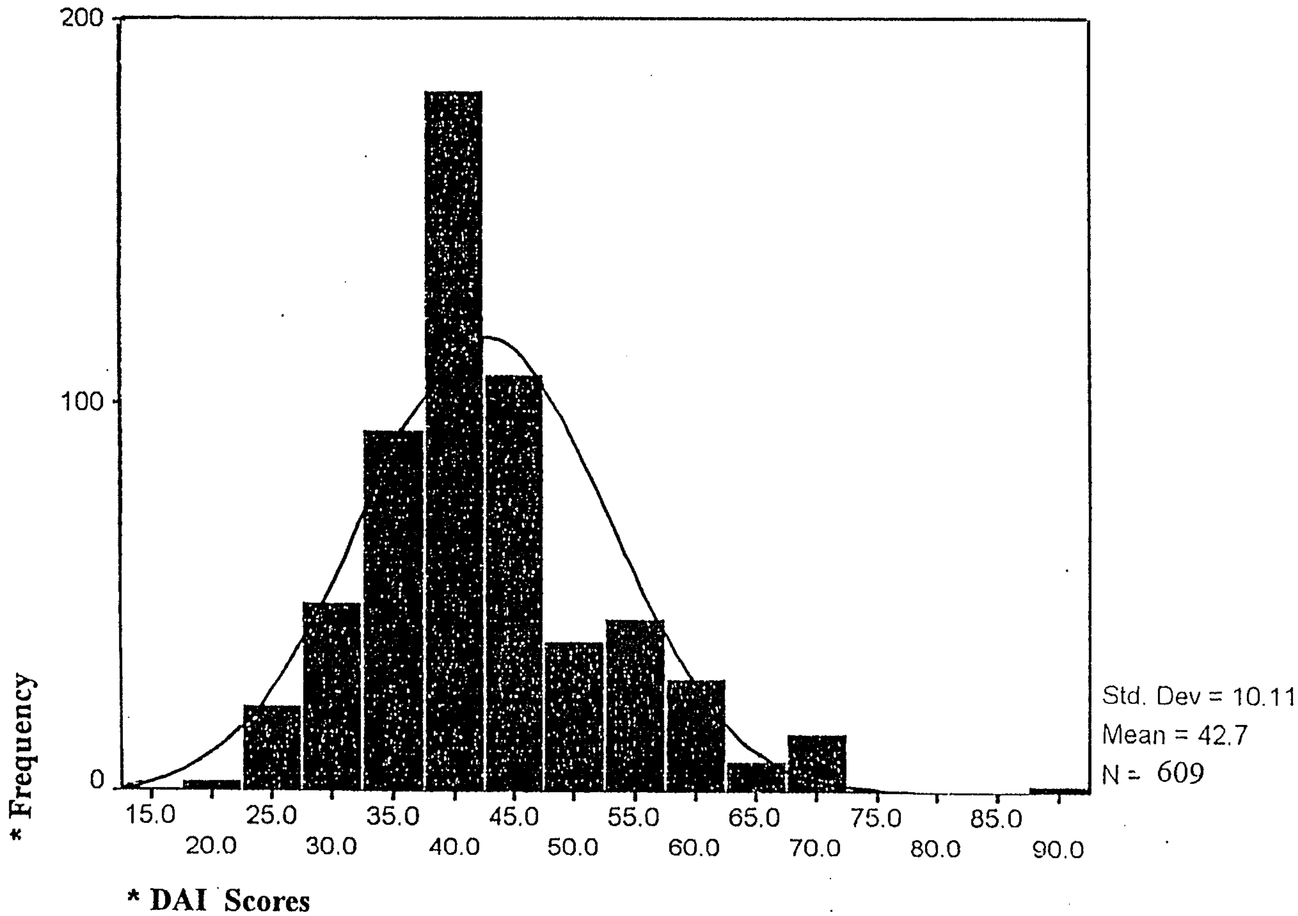


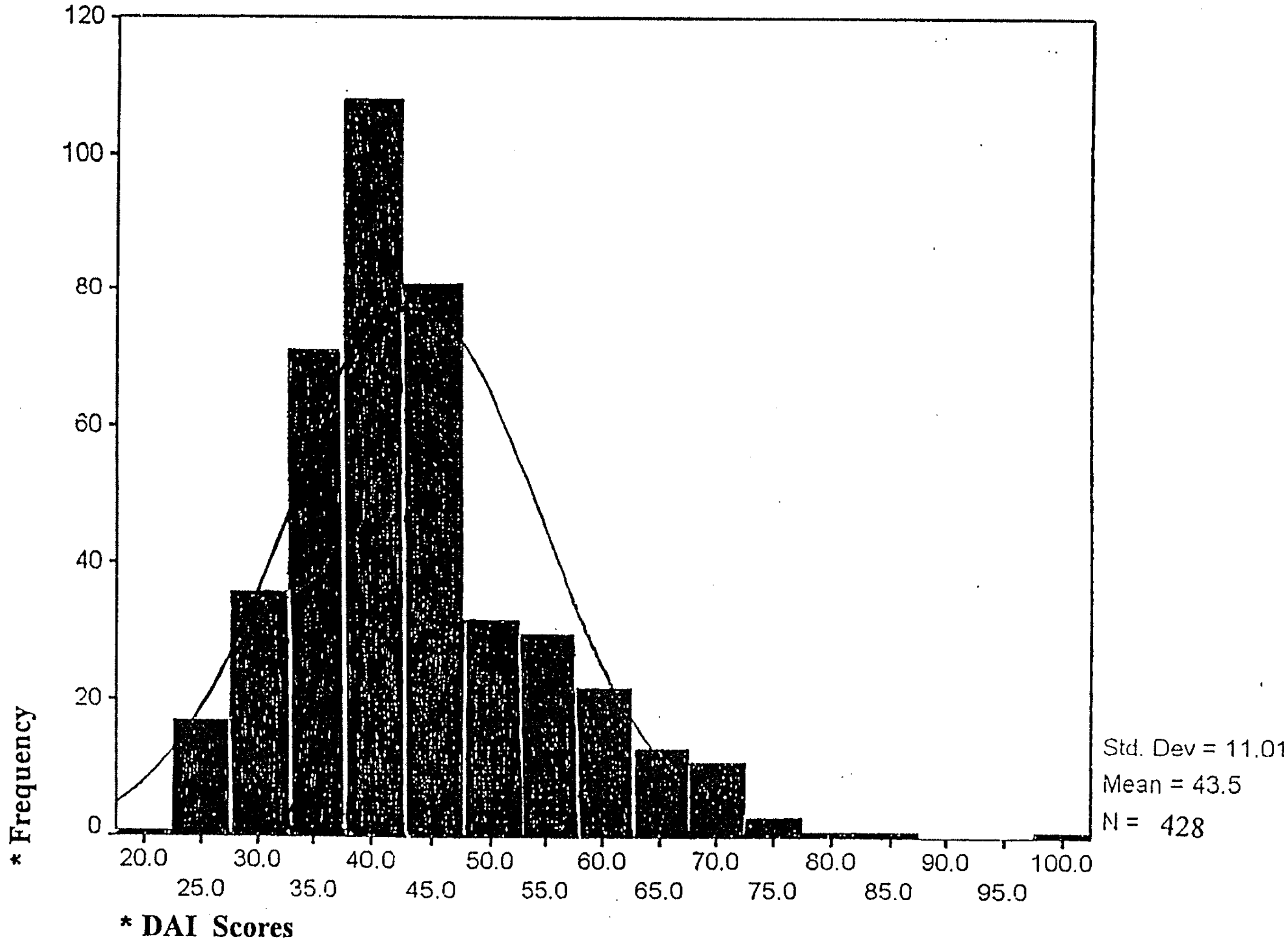
Figure 3.6 - PAR Pooled Group Mean ± 1 Standard Deviation
Group 1 = expert; Group 2 = auxiliary; Group 3 = GP's
N = Group variable measurements



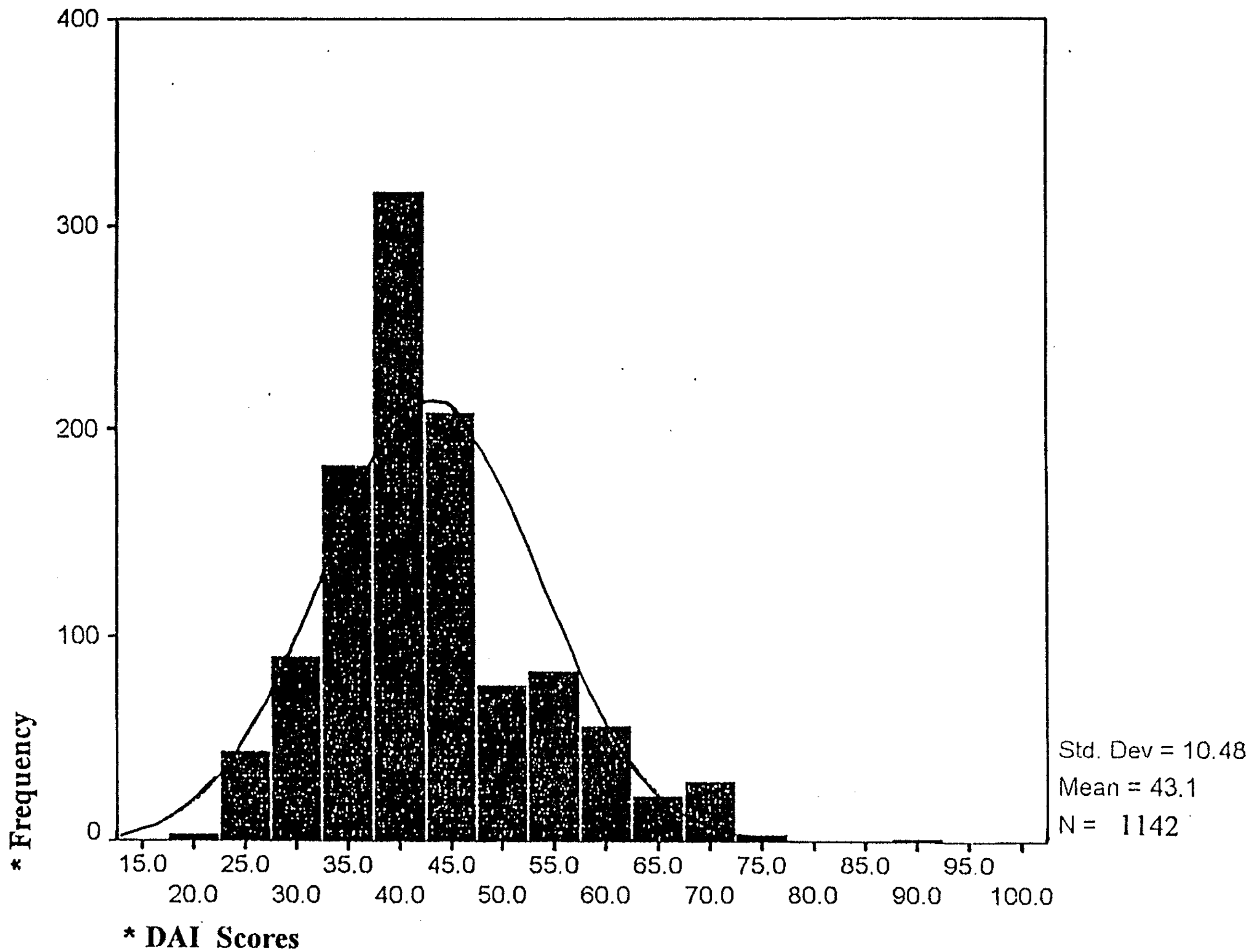
* **Figure 3.7** - Group 1 (expert) Total DAI Scores



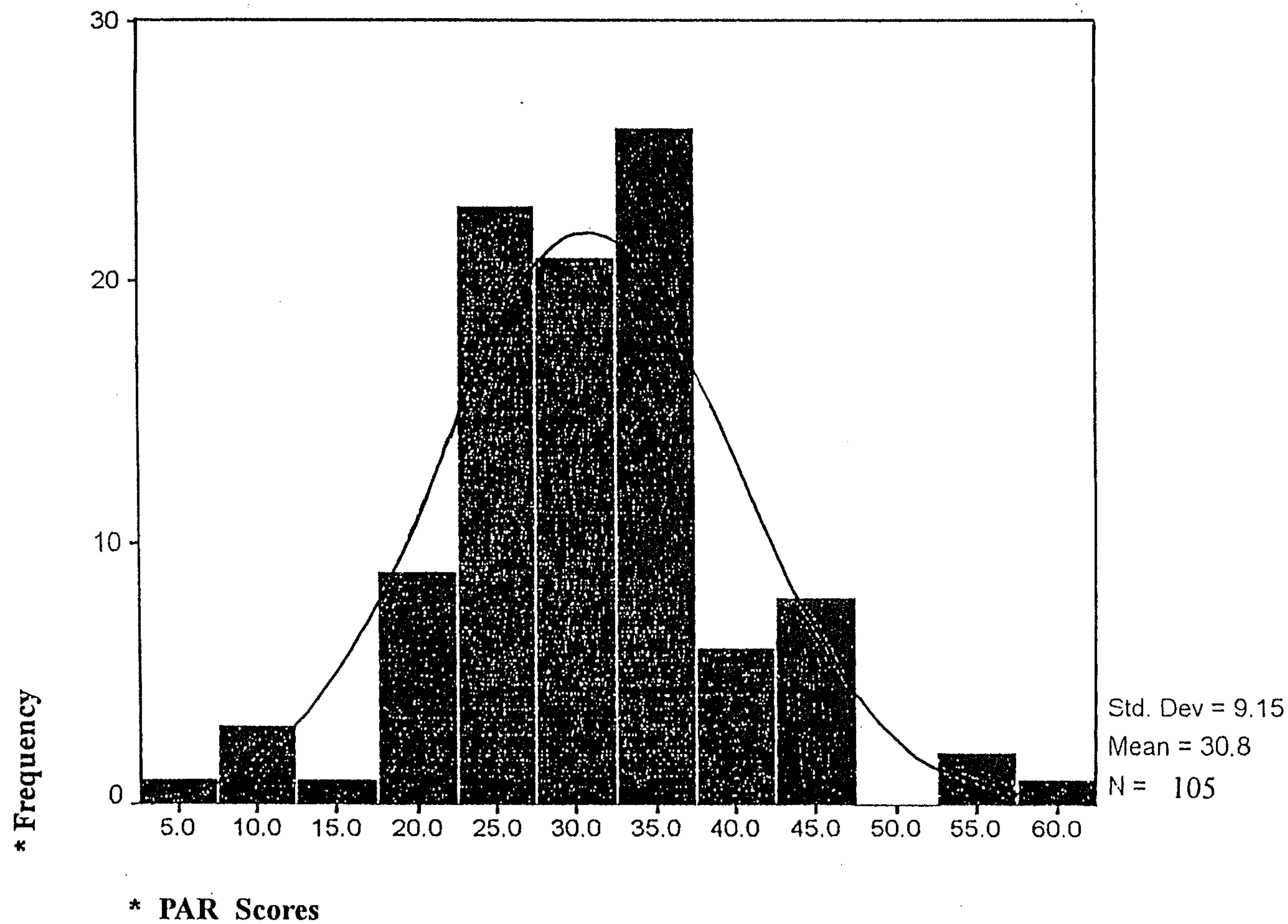
*** Figure 3.8** - Group 2 (auxiliary) Total DAI Scores



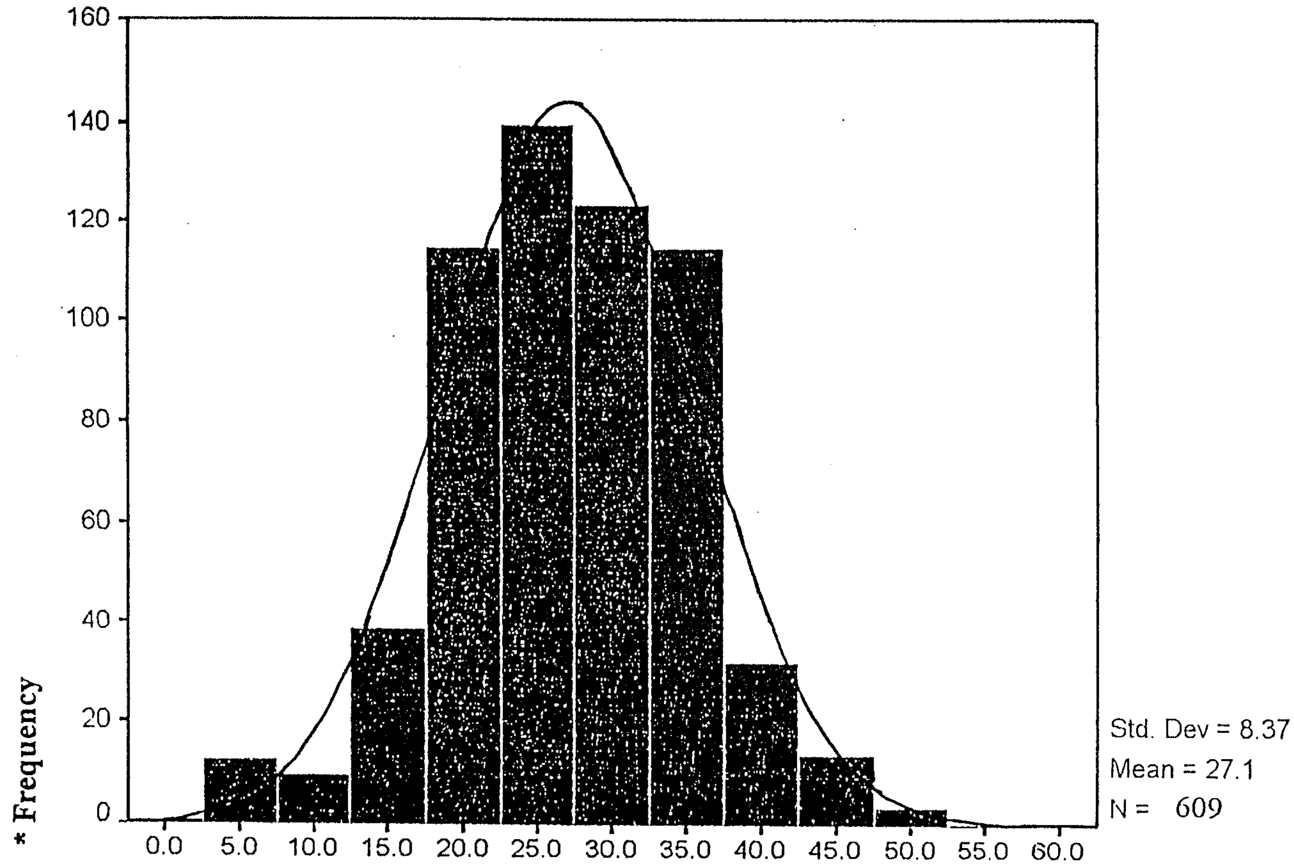
*** Figure 3.9** - Group 3 (GP's) Total DAI Scores



*** Figure 3.10 -** Pooled Group Total DAI Scores
Group = experts, auxiliaries, GP's

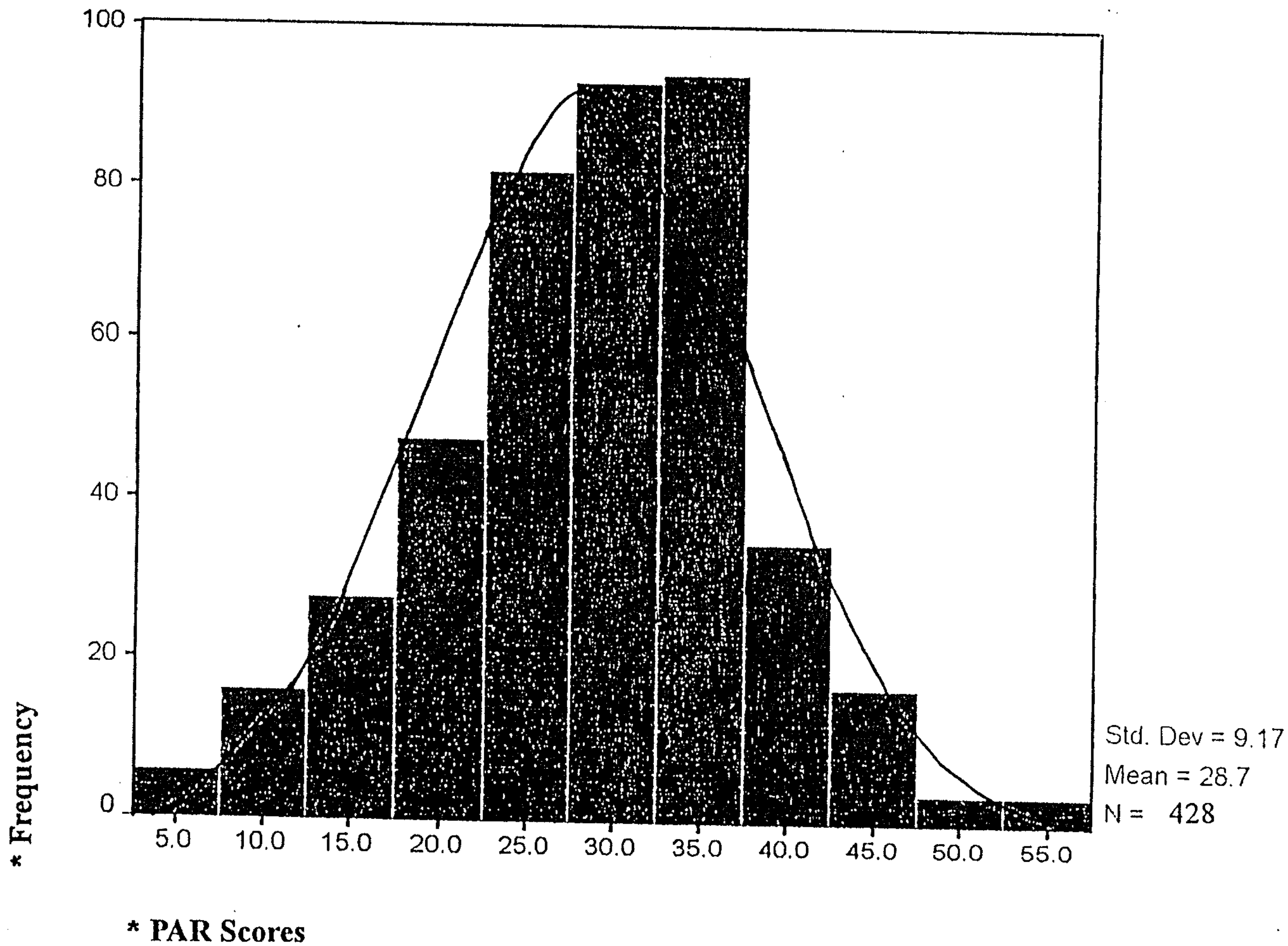


* **Figure 3.11** - Group 1 (expert) Total PAR Scores

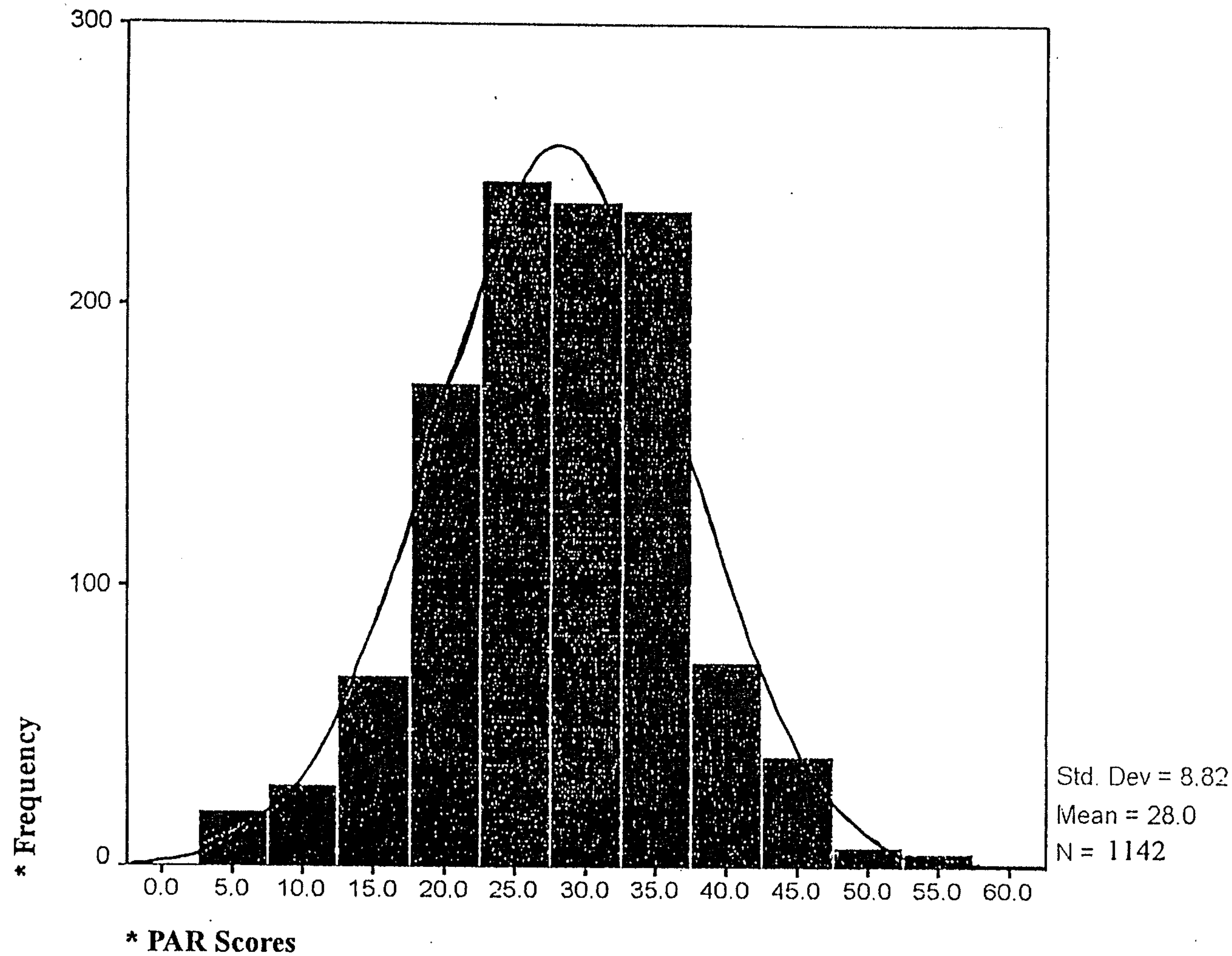


* **PAR Scores**

* **Figure 3.12** - Group 2 (auxiliary) Total PAR Scores



*** Figure 3.13** - Group 3 (GP's) Total PAR Scores



*** Figure 3.14** - Pooled Group Total PAR Scores
Group = experts, auxiliaries, GP's

Table 3.3 - Means, standard deviations and 95% confidence interval in brackets for DAI and PAR index scores
Group 1 = experts; Group 2 = auxiliaries; and Group 3 = GP's

	Means, Standard Deviations and (95% C.I.)		
	Group 1	**Group 2**	**Group 3**
PAR	30.8 ± 9.1 (28.9 - 32.6)	21.1 ± 8.4 (26.4 -28.0)	28.7 ± 9.1 (27.8 - 29.6)
DAI	43.4 ± 10.4 (41.5 -45.6)	42.7 ± 10.1 (41.9 - 43.6)	43.5 ± 11.1 (42.5 - 44.6)

No significant difference among the 3 Groups; p = > 0.001 for both the DAI and PAR index.

Table 3.5 - DAI Stepwise Multiple Regression Model
Dependent variable - DAI, malocclusion severity levels
Jenny and Cons (1993); Table 3.4.

Components of DAI	p value
missing teeth	0.0000 *
crowding	0.0000 *
spacing	0.0000 *
largest maxillary irregularity	0.0000 *
largest mandibular irregularity	0.0000 *
buccal occlusion	0.0000 *
over-jet measurement	0.0000 *
diastema	0.0002
open-bite measurement	0.0369

(R^2 = 0.56)
*** Components with significant influence on malocclusion severity.**

Table 3.6 - DAI Discriminant Function Analyses/Malocclusion Severity
Groups = mild, moderate, severe malocclusion
Jenny and Cons (1993); Table 3.4.
Variables = DAI components.

Components of DAI and step entered	Wilk's Lambda	p value
overjet measurement	.79	0.0000
buccal occlusion	.66	0.0000
largest anterior maxillary irregularity	.54	0.0000
missing teeth	.50	0.0000
crowding	.47	0.0000
largest anterior mandibular irregularity	.46	0.0000
spacing	.43	0.0000
diastema	.43	0.0000

Table 3.7 - DAI Classification Results for Group Membership
Group 1 = mild malocclusion
Group 2 = moderate malocclusion,
Group 3 = severe malocclusion
Cases = components of the DAI.

Actual Group	No. of Cases	Predicted Group Membership		
		1	2	3
1	23	10 45.5%	13 56.6%	0 0.0%
2	210	1 0.5%	160 76.2%	49 23.3%
3	896	0 0.0%	13 1.5%	883 98.5%

Percent of cases correctly classified: 93.27% (p < .05)

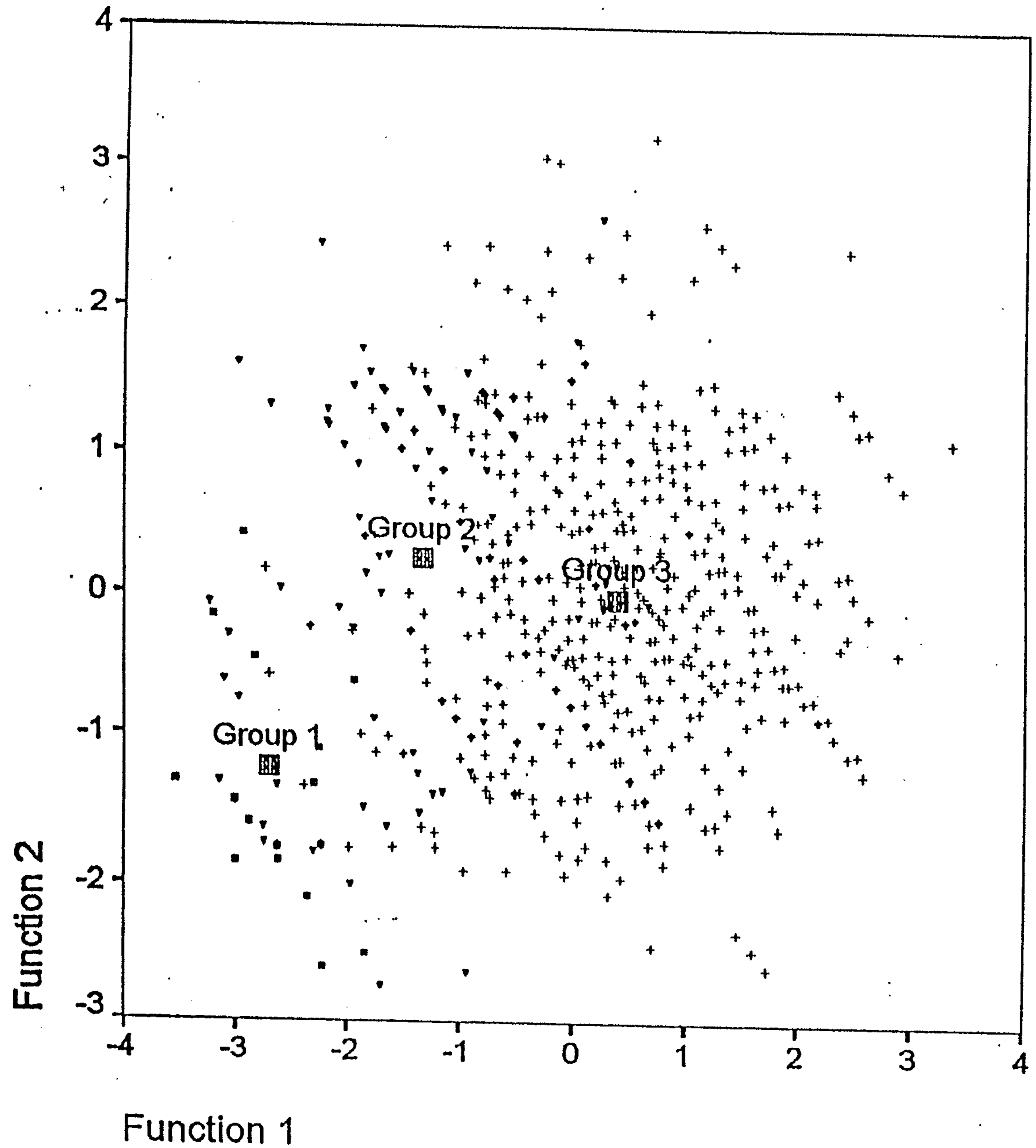


Figure 3.15 - DAI Index
Discriminant Function Analysis
Malocclusion Severity

■ Group 1 = mild malocclusion

▼ Group 2 = moderate malocclusion

\+ Group 3 = severe malocclusion

⊞ Group Centroids = means

Function = mathematical equation
for addition of index components

Table 3.8 - PAR Stepwise Multiple Regression Model
Dependent Variatble - DAI, malocclusion severity levels
Shaw *et al.* (1991); Table 3.4

Components of PAR	**p value**
upper anterior alignment	0.0000 *
overjet score	0.0000 *
overbite score	0.0000 *
midline	0.0000 *
buccal occlusion	0.0000 *
upper right alignment	0.0198
upper left alignment	0.0179
lower anterior alignment	0.2238
lower right alignment	0.4194
lower left alignment	0.4146

(R^2 = 0.57)
*** components with significant influence on malocclusion severity**

Table 3.9 - PAR Discriminant Function Analysis/Malocclusion Severity
Groups = mild, moderate, severe malocclusion
Shaw *et al.* (1991); Table 3.4
Variables = PAR components

Components of PAR and step entered	Wilk's Lambda	p value
overjet score	.79	0.0000
upper anterior alignment	.62	0.0000
buccal occlusion	.53	0.0000
overbite	.48	0.0000
centre-line	.45	0.0000

Table 3.10 - PAR Classification Results for Group Membership
Group 1 = mild malocclusion
Group 2 = moderate malocclusion;
Group 3 = severe malocclusion
Cases = components of the PAR index.

Actual Group	No. of Cases	Predicted Group Membership		
		1	2	3
1	40	35 87.5%	5 12.5%	0 0.0%
2	171	0.3 1.8%	146 85.4%	22 12.9%
3	925	0 0.0%	8 0.9%	917 99.1%

Percent of cases correctly classified: 96.65% ($p < .05$)

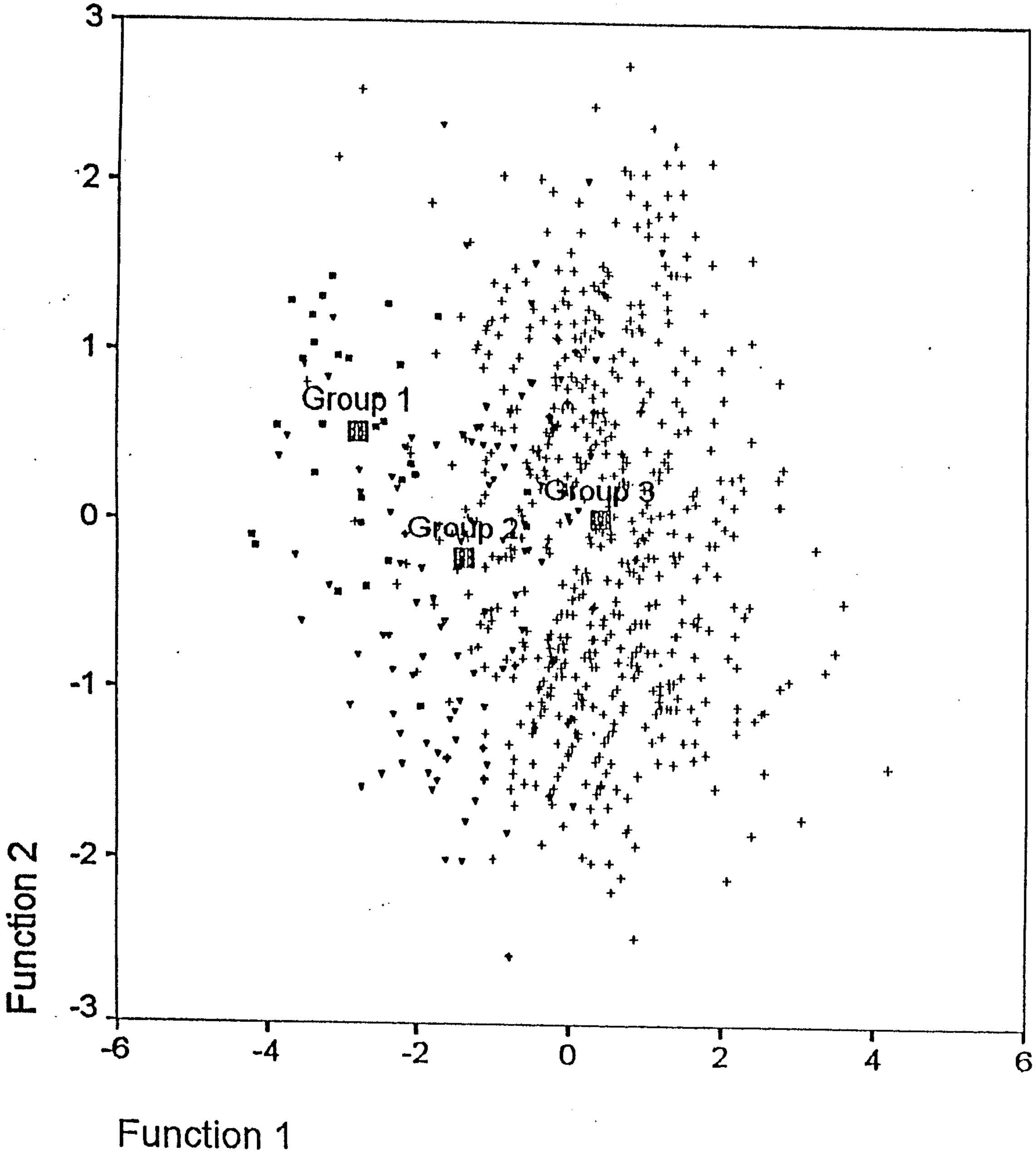


Figure 3.16 - PAR Index
Discriminant Function Analysis
Malocclusion Severity

■ Group 1 = mild malocclusion

▼ Group 2 = moderate malocclusion

+ Group 3 = severe malocclusion

⊡ Group Centroids = means

Function = mathematical equation
for addition of index components

Table 3.11 - Kappa values for "expert" examiners subjective assessment of treatment difficulty.

	Observer				
	1	2	3	4	5
Observer					
1	0.72	0.68	0.64	0.72	0.53
2		0.76	0.66	0.72	0.61
3			0.74	0.68	0.53
4				0.76	0.55
5					0.76

Table 3.12 - Interpretation of Kappa Values (Landis and Koch, 1977)

Agreement	Kappa Value
Poor	< 0.00
Slight	0.00 - 0.20
Fair	0.21 - 0.40
Moderate	0.41 - 0.60
Substantial	0.61 - 0.80
Almost Perfect	> 0.80

Table 3.13 - DAI Stepwise Multiple Regression Model
Dependent variable DAI
Treatment difficulty levels defined as easy, moderately difficult, and difficult.

Components of DAI	p value
missing teeth	0.0000 *
largest maxillary anterior irregularity	0.0000 *
buccal occlusion	0.0000 *
open bite	0.0000 *
spacing	0.0000 *
crowding	0.0000 *
overjet	0.0000 *
diastema	0.0000 *

(R^2 = 0.32)
*** Components with significant influence on treatment difficulty.**

Table 3.14 - DAI Discriminant Function Analysis/Treatment Difficulty
Groups = easy, moderately difficult, and difficult
Variables = DAI Components

DAI Components and step entered	Wilks Lambda	p value
buccal occlusion	.77	0.0000
missing teeth	.68	0.0000
largest anterior maxillary irregularity	.55	0.0000
spacing	.52	0.0000
open bite	.49	0.0000
overjet	.47	0.0000
crowding	.46	0.0000
diastema	.46	0.0000

Table 3.15 - DAI Classification Results for Treatment Difficulty
Group 1 = easy; Group 2 = moderately difficult; Group 3 = difficult
Cases = components of the DAI

Actual Group	No. of Cases	Predicted Group Membership		
		1	2	3
1	54	36 66.7%	17 31.5%	1 1.9%
2	710	9 1.3%	644 90.7%	57 8.0%
3	365	0 0.0%	110 30.1%	255 69.9%

Percent of cases correctly classified: 82.82% (p < .05)

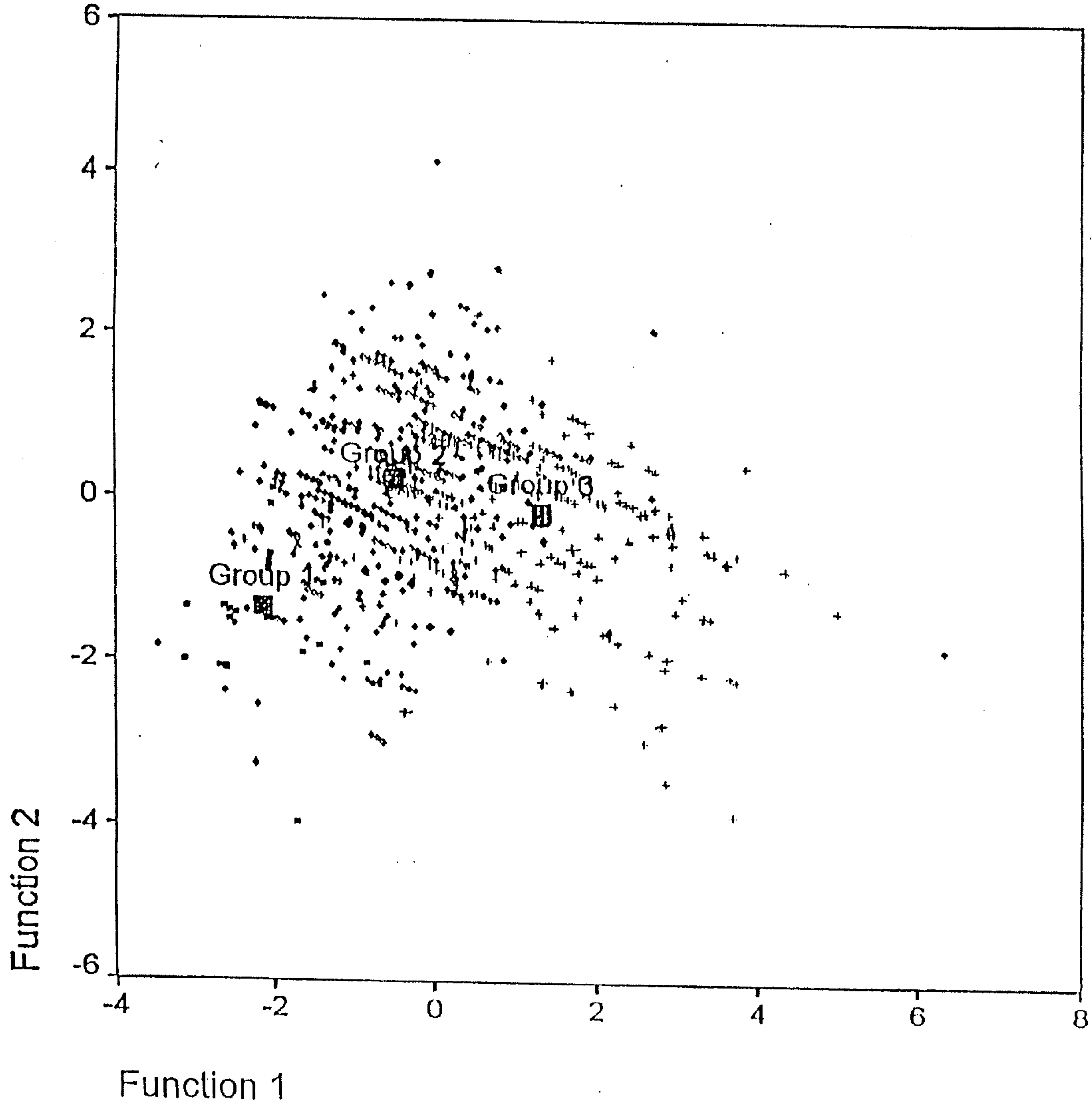


Figure 3.17 - DAI Index
Discriminant Function Analysis
Treatment Difficulty

■ **Group 1** = easy treatment

♦ **Group 2** = moderately difficult treatment

+ **Group 3** = difficult treatment

▩ **Group Centroids** = means

Function = mathematical equation stepwise addition of index components

Table 3.16 - PAR Stepwise Multiple Regression Model.
Dependent variable PAR
Treatment difficulty levels defined as easy, moderately difficult and difficult.

Components of PAR	p value
buccal occlusion	0.0000 *
upper anterior alignment	0.0000 *
centre-line	0.0000 *
overbite	0.0002 *
overjet	0.0092 *

(R^2 = 0.22)
*** Components with significant influence on treatment difficulty**

Table 3.17 - PAR Discriminant Function Analysis/Treatment Difficulty
Groups = easy, moderately difficult and difficult
Variables = PAR components

PAR components and step entered	Wilks Lambda	p value
buccal occlusion	.76	0.0000
upper anterior alignment	.73	0.0000
centre-line	.69	0.0000
overbite	.63	0.0000
overjet	.61	0.0000

Table 3.18 - PAR Classification Results for Treatment Difficulty
Group 1 = easy; Group 2 = moderately difficult; Group 3 = difficult
Cases = components of the PAR index.

Actual Group	No. of Cases	Predicted Group Membership		
		1	2	3
1	54	18 33.3%	34 63.0%	2 3.7%
2	718	1 0.1%	596 83.0%	121 16.9%
3	367	0 0.0%	179 48.8%	188 51.2%

Percent of cases correctly classified: 70.41% (p < .05)

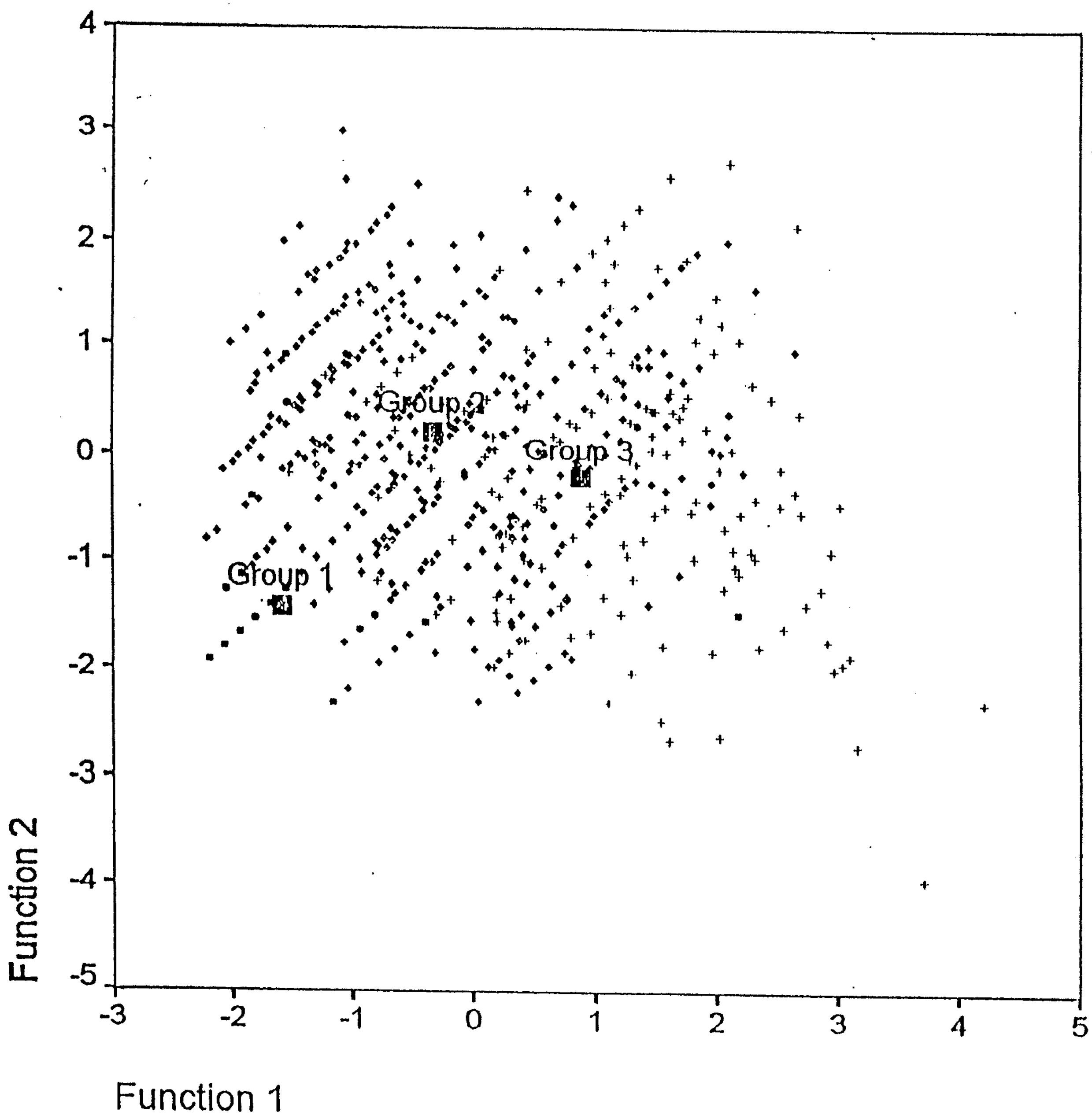


Figure 3.18 - PAR Index
Discriminant Function Analysis
Treatment Difficulty

■ **Group 1** = easy treatment

♦ **Group 2** = moderately difficult treatment

+ **Group 3** = difficult treatment

▣ **Group Centroids** = means

Function = mathematical equation stepwise addition of index components

Discussion

The numerous parameters within this study necessitate discussion of the null hypotheses under the following subsections:

- □ Examiner Groups
- □ Malocclusion Severity
- □ Treatment Difficulty

1. Examiner Groups

This section of the study was designed to test the ability of three Groups of examiners, with different levels of knowledge and expertise, to apply the DAI and PAR index measurement criteria to an Aboriginal sample of pre-treatment orthodontic casts. Following univariate and multivariate statistical analyses of results showed the first null hypothesis could not be rejected, i.e. there were no differences between examiner groups. The reproducibility of measurements for both indices were also considered satisfactory after statistical analyses of the replicated scores.

The use of indices to assess malocclusion is primarily intended to ensure interpretive uniformity (Helm, 1977a,b; So and Tang, 1993), although this will lead to limited advancement if they are unreliable (Shaw *et al.*, 1991). In this context reproducibility or reliability is defined as the ability of an index to reproduce the original scores when a subject is re-examined by the same or different examiners (Fleiss *et al.*, 1979). Such reliability is important, particularly if study cast evaluations are undertaken by two or more observers. Participating examiners must therefore be trained to provide consistent judgements (Richmond *et al.*, 1995a): (i) to reduce systematic bias or errors and (ii) to minimize variation between examiners (Newcombe, 1994). In this study, examiner training (standardization) prior to assessment of the casts minimized random error and variation, while monitoring (calibration) the examiners during the course of the survey served to minimize the potential impact of systematic errors.

Fleiss (1990) suggested certain examiners may require retraining or excluding to obtain consistency in evaluation. These concerns are not confined to orthodontics, for instance, Downer *et al.* (1979) found inter-examiner differences for decayed teeth exceeded the differences between the samples under study, whereas inter-examiner reliability for periodontal indices was even worse. Moreover, after training 22 dental officers, Mitropoulos and Downer (1987) found four in the group that failed to reach satisfactory agreement for scoring decayed surfaces. Even with retraining, Turner (1990) determined that some examiners cannot reach acceptable levels of standardization to assess malocclusions. Thus, it would seem likely that some examiners, despite their clinical qualifications, have difficulty learning to apply indices reliably. Some individuals in any group of examiners may also require extra training to calibrate consistently. While the auxiliaries (Group 2) required minimal extra review with dental terminology, teaching the index presented no particular problems. In the early stages, training the experts (Group 1) proved slightly more problematic as they tended to have differing preconceived ideas as to what and how malocclusion should be assessed, whereas the general dentists (Group 3) were more amenable to instruction. The results of the calibration exercise in this study indicate that all Groups could be trained to use both indices reliably, i.e. possession of an orthodontic qualification has no impact on the ability to score models.

Helm (1977a,b) questioned examiner reliability when subjective weightings were added to malocclusion assessments. In this study, statistical analyses on the unweighted individual variables of the DAI and PAR index showed that although some variation was present between the means for the Groups as no significant differences could be observed ($p > 0.05$). Similarly, differences exist between the total mean scores for the DAI and PAR index for the three Groups (Table 3.3 and Figures 3.1 - 3.6). However, multivariate analysis of variance showed no significant difference between the three groups ($p = 0.001$). Based on these analyses, the decision was made not to exclude any examiners. This is in agreement with Pipkin (1984) who wrote that "an isolated measurement which stands out...from the rest of the sample is known as an outlier and will...have an effect in small samples of grossly distorting the mean and variance. If the outlier is more than ± 5 x standard deviation away from the mean of the rest of the sample, then it is probably safe to exclude it...make [it] plain when you have done this, and be wary of doing it in small samples" (p.15). Based on this statement, one could argue that some evaluators should perhaps have been excluded, given the values observed in the tail positions of the histograms (Figures 3.7 to 3.14). However, several authors suggest caution when contemplating omitting data points from a statistical analysis because they "spoil" a pretty pattern (Pipkin, 1984; Glantz, 1992; Dawson-Saunders and

Trapp, 1994). In this study, these values were not attributed to clerical error, so therefore may have arisen due to an error of measurement or more likely, as has been suggested by some statisticians "for no apparent reason" (Begg, 1966; Jacobson, 1990).

Another trend in the data was the consistently lower scores of the auxiliaries, followed by the general dentists, with higher scores being assessed by the experts (orthodontists). This phenomenon has been noted by other researchers (Albino *et al.*, 1978; Richmond *et al.*, 1995a). One might speculate that the auxiliaries had too little knowledge or expertise to perceive some problems, whereas the experts may have over-compensated for some measurements...or more likely, become complacent and used subjective judgement as opposed to an objective measurement. For example, the auxiliary might have tended to err on the conservative side when measuring overjet or tooth displacement, while the expert tended to become less vigilant with time and "eye-ball" some measurements, resulting in over-estimation of scores. Nevertheless, the data indicate that in general, persons with varying levels of expertise are capable of applying occlusal indices with reasonable consistency and reliability.

It has been suggested that employing reliably trained and calibrated personnel to apply occlusal indices could have economic advantages for public funded programs and third party payment agencies (Neenan *et al.*, 1993). Richmond *et al.* (1993c, 1995a) have shown that it is possible to teach non-dentally trained personnel and general dentists to apply the PAR index with a high degree of reliability. Cons *et al.* (1986) have also determined that general dentists and dental assistants can, after training, measure the DAI reliably on study models. From its inception, the PAR index has proved to be a highly reproducible index when used by trained operators (Richmond, 1992a, b). Numerous studies have tested the reliability of operators when using the PAR index and have found, on average, intra-class correlation co-efficients (ICC) ranging from 0.83 to 0.98 (Fox, 1993; Kerr *et al.*, 1993; Buchanan *et al.*, 1993; Turbill *et al.*, 1994; Otuyemi and Jones, 1995; DeGuzman *et al.*, 1995). Fleiss (1990) has suggested that ICC values greater than 0.80 represent almost perfect agreement among the examiners. The DAI, although not tested extensively, has also proved to have satisfactory intra- and inter-examiner reliability (Jenny *et al.*, 1983; Keay *et al.*, 1993; Ansai *et al.*, 1993; Lobb *et al.*, 1994).

Both the DAI and PAR index are simple to use in the measurement of occlusal traits (Keay *et al.*, 1993). Concerns arose about the complexity of the PAR index with increased risk of measurement error (Bahiraei, 1995), although the results compare favourably with previous studies. These findings also contradict those of Turner (1990), who concluded that no index can be used consistently by personnel untrained or with limited experience in orthodontics.

2. Malocclusion Severity

The purpose of this study was also to investigate the abilities of the DAI and PAR index to quantify malocclusion severity. Essentially malocclusion severity was classified as mild, moderate or severe based on the scores defined by Jenny and Cons (1993) for the DAI and Shaw *et al.* (1991) and Richmond *et al.* (1993b) for the PAR index (Table 3.4). Moreover, when multiple regression and discriminant function analyses were applied to the data, the results of this study showed that the second null hypothesis must be rejected and the alternate hypothsis accepted, i.e. both the DAI and PAR index are able to distinguish various degrees of malocclusion severity.

A number of scoring systems and indices have been developed for the objective assessment of malocclusions (Draker, 1960; Grainger, 1967; Salzmann, 1968; Summers, 1971). Proffit and Ackerman (1973) have argued that without pertinent radiographic information, complex judgements are oversimplified. However, Han *et al.* (1991) have found that 54.9% of treatment decisions are based on study models alone, whereas Atchison *et al.* (1991) showed that orthodontists are 75% sure of their diagnosis before reviewing radiographs. DeGuzman *et al.* (1995) has also found that the addition of cephalometric radiographs do not alter expert diagnoses. Therefore, on the basis of the literature, no radiographs were included in this study.

Any index should reflect the characteristics of a given disorder (Summers, 1971). Therefore, malocclusion indices should therefore reflect the severity of the occlusion to determine the priority for treatment (Tang and Wei, 1993). Concerns about the validity of such measures primarily express the degree to which scores reflect the clinical judgements of orthodontists (Draker, 1970; Helm, 1977a,b). "Objective" indices may also introduce silent but pertinent subjective components which bias the data (Proffit and Ackerman, 1973).

The validity of an index is defined in terms of its ability to measure what it intends to measure (Summers, 1971). In clinical studies, validation is frequently established by soliciting the subjective opinion of knowledgeable "experts". Carlos (1970) has argued that this procedure is imperfect, because clinical decisions are based on the same information obtained from an index --- i.e. the two are not independent.

Draker (1970) also suggests that clinical judgement is not without problems, as "experts'" intrinsic criteria may form unknown variables which impact on clinical decisions. The prevalent climate of dental opinion may also influence judgement (Newcombe, 1994) and clinical decisions made by experts may vary considerably (McCreery and Truelove, 1991). Variations in decision making are a result of risk assessment and evaluating treatment outcomes, with differences essentially arising from perceptual variation and judgemental variation (Kay and Nuttall, 1995). Nevertheless, the criteria used by orthodontists to judge the need for treatment remain unclear (Phillips *et al.*, 1994). It is generally believed that treatment need determinations depend upon the recognition of aesthetic and occlusal variation as well as the beliefs and suppositions held with respect to implications of any variation noted (Prahl-Anderson *et al.*, 1979; Albino *et al.*, 1982; Tedesco *et al.*, 1983; Phillips *et al.*, 1994). Parents' and patients' awareness of orthodontic problems and agreement with orthodontic opinion are also major determinants (Espeland *et al.*, 1993; Peitilä and Peitilä, 1994; Tuominen *et al.*, 1994).

The long term implications of malocclusion are poorly understood (Shaw *et al.*, 1991), so it would be surprising if expert examiners were uniform in determining treatment need, since no firm diagnostic criteria are established. In practice, dentists and orthodontists exercise professional judgement. A number of studies indicate such judgement is inconsistent between examiners (Freer *et al.*, 1973; Bowden and Davies, 1975; O'Brien *et al.*, 1989; Richmond, 1992a; Richmond *et al.*, 1995a). However, other investigations have presented evidence to suggest subjective (expert) opinion of the severity of malocclusion correlates closely with objective indices (Lewis *et al.*, 1982;

Shaw *et al.*, 1991; Richmond *et al.*, 1992a; Jenny *et al.*, 1992; Turbill *et al.*, 1994; Younis *et al.*, 1995; DeGuzman *et al.*, 1995).

Considering the restrictions of third-party funding for orthodontics, an equitable system of prioritizing cases is desirable. Shaw *et al.* (1995) feel that the specialty itself should develop the guidelines or index because until one is accepted and used by the profession, distortions of the need and demand for orthodontic treatment will continue (Richmond *et al.*, 1994a). Any index of malocclusion severity and treatment need should, however, be related to the consensus view of clinicians, i.e. the DAI and PAR index (Jenny *et al.*, 1993; Richmond *et al.*, 1995b). Although it was not the intent of this study to investigate the validity of the DAI or PAR index with respect to orthodontic opinion, the criticisms require further elaboration.

For an index to be truly effective, malocclusions must be categorized into groups, according to urgency and need for treatment (Salzmann, 1969; Baume *et al.*, 1973). Individuals with greatest treatment need can then be assigned priority when resources are limited. Similarly, individuals with minimal treatment need can be safeguarded from potential risks (Shaw, 1981). Jenny and Cons (1993) as well as Shaw *et al.* (1991) and Richmond *et al.* (1993b) developed "cut-off" scores in the DAI and PAR index (respectively) which would determine various levels of malocclusion severity for treatment allocation. Based upon this literature, the pooled data from this study was classified and divided into three malocclusion Groups, i.e. mild, moderate or severe (Table 3.4).

Following multiple regression analyses, results for both the DAI and PAR index identified those components having significant correlation and influence on malocclusion severity (Tables 3.5 and 3.8). These outcome analyses compare favourably with previous studies (Cons *et al.*, 1986; Jenny and Cons, 1988; Richmond *et al.*, 1992a; DeGuzman *et al.*, 1995). The fact that diastema and open-bite, components of the DAI, were not identified as having significant influence on malocclusion severity was likely due to the sample selection, i.e. few subjects were identified as having these characteristics. Similarly, upper and lower buccal alignment as well as lower anterior alignment, components of the PAR index, had no significant influence on malocclusion severity. This phenomena has been noted by other investigators (Brook and Shaw, 1989; Richmond *et al.*, 1992a). Several studies have found that demand for orthodontic treatment stems largely from visible aesthetic concerns (Stricker *et al.*, 1979; Espeland and Stenvik, 1991; Espeland *et al.*, 1993). This could suggest that posterior buccal alignment and lower anteriors have little aesthetic value and therefore do no necessarily influence malocclusion severity. Of note is that 56% and 57% of the variation determining malocclusion severity levels is explained by the DAI and PAR index components. Slightly less than half the variation is unexplained, due to perceptual differences of the examiners --- or as has been suggested, several factors remain unidentified which are required to predict malocclusion severity levels (DeGuzman *et al.*, 1995).

Examination of the discriminant function analyses confirm the regression analyses results, as well as indicating which components of the DAI and PAR index are best able to discriminate malocclusion severity and their priority (Table 3.6 and 3.9). The component overjet was entered first for both indices. This is in agreement with several investigators who found that extreme overjet had the greatest effect on dental appearance (Helm *et al.*, 1986; Gosney, 1986; Graber and Lucker, 1980). This was followed by the addition of buccal occlusion and maxillary anterior irregularity, for both indices. Horowitz *et al.* (1971) as well as Ingervall and Hedegard (1974) found that conspicuous crowding and irregular alignment affected perceptions of dental appearance in adolescents. Although no evidence exists in the literature, buccal relationships may affect malocclusion severity due to the influence of mandibular position on overjet and facial features.

Discriminant function analyses determine which components of the indices best discriminate among mild, moderate and severe malocclusions. The classification analyses confirms/checks the "goodness" of the discriminant functions (Norman and Streiner, 1986). The results indicate that overall 93% of the DAI cases and 97% of the PAR cases are correctly classified into the mild, moderate or severe malocclusion categories. However, while the PAR index correctly predicted the individual malocclusion levels 90% of the time, the DAI incorrectly predicted mild malocclusions in 56% of the cases (Tables 3.7 and 3.10). This has implications for publicly funded programs in that mild malocclusions may be classified as moderate, thereby increasing demand and depleting resources. This is in agreement with Keay *et al.* (1993) who found that the DAI correctly predicts a high proportion of those cases requiring treatment (86%), but overestimates the numbers requiring treatment (54%). The fact that the DAI heavily weights maxillary anterior irregularities may result in the index being overly sensitive to minor displacements of individual teeth --- a fact which requires further investigation.

Based on the present study, the DAI and PAR index are likely to include nearly all of those cases requiring treatment, but at the cost of over-estimation for the DAI assessment. If malocclusion indices are to be used to determine orthodontic treatment allocation, the inherent error of the measurement should be considered. When the direction of the error is evaluated for the DAI, it is in allocating treatment to those cases who may not require treatment. In the presence of reduced fianances, the over-estimation of malocclusion severity may rapidly deplete resources. More importantly, reliance on the DAI and PAR index, may deny orthodontic treatment to patients truly in need.

3. Treatment Difficulty

The last part of this study was designed to investigate the ability of the DAI and PAR index to determine treatment realtive to malocclusion severity. But, following multiple regression, discriminant function and classification analyses, the results showed that the third null hypothesis could not be rejected, i.e. both the DAI and PAR index are unable to distinguish treatment difficulty.

As the cost of health and dental services continues to rise, it becomes increasingly important to develop significant barometers to determine the adequacy of the health care system (Furino and Douglas, 1990; Caplan and Weintraub, 1993). The ability of an index to reflect treatment difficulty is therefore an important requirement for decisions made regarding public or third party allocations to reimburse orthodontic care. Arguably, fees should be assigned to reflect the complexity of treatment (Vig *et al.*,

1995) and assist in ensuring that patients are treated by those with appropriate levels of skill.

The degree of treatment difficulty arises from a problem solving process which determines the best and least laborious form of orthodontic treatment. Difficulty may also influence effectiveness of treatment modalities, duration of treatment and expected outcome. Without doubt, difficulty is an important determinant of referral to tertiary care providers relative to third-party financial restrictions.

The DAI and PAR index have primarily been used to assess malocclusion severity. Few studies have investigated the relationship of malocclusion severity to treatment difficulty. Rowe (1989) evaluated the relationship between malocclusion severity and treatment difficulty after 30 orthodontists examined six pre-treatment casts. Summers' Occlusal Index was used to measure severity while difficulty was assessed with subjective expert opinion. Malocclusion severity and treatment difficulty were regarded as distinct but related entities, although the components of malocclusion severity (overjet, tooth irregularities, etc.) were not reliable predictors of treatment difficulty. In contrast, DeGuzman *et al.* (1995) found that malocclusion severity assessed by the PAR index, displayed a strong association with perceived treatment difficulty. Moreover, five components of malocclusion ranked in order of importance (overjet, overbite, midline, upper anterior alignment and buccal occlusion) explained 57% of the variation in the determination of treatment difficulty .

The results of the current study, however, suggest that severity of malocclusion measured by both the DAI and PAR index display relatively weak correlations with perceived treatment difficulty. Examination of the multiple regression analyses indicate that the same components which determined malocclusion severity also significantly influence treatment difficulty. However, only 32% of the variation is explained by the DAI components and only 22% of the variation in the ranking of treatment difficulty is explained by the PAR components (Tables 3.13 and 3.16). The results of the discriminant function analyses confirm that these components are significant discriminators of treatment difficulty (Tables 3.14 and 3.17). However, their relative importance as discriminators has slight resemblance to the malocclusion severity discriminators. 'Overjet', in both indices, was the first discriminator for malocclusion severity, whereas 'buccal occlusion' was the major discriminator, in both indices for treatment difficulty. The 'overjet' variable, however, was one of the last predictors to be added into the analyses. The disparity between these two studies is difficult to explain, even taking into account the different statistical analyses. Nevertheless, several dissimilarities may explain the contradictory findings:

(i) sample size - DeGuzman *et al.* (1993) used 200 pre-treatment casts representing a wide range of malocclusions. The current study was based on a representative sample of 21 casts presenting with a Class II Division I malocclusion. This obviously resulted in a bias toward increasing the numbers/weighting of the buccal occlusion component for both indices.

(ii) examiners - DeGuzman *et al.* (1993) had two calibrated examiners determine the PAR scores and 11 orthodontists give subjective opinions on treatment difficulty. The present study had 51 examiners determine both DAI and PAR scores and 5 orthodontists give subjective opinions on treatment difficulty. Fewer examiners may have resulted in less variability of the index scores and therefore a greater correlation between the index components for treatment difficulty and malocclusion severity.

However, the results of the current study indicate that although components of malocclusion severity are related to treatment difficulty, the factors do not necessarily have the same importance as discriminators for treatment difficulty. These findings contrast with those of DeGuzman *et al.* (1995), but compare favourably with the findings of Rowe (1989).

The results from the classification analysis confirm the inconsistency of both indices, particularly the PAR index, to predict treatment difficulty (Tables 3.15, 3.18). Although the PAR index correctly classifies 70% of the casts with respect to treatment difficulty, 66% of easy cases are classified as moderately difficult or difficult. The PAR index also tends to underestimate the number of difficult cases by approximately 50%. This has serious implications, if difficulty indices are used to reflect remuneration levels. In addition, even though components of both indices significantly influence treatment difficulty, they only account for a small percent of the variation. Indices must therefore ignore certain facets of malocclusion which orthodontists use to assess treatment difficulty.

Some of the factors which influence the perception of orthodontic treatment difficulty may be summarized as:

(i) operator related factors - knowledge, expertise and years of experience (O'Brien *et al.,* 1993)

(ii) patient related factors - age, sex, growth patterns, medical problems, skeletal and soft tissue discrepancies (Weiss and Eiser, 1977)

(iii) treatment modalities - non-extraction/extraction, removable/fixed, non-surgical/surgical (Howes, 1960; Bishara *et al.,* 1995)

(iv) co-operation factors - patients/parents beliefs, attitudes, expectations (Nanda and Kieri, 1992)

In contrast with the inability of the DAI and PAR indices to determine treatment difficulty, results of this study indicate moderate to substantial agreement for subjective opinion of the "experts" (Table 3.11 and 3.12). This is in agreement with Pietilä *et al.* (1992) who found orthodontists generally agreed on the complexity of orthodontic cases. In contrast, there was substantial disagreement between general dentists for those cases which orthodontists classified as having difficult treatment problems. This finding is in accord with the study by Persson and Thilander (1976) who concluded that general dentists overestimate their skills in orthodontics, compared with orthodontists' evaluation of their own skills. Foster and Menezez (1976) also suggest that "experts" should assess the difficulty of treatment and several others have stressed the importance of diagnostic skills for the recognition of difficult cases (Linge, 1987; Jacobs, 1988). The development of an index to adequately assess treatment difficulty would therefore provide an excellent service for both patient and practitioner, as it could be used for determination of treatment where various care-givers have different levels of expertise.

Currently, neither the DAI nor PAR index is able to determine treatment difficulty with any great degree of reliability or validity as evidenced by this study. Further proof is offered by examining individual cases used in this study. Although the consensus "expert" opinion was not limited to the following, these cases provide a representative sample (Figures 4.1 - 4.4):

Case No. 22A

Expert opinion on treatment difficulty was **easy**
Mean DAI score = 34
Mean PAR score = 21

Case No. 7A

Expert opinion on treatment difficulty was **moderately difficult**
Mean DAI score = 24
Mean PAR score = 34

Case No. 19A

Expert opinion on treatment difficulty was **difficult**
Mean DAI score = 54
Mean PAR score = 51

Case No. 20A

Expert opinion on treatment difficulty was **moderately difficult**
Mean DAI score = 23
Mean PAR score = 11

Most notable among these cases is the fact that although two cases (7A and 19A) appear to coincide with DAI and PAR malocclusion severity scores, whereas Cases 20A and 22A do not. Case 20A, a moderately difficult case to treat, based on "expert" orthodontic opinion, has been given significantly lower DAI and PAR scores than Case 22A which was assessed as easily treatable. Without modification, the DAI and PAR index are unable to consistently determine treatment difficulty.

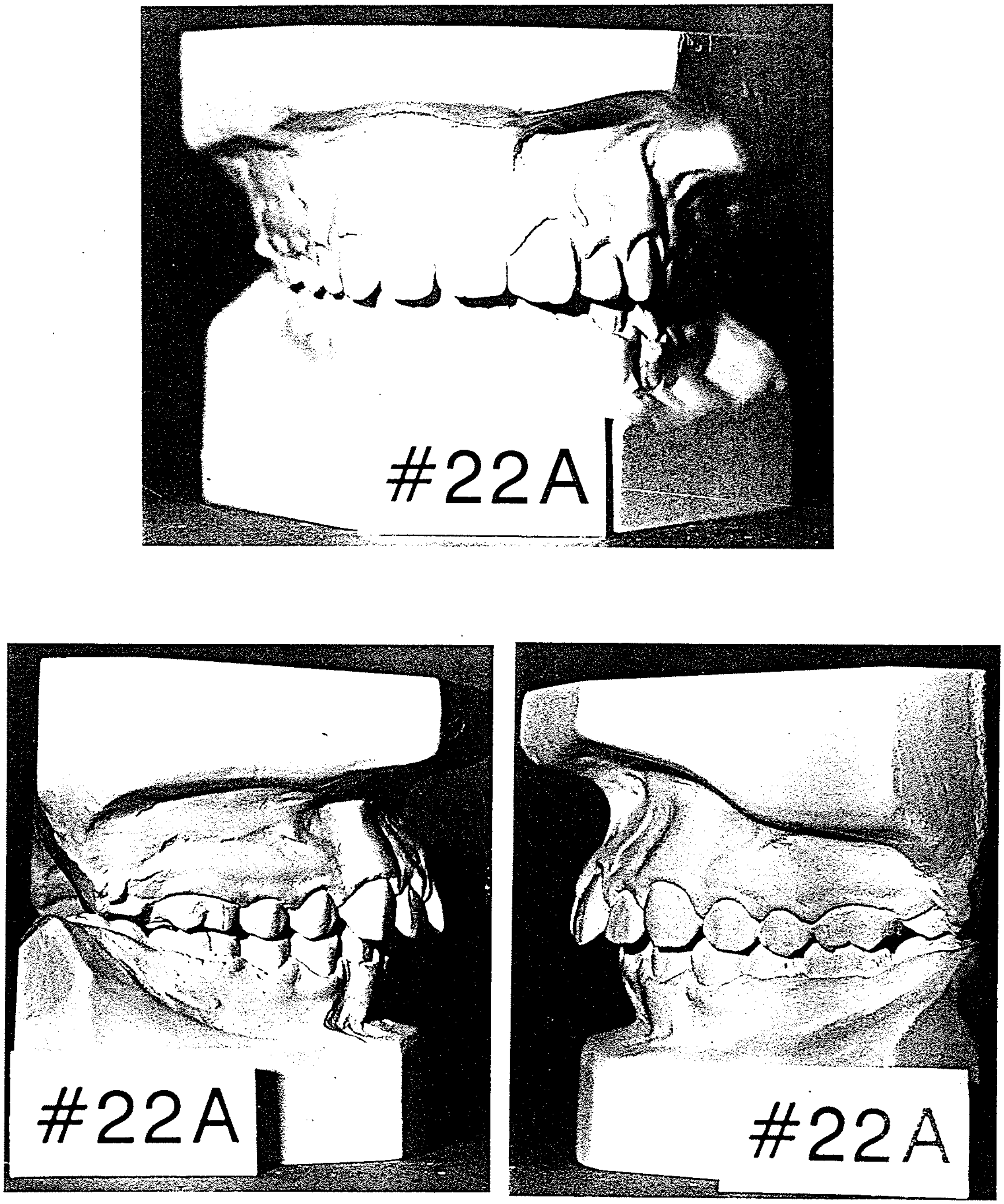


Figure 4.1 - **Case No. 22 A**

Consensus expert opinion on treatment difficulty was easy
DAI score = 34; moderate bordering on severe malocclusion
PAR score = 21; moderate malocclusion

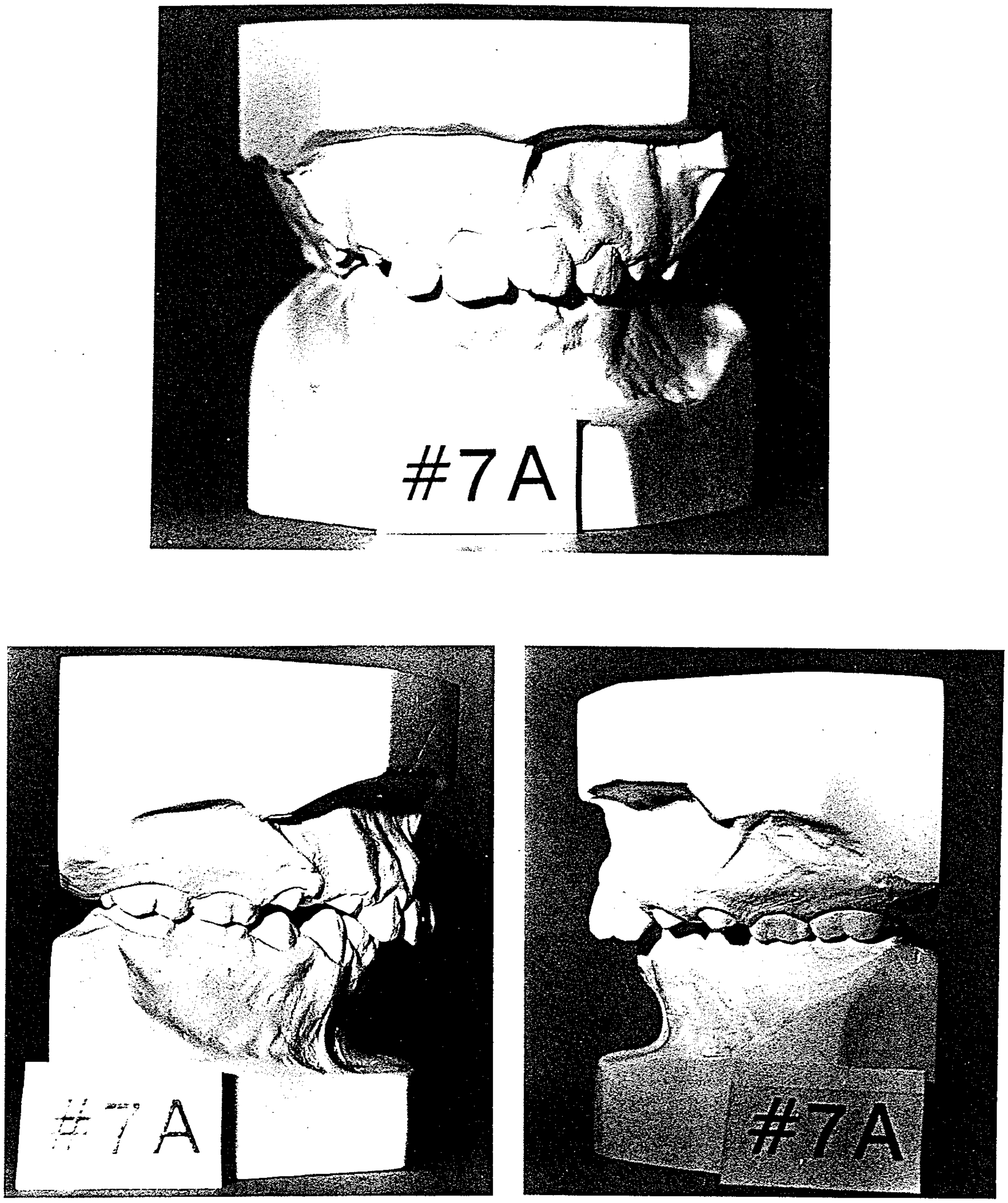


Figure 4.2 -Case No. 7 A

Consensus expert opinion on treatment difficulty was moderately difficult
DAI score = 24; moderate malocclusion
PAR score = 34; moderate bordering on severe malocclusion

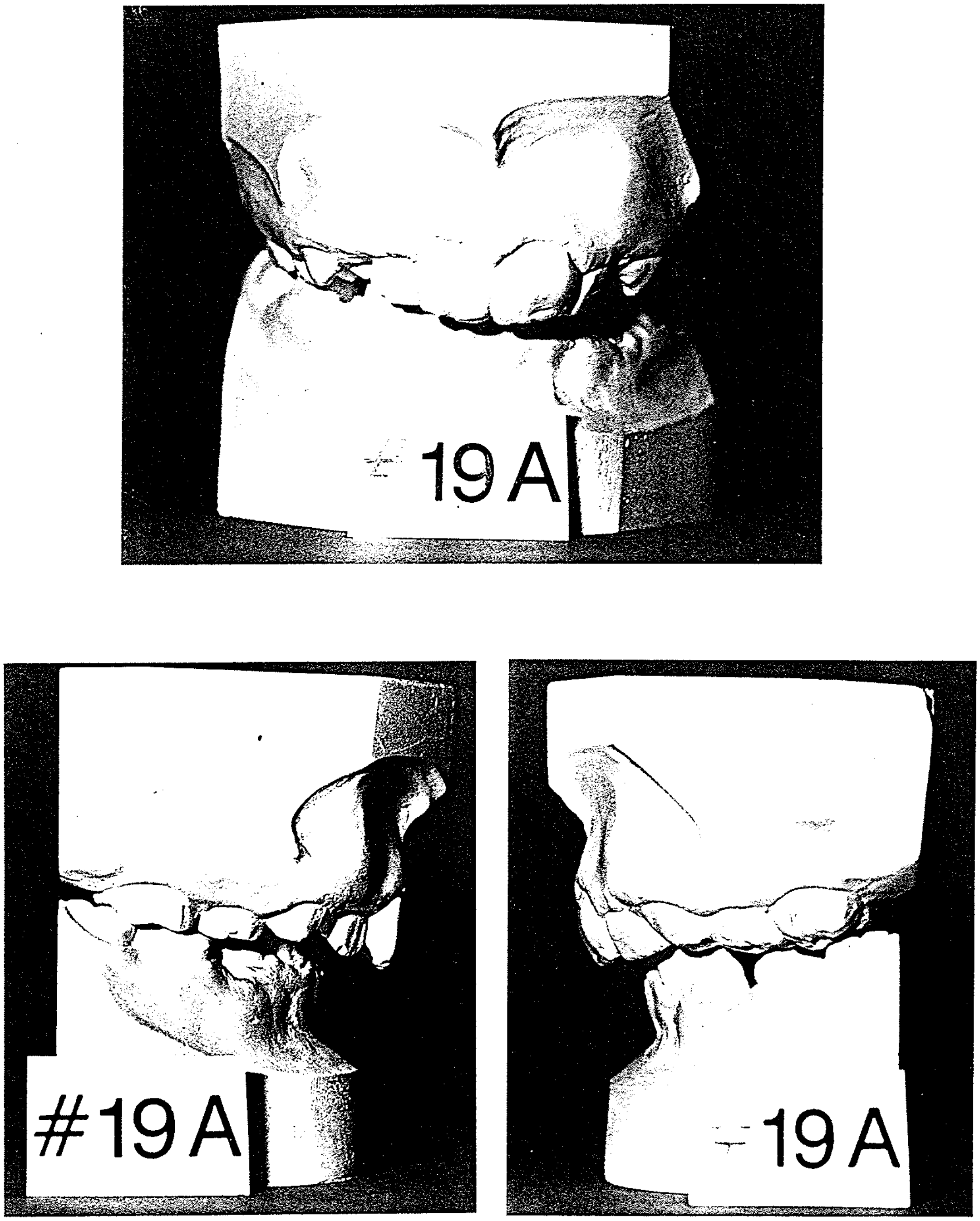


Figure 4.3 - Case No. 19 A

Consensus expert opinion on treatment difficulty was difficult
DAI score = 54; severe malocclusion
PAR score = 51; severe malocclusion

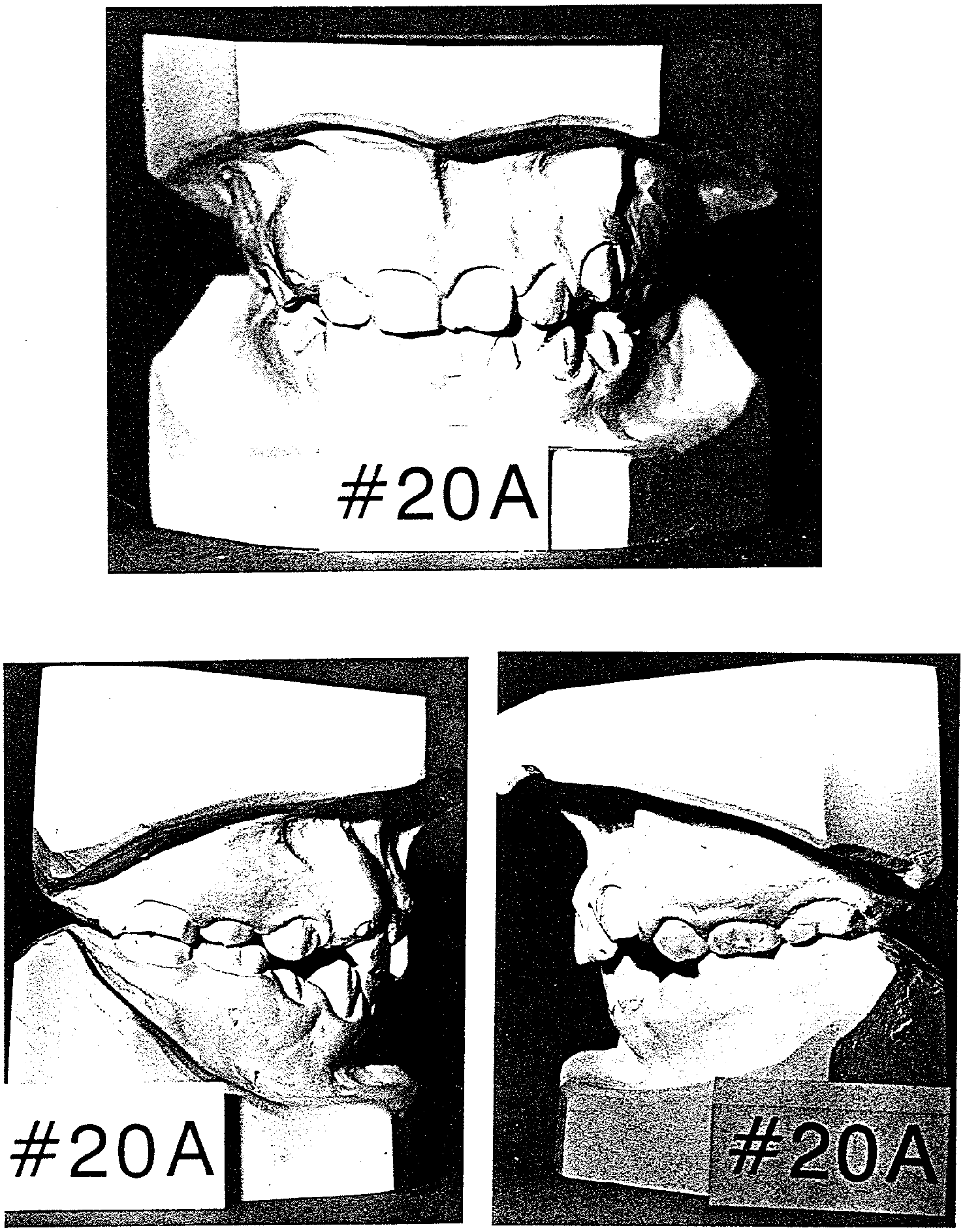


Figure 4.4 - Case No. 20 A
Consensus expert opinion on treatment was moderately difficult
DAI score = 23; mild malocclusion
PAR score = 11; mild malocclusion

Limitations of Occlusal Indices

The use of occlusal indices provides a rapid, valid and accurate method of evaluating the dento-occlusal aspects related to malocclusion severity and treatment need. However, such assessments have limitations. Changes in aesthetics, facial profile and radiographic parameters are not evaluated, although there is no consensus upon methods developed to assess facial profile and aesthetics. In addition, patterns of facial growth are subject to individual variation. An ideal cephalometric analysis does not exist. Also, no consensus has been achieved with respect to cephalometric goals of orthodontic treatment. Because indices are generally applied to study casts, there is no functional component to the analyses. Also, there is no assessment of the temporomandibular joint in any occlusal index. However, even within the literature, an accurate definition and diagnosis of this disorder has proved problematic (Guttu and Spektor, 1981; Dibbets and Van der Weele, 1987, 1992; Widmer *et al.*, 1990). Another major disadvantage of indexing systems is the risk of insensitivity and misjudgment of the needs of individual patients (Green and O'Brien, 1994).

Nevertheless, until further measures are developed, the only available method of assessing malocclusion severity and treatment need is by using occlusal indices. These facilitate accurate, objective assessments and minimize distortions presented by subjective opinions of the malocclusion.

Limitations of the Study

This preliminary investigation may present an oversimplification of malocclusion severity and treatment difficulty. Both are influenced by numerous factors and many are not only impossible to measure as discrete variables but also comprise deficiencies inherent with the use of occlusal indices. The results of this study were also dependent on the examiners and the cast sample. Although a total of 51 examiners gives power to the study, the small number of "experts" may have reduced the confidence level of the responses. As well, the commitment of the examiners to the investigation must be noted. In general, this proved satisfactory for most participants, but as with any large group, a few were less than enthusiastic. Rater bias may also have been introduced due to previous experience or training. Although this was anticipated, it could not be eliminated and may have been particularly noticeable in the "expert" group as all graduated from the same specialty program.

The sample of study casts were chosen because they represented a group of Aboriginal patients that had been approved for orthodontic treatment. All had a predetermined dental Class II, Division I malocclusion. This may have been reflected in the results, i.e. a heavier weighting assigned to the buccal occlusions. A wider range of malocclusions would have reduced this bias, although their relative assessments would then have been too complex.

The DAI and PAR indices, as with all indices, have inherent deficiencies. Although both were easy to use, by combining them, the number of variables that examiners needed to assess likely increased the measurement error due to fatigue and time constraints during the evaluations.

Several refinements are suggested for future investigations:

(i) increase pre-treatment sample size to include a wider variety of malocclusions,

(ii) increase the number of "expert" examiners, and solicit the subjective opinion of GP's re: treatment difficulty and,

(iii) limit investigation to one malocclusion index at a time.

Summary and Future Investigations

Two malocclusion indices, the Dental Aesthetic Index (DAI) and Peer Assessment Rating Index (PAR), were applied to a sample of pre-treatment orthodontic casts. The examiners were divided into three Groups based on expertise. The study demonstrated that non-orthodontic personnel can be trained to use occlusal indices with the same degree of reliability as a group of orthodontists. The results also showed that both the DAI and PAR indices can distinguish levels of malocclusion severity, classified as mild, moderate or severe, based on pre-determined cut-off points. In the case of the DAI, however, it is at the cost of over-estimating treatment need. The results of the study showed that inter- and intra-reliability with respect to subjective opinion on treatment difficulty was substantial. Objective assessments of treatment difficulty using the DAI and PAR indices however, were inconsistent. The results indicate that malocclusion severity and treatment difficulty share many of the same index variables, but are distinct entities, as different components account for the categorical rankings.

While much has been learned from the present study, continued investigation is required, especially in the areas of establishing treatment need "cut-off" points and assessing treatment difficulty , including its inherent determinants.

Intimations have been made about the poor standard of orthodontic care provided by non-specialists. Moyers (1990) has said that this problem occurs in dentistry because there is no other field in which a large proportion of all treatment is provided by clinicians with little training and no testing of competence. Development of an "Index of Treatment Difficulty" would, at the very least, ensure patients receive treatments by an appropriate care giver with a suitable level of expertise, although not all specialists are equally competent.

Further research into this area should include general practitioners and pediatric dentists. An evaluation of their perceptions of malocclusion severity and criteria used for determining treatment difficulty would provide useful insights. If differences exist in relation to orthodontic opinion, the disparity between pretreatment assessments and referral decisions may then be explained.

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APPENDIX A

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

1. COMPREHENSIVE ORTHODONTIC TREATMENT

The MSB-Blue Cross Dental Form for pre-authorization must:

(a) have all sections (i.e., Parts 1, 2 and 3) completed and bear the dentist's signature; 105

(b) summarize the diagnostic findings, treatment plan and treatment time anticipated;

(c) indicate a comprehensive orthodontic procedure code (from MSB Fee Schedule, p. GP-12) and specify the total fee, including laboratory costs; and

(d) be accompanied by quality patient records that would support the request for pre-authorization:

(i) **trimmed** orthodontic casts and bite registration

(ii) radiographs — panoramic film or full mouth series
— cephalometric film with tracing

(iii) photographs

(iv) a detailed case description to include the sequence of orthodontic treatment procedures; malocclusion classification; skeletal/dental factors; patient habits contributing to malocclusion; skeletal and dental midlines; lip position/competency; complications anticipated (e.g., rotations, periodontal, tooth size, congenital absence of teeth, orthognatic surgery, etc.); treatment alternatives (e.g., prosthetics, single arch treatment) etc.

Payment

Claims are to be submitted on an MSB-Blue Cross Dental Form to Ontario Blue Cross. Reimbursement is provided in three (3) equivalent instalments:

- 1/3 of the fee to be claimed when active treatment is initiated (bonding, appliance insertion);
- 1/3 of the fee to be claimed twelve months after the date of initiation of treatment; and
- 1/3 of the fee to be claimed when active therapy is completed and the patient is placed in retention.

Pre-authorization is also required prior to a claim for the final one-third of the fee. All pre-treatment diagnostic patient records and all post-treatment final diagnostic records, including trimmed orthodontic casts, panoramic or full mouth series radiographs and cephalometric radiograph with tracing, must be forwarded with an MSB-Blue Cross Dental Form for pre-authorization to the Regional Dental Officer at the address above.

2. LIMITED ORTHODONTIC TREATMENT

— Examples: simple crossbite correction, closure of a diastema, arch expansion.

An MSB-Blue Cross Dental Form for pre-authorization should include a brief description of the malocclusion, treatment time and oral health status in the space provided (in Part 1 of the form). Procedure code(s) and assigned fees (see MSB Schedule, p.GP-11) must also be indicated.

Travel arrangements for MSB clients referred from outlying communities are made by the MSB Referral Unit, telephone 982-2151. Patient eligibility for MSB dental benefits can be confirmed by contacting the MSB dental office at telephone 983-2907 or 983-6043. Prior to referral or acceptance of an **ongoing** orthodontic case being transferred between practitioners, please consult with the MSB dental office.

Note: For orthodontic cases pre-authorized prior to July 11, 1987, claims must be submitted, using an Application for Treatment and Dental Account Form, to the attention of the Regional Dental Officer at the address above. The claims schedule and patient record submission(s) are as indicated above.

APPENDIX B

WHO Requirements for an Occlusal Index (Tang and Wei, 1993)

1. Status of the group is expressed by a single number which corresponds to a relative position on a finite scale with definite upper and lower limits; running by progressive gradation from zero, i.e., absence of disease, to the ultimate point, i.e., disease in terminal stage.

2. The index should be equally sensitive throughout the scale.

3. Index value should correspond closely with the clinical importance of the disease stage it represents.

4. Index value should be amendable to statistical analysis.

5. Reproducible.

6. Requisite equipment and instruments should be practicable in actual field situation.

7. Examination procedure should require a minimum of judgement.

8. The index should be facile enough to permit the study of a large population without undue cost in time or energy.

9. The index would permit the prompt detection of a shift in group conditions, for better or for worse.

10. The index should be valid during time.

APPENDIX C

The Dental Aesthetic Index: Protocol of Usage

Missing Visible Teeth: Incisors, Canines and Premolar

Count the number of missing permanent incisors, canine and premolar teeth on the upper and lower arches. Counting the teeth present starting at the right second premolar and moving forward to the left second premolar. There should be 10 teeth present in each arch. If there are less than 10 the difference is the number missing, record that number.

If the spaces are close, do no count the teeth as missing. If a primary tooth is still in position and its successor has not yet erupted, do not count the teeth as missing.

Crowding in the Incisal Segments of the Arch

Examine both upper and lower incisal segments for crowding from lateral to lateral. Teeth may be rotated or displaced out of alignment in the arch. The number of incisal segments (each incisal segment consists of four incisors in either the upper or lower arch) with crowding recorded as 0, 1, or 2 (0 = no segments crowded; 1 = 1 segment crowded; 2 = 2 segments crowded). When in doubt, assign the lower score.

Do not mark the incisal segment crowded if four incisors are in proper alignment but either or both canines are displaced.

Spacing in the Incisal Segment

Examine both the upper and lower incisal segments for spacing from lateral to lateral. If one or more incisor teeth have proximal surfaces without any interdental contact the segment is recorded as having space. The number of incisal segments in both arches with spacing is recorded as either 1, 1 or 2 (0 = no segments crowded; 1 = 1 segment crowded; 2 = 2 segments crowded). When in doubt assign the lower score.

Diastema

A midline diastema is defined as the space, in millimetres, between the two permanent maxillary incisors. This measurement can be made at any level between the mesial surfaces of the central incisors and should be recorded to the nearest whole millimetre.

Largest Anterior Irregularity on the Upper (maxillary) Arch

Irregularities may be either rotations out of, or displacement from, normal alignment. Measure the site of the greatest irregularity between adjacent teeth using the ruler provided. It is placed into contact with the labial surface of the most lingually displaced or rotated incisor while it is held parallel to the occlusal plane and at right angles to the normal arch line. The irregularity in millimetres can then be recorded to the nearest whole millimetre. If there is sufficient space for all four incisors in the normal alignment but some are rotated or displaced <u>do not</u> mark that segment as crowded but record the largest irregularity. Irregularities at the distal of the lateral incisors should also be considered, if present.

Largest Anterior Irregularity on the Lower (mandibular) Arch

Measurement is the same as on the upper arch except that it is made on the lower (mandibular) arch. The greatest irregularity between adjacent teeth on the lower arch is located and measured as described above for the upper teeth.

Anterior Maxillary Overjet

Measurement of the horizontal relation of the incisors is made with the teeth in centric occlusion. Record only the largest maxillary overjet with a metric ruler to the nearest whole millimetre from the labio-incisal edge of the most prominent upper incisor to the labial surface of the corresponding lower incisor holding the instrument parallel to the occlusal plane. This trait is <u>not</u> recorded if all upper incisors are missing or in lingual crossbite.

Anterior Mandibular Overjet (mandibular protrusion)

Record this trait when any lower incisor protrudes anteriorly, or labially, to the opposing upper incisor, i.e. it is in crossbite. Record the <u>largest</u> mandibular overjet (mandibular protrusion) or crossbite of any of the incisors in the lower arch to the nearest whole millimetre. Measure in the same manner as described for anterior maxillary overjet. <u>Do not</u> mark the tooth as a mandibular overjet if a lower incisor is rotated so that one part of the incisal edge is in crossbite.

Vertical Anterior Openbite

If there is a lack of vertical overlap between any of the opposing pairs of incisors (openbite) the amount of openbite is measured with a metric ruler to the nearest whole millimetre.

Anterior-posterior Molar Relation

This assessment is most often based on the relation of the permanent upper and lower first molars. If the assessment cannot be based on the first molars because one or both are absent, not fully erupted, or misshaped because of extensive decay or fillings, the relations of the permanent canines and premolar are assessed.

The right and left sides with the teeth in occlusion and only the largest deviation from the normal molar relation is recorded. Score as follows:

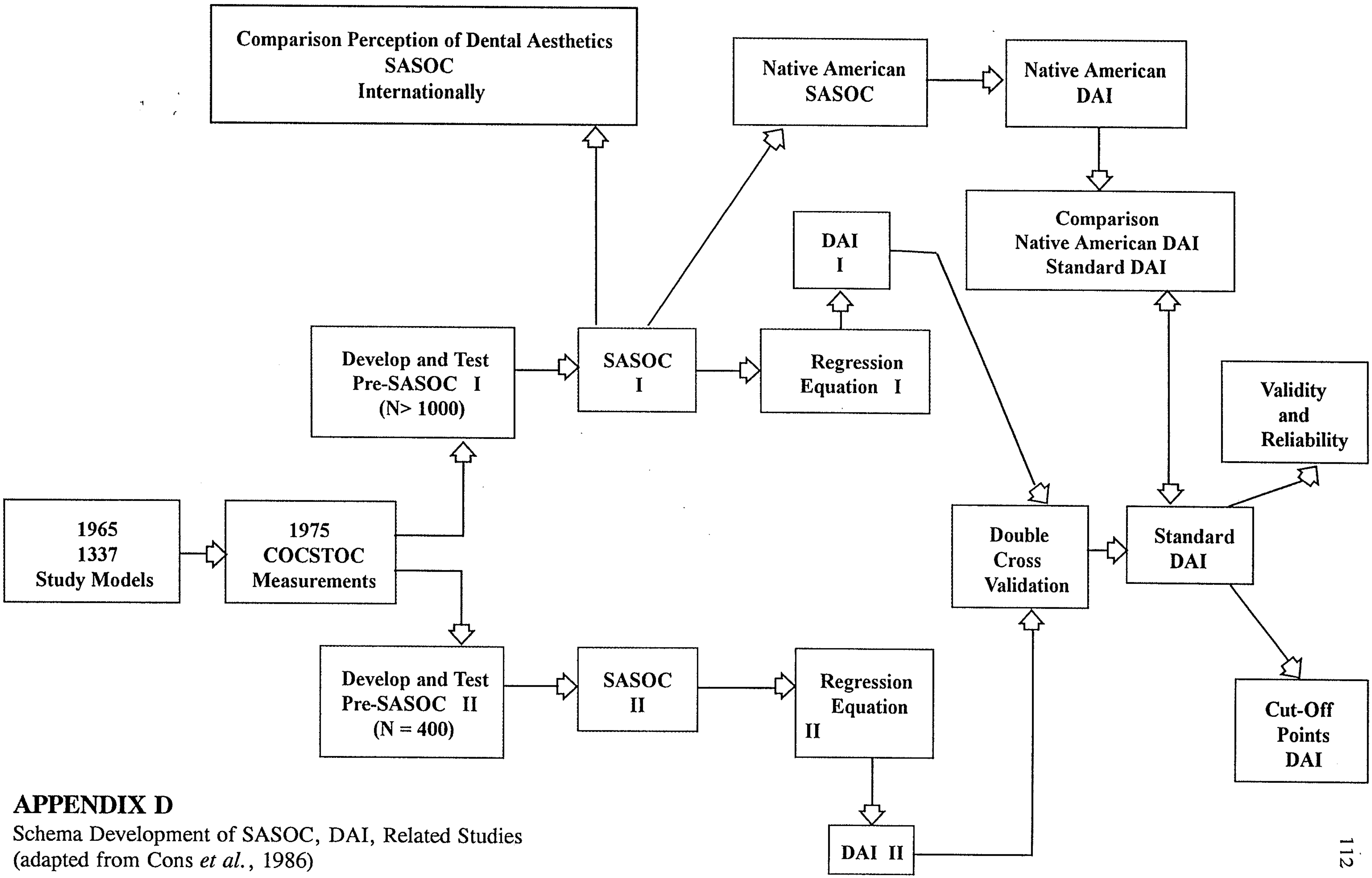
0 = normal molar relation

1 = lower first molar on either side is 1/2 cusp either mesial or distal to the upper first molar

2 = lower first molar on either side is one full cusp or more either mesial or distal to the upper first molar. When in doubt assign the lower score.

The Standard DAI : **its components, their actual and rounded regression coefficients (weights) and its constant (Cons et al, 1994)**

DAI components	**Regression Coefficients** Actual weights	Rounded weights
1. Number of missing teeth (incisors, canines and pre-molars in both arches)	5.76	6
2. Assessment of crowding in the incisal segments: 0=no segments crowded, 1=1 segment crowded, 2=2 segments crowded	1.15	1
3. Assessment of spacing in the incisal segments: 0=no segments spaced, 1=1 segment spaced, 2=2 segments spaced	1.31	1
4. Measurement of midline diastema in millimetres	3.13	3
5. Largest anterior irregularity, maxilla, in millimetres	1.34	1
6. Largest anterior irregularity, mandible, in millimetres	0.75	1
7. Measurement of anterior maxillary overjet in millimetres	1.62	2
8. Measurement of anterior mandibular overjet in millimetres	3.68	4
9. Measurement of vertical anterior openbite in millimetres	3.69	4
10. Assessment of antero-posterior molar relation; largest deviation from normal either left or right, 0=normal, 1=1/2 cusp either mesial or distal, 2=one full cusp or more either mesial or distal	2.69	3
11. Constant	13.36	13



APPENDIX D

Schema Development of SASOC, DAI, Related Studies
(adapted from Cons *et al.*, 1986)

Table V - Spearman rank-order correlations between rankings for dental aesthetics of occlusal conditions by American, Australian, Chinese, German, Japanese, Latvian, Native American, Korean, Singaporean Chinese, Singaporean Indian, Singaporean Malay and Thai students

	Amer (n=1000)	Aus (n=1450	China (n=413)	Ger (n=100)	Japan (n=200)	Latvia (n=420)	Nat Amer (n=656)	ROK (n=200)	Chin (n=70)	Singaporean Ind (n=30)	Mal (n=70)	Thai (n=164)
American	1.00	0.94	0.90	0.89	0.92	0.84	0.92	0.93	0.90	0.90	0.91	0.87
Australian		1.00	0.91	0.96	0.95	0.83	0.95	0.94	0.93	0.95	0.93	0.89
Chinese			1.00	0.88	0.96	0.92	0.93	0.96	0.92	0.91	0.94	0.90
German				1.00	0.92	0.83	0.92	0.91	0.92	0.93	0.92	0.86
Japanese					1.00	0.88	0.96	0.98	0.95	0.94	0.95	0.94
Latvian						1.00	0.88	0.88	0.81	0.83	0.87	0.85
Native American							1.00	0.98	0.94	0.95	0.96	0.93
ROK								1.00	0.96	0.95	0.98	0.93
Singaporean Chinese									1.00	0.98	0.98	0.94
Singaporean Indian										1.00	0.98	0.96
Singaporean Malay											1.00	0.96
Thai												1.00

P<0.0001 for all of the above correlations

(adapted from Cons et al, 1994)

APPENDIX E

APPENDIX F
The PAR Index: Protocol of Usage

The concept is to assign to various occlusal traits which make up a malocclusion. The individual scores are summed to obtain an overall total, representing the degree a case deviates from normal alignment and occlusion. The score of zero would indicate good alignment and higher scores (rarely beyond fifty) indicating increased levels of irregularity. The overall score is recorded in the pre- and post-treatment dental casts. The difference between these scores represents the degree of improvement as a result of orthodontic intervention and active treatment. There are five components of the PAR Index (Table A1)

Table A1 **Components of the PAR Index**

1. Upper and lower anterior segments
2. Left and right buccal occlusions
3. Overjet
4. Overbite
5. Centerline

Anterior Segments

Scores are recorded for both upper and lower anterior segments. The recording zone is from the mesial of the canine on one side to the mesial of the canine on the opposite side. The occlusal features recorded are crowding, spacing and impacted teeth (Table A2). Displacements are recorded as the shortest distance between contact points of adjacent teeth in relation to the occlusal plane. The greater the contact point displacement, the greater the score.

Table A2 **Displacement Scores**

Score	Discrepancy
0	0 mm to 1 mm
1	1.1 mm to 2 mm
2	2.1 mm to 4 mm
3	4.1 mm to 8 mm
4	greater than 8 mm
5	impacted teeth (space $\leq$ 4.0 mm)

An impacted tooth is recorded if the space between two adjacent teeth is less than or equal to 4 mm. Impacted and/or ectopic incisors and canines are recorded in the anterior segment. Scores for the displacements are added to give an overall score for the anterior segment.

If there is potential crowding in the mixed dentition, average mesio-distal widths are used to calculate the space deficiency (Table A3). If the space remaining for an unerupted tooth is 4mm or less an impaction is recorded.

Table A3 **Mixed dentition crowding assessment using average mesio-distal widths**

Upper		
canine	8 mm	
1st premolar	7 mm	Total = 22 mm (impaction < = 18 mm)
2nd premolar	7 mm	
Lower		
canine	7 mm	
1st premolar	7 mm	Total = 21 mm (impaction < = 17 mm)

Buccal occlusion

The buccal occlusion is recorded for both left and right sides. The fit of the teeth is scored in all three planes of space. The recording zone is from the canine to the last molar, either first, second or third. All discrepancies are recorded when the teeth are in occlusion. The antero-posterior, vertical and transverse are summed for each buccal segment (Table A4).

Overjet

Positive overjet as well as teeth in crossbite are recorded (Table A5). The recording zone includes all incisor teeth. The most prominent aspect of <u>any</u> incisor is recorded to the labial aspect of the incisal edge. When recording the overjet, the ruler is held parallel to the occlusal plane and radial to the line of the arch. It is not uncommon to see two upper laterals in crossbite as well as increased overjet on the central incisors. In this situation, if the overjet were 4 mm, the score would be 3 for the crossbite and 1 for the positive overjet, 4 in total.

Table A4 **Buccal occlusion assessments**

a) Antero-posterior

Score	Discrepancy
0	Good interdigitation Class I, II and III
1	Less than half unit discrepancy
3	Half a unit discrepancy (cusp to cusp)

b) Vertical

0	No open bite
1	Lateral open bite on at least two teeth greater than 2 mm

Temporary developmental stages and submerging deciduous teeth are excluded.

c) Transverse

0	No crossbite
1	Crossbite tendency
2	Single tooth in crossbite
3	More than one tooth in crossbite
4	More than one tooth in scissorbite (complete crossbite)

Table A5 **Overjet measurements**

a) Overjet

Score	Discrepancy
0	1 to 3 mm
1	3.1 to 5 mm
2	5.1 to 7 mm
3	7.1 to 9 mm
4	greater than 9 mm

b) Anterior crossbites

Score	Discrepancy
0	no discrepancy
1	one or more teeth edge to edge
2	one single tooth in crossbite
3	two teeth in crossbite
4	more than two teeth in crossbite

Overbite

Records the vertical overlap or open bite of the anterior teeth. Overbite is recorded in relation to the coverage of the lower incisors or the degree of open bite (Table A6). The recording zone includes the lateral incisors.

Table A6 **Overbite measurements**

a) Open bite

Score	Discrepancy
0	No open bite
1	Open bite less than and equal to 1 mm
2	Open bite 1.1 mm to 2 mm
3	Open bite 2.1 mm to 3 mm
4	Open bite greater than or equal to 4 mm

b) Overbite

Score	Discrepancy
0	Less than or equal to one third coverage of the lower incisor
1	Greater than one third but less than two thirds coverage of the lower incisor
2	Greater than two thirds coverage of the lower incisor
3	Greater than or equal to full tooth coverage

Crossbites including the canines are recorded in the anterior segment

Dental Midline

Records the centerline in relation to the lower central incisors (Table A7). If a lower has been extracted, the measurement is not recorded.

Table A7 **Centerline assessments**

Score	Discrepancy
0	Coincident and up to one quarter lower incisor width
1	One quarter to one half lower incisor width
2	Greater than one half lower incisor width

Conventions for the PAR Index

General

1) All scoring is cumulative.
2) There is no maximal cut-off level.
3) The occlusion should be scored disregarding functional displacement as this cannot be determined from dental casts alone.
4) The contact points between the first, second and third premolars are not recorded. The contact points between molars are so variable. However, if severe deviations will produce a crossbite, it will be noted in the buccal occlusions.
5) If the contact point displacement is a result of poor restorative work (restorations or crowns), the displacement is not recorded.
6) Contact points between deciduous teeth are not recorded.

Canines

1) Where there are missing canines, displacements resulting from discrepancies between the mesial contact point to the first premolar and the distal of the lateral incisor should be recorded in the anterior segment.
2) Canine crossbites should be recorded in the anterior segment.
3) Contact points between the canines and premolars are scored as follows: the distal contact point of the canine to the midpoint on the mesial surface of the adjacent premolar.

Impactions

1) If a tooth is unerupted and displaced from the line of the arch either buccally or palatally due to insufficient space, this is regarded as an impaction. However, if the tooth is erupted and displaced, the displacement score is recorded.

Incisors

1) When recording an overjet, if the tooth falls on the line, the lower grade is recorded.
2) If a lower incisor has been extracted or is missing, the centerline is not recorded.

Validation

The PAR Index has been validated in accordance with current British orthodontic opinion (Richmond, 1992a, b) and American orthodontic opinion (DeGuzman, 1995). In light of the views expressed by these panels of dentists, various degrees of importance have been attached to the five components (Table A8).

Table A8 Weightings derived for the five components of the PAR

Components	**Br. wt.**	**N.A. wt**
1. mx. and md. anterior segment	x1	x1*
2. left and right buccal occl.	x1	x2
3. overjet	x6	x5
4. overbite	x2	x3
.5 centerline	x4	x3

The individual scores for each PAR component are multiplied by the weightings shown and then summer to establish the overall total.

*** Only considers anterior segment score.**

APPENDIX G

THE PEER ASSESSMENT RATING (PAR) AND DENTAL AESTHETIC INDEX (DAI)

INSTRUCTIONAL MANUAL

Although these instructions appear overwhelming, in reality, the system is very simple. The object of the indices is to assign a score to those occlusal traits which deviate from an ideal or normal occlusion. There are a number of components which are measured, scored and recorded as follows:

1. Missing visible teeth
2. Crowding in the incisal segment
3. Spacing in the incisal segment
4. Diastema
5. Largest anterior irregularity in the maxillary incisal segment
6. Largest anterior irregularity in the mandibular incisal segment
7. Maxillary right buccal segment
8. Maxillary anterior segment
9. Maxillary left buccal segment
10. Mandibular right buccal segment
11. Mandibular anterior segment
12. Mandibular left buccal segment
13. Right buccal occlusion
14. Left buccal occlusion
15. Overjet
16. Overbite
17. Centre-line

A detailed explanation of the method for measurement is provided in the following pages. An easy reference guide is supplied with the examiners recording form.

DENTAL MEASUREMENTS REQUIRED

1. Missing Visible Teeth; Incisors, Canines and Premolars

Count the number of missing permanent incisor, cuspid, and bicuspid teeth in the maxillary and mandibular arch. There should be 10 teeth present. If there are less than 10, the difference is the number missing. Record this number (e.g. 10 - 8 = 2; Record 2).

If spaces are closed, do not count the teeth as missing. If a primary tooth is in position and its successor has not yet erupted, do not count the tooth as missing.

2. Crowding in the Incisal Segments of the Arch

Examine both maxillary and mandibular incisal segments for crowding. Crowding in the incisal segment results when the space between the cuspids is insufficient to accommodate all four incisors in normal alignment. Teeth may be rotated or displaced out of alignment in the arch. The number of incisal segments (each incisal segment consists of four incisors in either the maxillary or mandibular arch) with crowding is recorded as 0 = no segments crowded; 1 = 1 segment crowded; 2 = 2 segments crowded. When in doubt assign the lower score.

Do not mark the incisal segment crowded if the four incisors are aligned, but either or both cuspids are displaced.

3. Spacing in the Incisal Segment of the Arch

Examine both maxillary and mandibular incisal segments for spacing. Spacing in the incisal segment results when the space between the cuspids exceeds that required to accommodate all four incisors in normal alignment. If one or more incisor teeth have proximal surfaces without any interdental contact, the segment is recorded as having space; 0 = no segments spaced; 1 = 1 segment spaced; 2 = 2 segments spaced. When in doubt assign the lower number.

4. Diastema

A midline diastema is defined as the space, in millimeters, between the two maxillary incisors. This measurement can be made at any point between the mesial surfaces of the central incisors and is recorded in millimeters to the nearest whole number.

5. Largest Anterior Irregularity in the Maxillary Incisal Segment

Irregularities may be either rotations out of, or displacements from, normal alignment as seen in Figure A1.

FIGURE A1. ANTERIOR IRREGULARITIES AND CROWDING

Measure the site of the greatest irregularity between adjacent teeth using a millimeter ruler, the handle end of the Boley gauge or a tongue blade and pencil as illustrated in Figure A2. The edge of the tongue blade is placed parallel to the occlusal plane and at right angles to the arch and in contact with the labial surface of the most lingual malpositioned tooth. A sharp pencil is placed on the labial surface of the adjoining tooth and slid along that surface to mark the tongue blade which can then be measured and recorded in millimeters to the nearest whole number.

Irregularities may occur with or without crowding. If there is sufficient space for all four incisors in normal alignment but some are rotated or displaced, do not mark that segment as crowded but do record the largest irregularity.

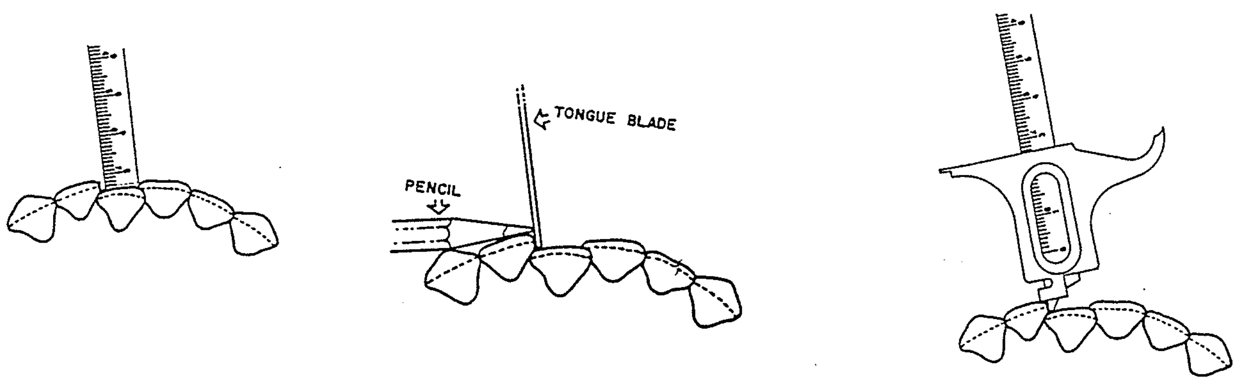


FIGURE A2. MEASURING IRREGULARITIES WITH A RULER, BOLEY GAUGE OR TONGUE BLADE AND PENCIL

6. Largest Anterior Irregularity in the Mandibular Anterior Segment

Measurement and recording of the greatest irregularity between adjacent teeth in the mandibular anterior segment is performed as described previously for the maxillary arch.

7-12. Displacement in the Buccal and Anterior Segments

Each arch is divided into three recording zones, left and right buccal and anterior segments. Scores are recorded separately for both the maxillary and mandibular arch as seen in Figure A3.

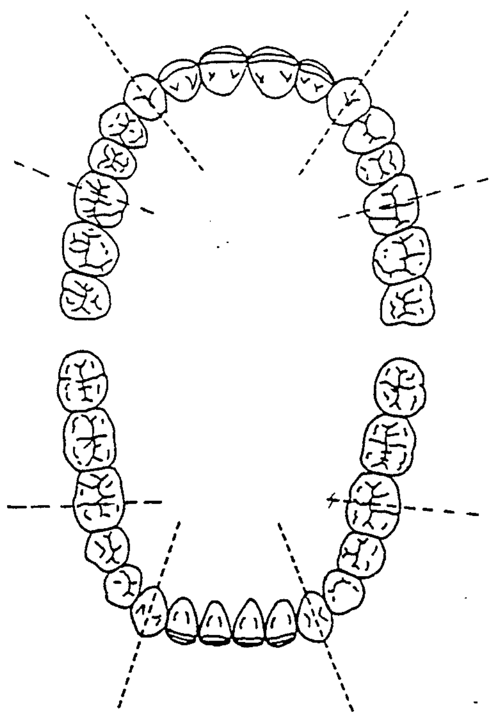


FIGURE A3. THE DIVISION OF THE DENTAL ARCH INTO THREE RECORDING ZONES.

The buccal recording zone is from the mesial of the first permanent molar to the distal of the cuspid. The anterior recording zone is from the mesial of one cuspid to the mesial surface of the contralateral cuspid.

The features measured in each recording zone are crowding, spacing and impactions, collectively termed displacement scores as shown below in Table A1.

Score	Discrepancy
0	0 - 1 mm
1	1.1 - 2 mm
2	2.1 - 4 mm
3	4.1 - 8 mm
4	Greater than 8 mm
5	Impacted teeth

TABLE A1. DISPLACEMENT SCORES.

The relationship between each tooth is observed in a given segment and measured using the same method described in section 5 and 6 using the ruler, Boley Gauge and/or tongue depressor technique as seen previously in Figure A2. The discrepancy is given a score which is then recorded. A tooth is judged to be impacted if the space between two adjacent teeth is less than or equal to 4.0 mm. Impacted cuspids are included in the anterior segment score.

13-14. <u>Buccal Occlusion Assessment</u>

The buccal occlusion is recorded separately for the left and right side and scored in the anteroposterior, vertical and transverse planes of space with the teeth in occlusion, as indicated in Table A2 on the following page.

Score	Discrepancy
(a) Anteroposterior	
0	Less than half-cusp discrepancy
1	Half-a-cusp discrepancy (cusp-to-cusp)
2	More than half-cusp discrepancy
(b) Vertical	
0	No discrepancy in intercuspation
1	Lateral open bite on at least two teeth greater than 2 mm
Temporary developmental stages and submerging deciduous teeth are excluded	
(c) Transverse	
0	No crossbite
1	Crossbite tendency
2	Single tooth in crossbite
3	More than one tooth in crossbite
4	Entire segment in crossbite

TABLE A2 BUCCAL OCCLUSION ASSESSMENT

The anteroposterior assessment is based on the relation of the permanent maxillary and mandibular first molars, but if this is not possible, the relation of the permanent cuspids and bicuspids are assessed. Only the <u>largest</u> deviation from normal molar relation is recorded. The schematic drawings in Figure A4 can be used as a scoring guide. Note the position of the arrows on the first molars and cuspids to determine the scoring.

VIEW OF THE TEETH FROM THE RIGHT SIDE

BACK

FRONT

Half cusp discrepancy = 1 **More than half cusp discrepancy = 2**

FIGURE A4. ANTERO-POSTERIOR MOLAR RELATION

15. Overjet Measurements

Measurement of the horizontal relation of the incisors is made with the teeth in occlusion. Record the largest overjet to the nearest whole millimeter from the labio-incisal edge of the most prominent maxillary incisor to the labial surface of the corresponding mandibular incisor holding the instruments parallel to the occlusal plane, as seen in Figure A5.

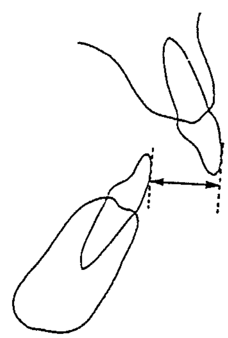


FIGURE A5. ANTERIOR MAXILLARY OVERJET

The positive overjet and any teeth in anterior crossbite are also noted and given a score as indicated in Table A3.

Score	**Discrepancy**
(a) Overjet	
0	0-3 mm
1	3.1-5 mm
2	5.1-7 mm
3	7.1-9 mm
4	Greater than 9 mm
(b) Anterior crossbites	
0	No discrepancy
1	One or more teeth edge-to-edge
2	One single tooth in crossbite
3	Two teeth in crossbite
4	More than two teeth in crossbite

TABLE A3 OVERJET MEASUREMENT

16. Overbite Measurements

If there is a lack of vertical overlap (open bite) between the maxillary and mandibular incisors, the amount is measured directly with a Boley gauge or ruler and recorded to the nearest whole millimeter, as illustrated in Figure A6.

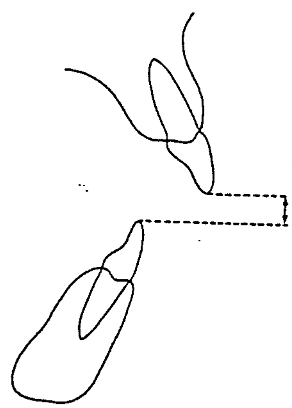


FIGURE A6. VERTICAL ANTERIOR OPEN BITE

The open bite discrepancy is given a score as seen in Table A4, on the following page. As well, the amount of overlap or overbite is noted and scored accordingly.

Score	Discrepancy
(a) Open bite	
0	No open bite
1	Open bite less than and equal to 1 mm
2	Open bite 1.1-2 mm
3	Open bite 2.1-3 mm
4	Open bite greater than or equal to 4 mm
(b) Overbite	
0	Less than or equal to one-third coverage of the lower incisor
1	Greater than one-third but less than two-thirds coverage of the lower incisor
2	Greater than two-thirds coverage of the lower incisor
3	Greater than or equal to full tooth coverage

TABLE A4 OVERBITE MEASUREMENTS

17. Centre-line Measurements

The discrepancy between the maxillary and mandibular dental midlines is assessed and scored according to Table A5.

Score	Discrepancy
0	Coincident and up to one-quarter of lower incisor width
1	One-quarter to one-half lower incisor width
2	Greater than one-half lower incisor width

TABLE A5 CENTRE-LINE MEASUREMENTS

APPENDIX G (con't)
PAR AND DAI SCORES/RECORDING FORM

Examiner No. ________ **Patient No.** __________

COMPONENTS	SCORE
1. Missing visible teeth (No.)	________
2. Crowding in incisal segments (No. segments crowded - 0, 1, 2)	________
3. Spacing in incisal segments (No. segments spaced - 0, 1, 2).	________
4. Diastema (mm)	________
5. Largest anterior irregularity in maxillary incisal segment (mm)	________
6. Largest anterior irregularity in mandibular incisal segment (mm)	________
7-12. Displacement scores (see Table A1)	
7. Maxillary Right segment (16/15)____ (15/14)____ (14/13)____	________
8. Maxillary Anterior Segment (13/12)____ (12/11)____ (11/21)____ (21/22)____ (22/23)____	________
9. Maxillary left segment (26/25)____ (25/24)____ (24/23)____	________
10. Mandibular right segment (46/45)____ (45/44)____ (44/43)____	________
11. Mandibular anterior segment (43/42)____ (42/41)____ (41/31)____ (31/32)____ (32/33)____	________
12. Mandibular left segment (36/35)____ (35/34)____ (34/33)____	________

OVER

13-14. Buccal occlusion assessment (see Table A2)

13. Right buccal occlusion

anteroposterior ____________

vertical ____________

transverse ____________

14. Left buccal occlusion

anteroposterior ____________

vertical ____________

transverse ____________

15. Overjet measurements (see Table A3)

Actual overjet <u>in mm</u> ____________

(a) score OJ ____________

(b) anterior crossbite score ____________

16. Overbite measurements (Table A4)

Actual open bite <u>in mm</u> ____________

(a) open bite score ____________

(b) overbite score ____________

17. Centre-line measurement (Table A5) ____________

Based on the above assessment and your subjective opinion, please classify this case as easy, moderate, difficult, in terms of the difficulty of the treatment.

____ easy ____ moderate ____ difficult