EVALUATION OF ESTHETIC ARCH WIRES

by

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ABSTRACT

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The advent of ceramic brackets has improved the appearance of orthodontic appliances considerably. However, the orthodontic wires used currently are still generally not esthetic. The purpose of this study was to: (1) Evaluate the usefulness of a new esthetic synthetic material for use as an initial orthodontic wire. (2) Compare the clinical efficacy of this synthetic material with Optiflex and multistrand wire before and after use. (3) Study the surface of the new synthetic wire (NSW) with scanning electronic microscopy (SEM).

Fifteen boys and girls between the ages of eleven and fifteen years presenting with lower anterior crowding were randomly divided into three groups of five patients each. Group 1 was treated with the new synthetic wire, group 2 with Optiflex and group 3 with multistrand stainless steel arch wire.

Models of the lower arch were taken before treatment and after eight weeks of treatment. Lower anterior crowding was measured before and after treatment using the irregularity index as described by Little.

All three wires were found to be effective in aligning teeth. There was no significant difference when comparing the multistrand wire with the new synthetic wire and Optiflex ($p < 0.05$). However, Optiflex fractured in four occasions and had to be replaced, thereby increasing the number of visits by the patient. SEM images of the NSW showed some deposits on the surface after use in the mouth but no cracks or structural faults were evident.

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DEDICATION

TO

My parents and all family members,

who helped make my education possible.

Thank you for your constant support and

God bless you all.

TABLE OF CONTENTS

Page

ABSTRACT ii

ACKNOWLEDGEMENTS iii

DEDICATION iv

LIST OF TABLES vi

LIST OF FIGURES viii

INTRODUCTION 1

LITERATURE REVIEW 2

MATERIALS AND METHODS 19

RESULTS 31

DISCUSSION 40

SUMMARY AND CONCLUSIONS 47

REFERENCES 49

LIST OF TABLES

Tables Page

I. Esthetic materials tested by Johnson (1990). 6

II. Flexural E Modulus as reported by Johnson (1990). 7

III. The arch wires used, patient sample and age. 19

IV. Flexural E Modulus and Yield strength as reported by Johnson (1990). 20

V. Arch wire diameters available for Optiflex, PEEK and multistranded. 22

VI. Flexural yield strength of PEEK, Optiflex and multistranded as reported by Johnson (1990). 23

VII. Mean and Standard deviation for Optiflex, PEEK multistranded initial measurements. 31

VIII. Data, Mean and Standard deviation for initial measurements. 32

Tables **Page**

IX. Data for final measurements. 33

X. Mean and Standard deviation for final measurements. 33

XI. P value for comparison of tretment groups 34

XII. PEEK diameters as reported from the SEM 36

LIST OF FIGURES

Figure Page

1. Lower model showing anterior irregularity 25

2. Lower model showing caliper from a occlusal view. 27

3. Lower model showing caliper from a buccal view. 28

4. Histogram showing average change per wire type 35

5. SEM image of unused PEEK wire 37

6. SEM image of used PEEK wire 38

7. SEM image of used PEEK wire 39

INTRODUCTION

Even with the introduction of the so called "esthetic or clear braces", patients are not totally satisfied with the appearance of these appliances in their mouth. During the last few years, several "esthetic arch wires" have been introduced into the market.

The objectives of this study were:

(1) To clinically evaluate the Optiflex esthetic arch wire. This is a fiber optic composed of a glass core and nylon coating. It was introduced by Ormco Co. in 1990 as an initial arch wire during the first phase of orthodontic treatment. Although it is being used no literature is available proving its efficacy during alignment of teeth.

(2) Clinically evaluate the PEEK (Polyether ether ketone) wire. This is a thermoplastic used for several engineering applications such as wire coating and others. According to the results obtained by Johnson in 1990, its physical properties compare with the D-Rect. .016 x .022" which is an arch wire used in Orthodontics for initial alignment of teeth.

(3) Compare the results with the Multistranded stainless steel arch wires. Different studies have shown its clinical efficiency and is widely used for initial alignment of teeth.

(4) Obtain SEM (Scanning electron microscope) images of the PEEK wires to compare the surface and diameter before and after use. Conclusions were then made as to whether these arch wires were of any clinical significance or not.

REVIEW OF LITERATURE

Recent advances in orthodontic wire alloys have resulted in a varied array of wires that exhibit a wide spectrum of properties. Up until 1929, the only orthodontic wires available were made of gold[1,2]. Austenitic stainless steel, with its greater strength, higher modulus of elasticity , good resistance to corrosion, and moderate costs, was introduced as an orthodontic wire in 1929, and shortly afterward gained popularity over gold. Since then several other alloys with desirable properties have been adopted in orthodontics. These include cobalt-chromium, nickel titanium, beta-titanium and multistranded stainless steel wires.

Presently, the orthodontist may select from all the available wire types, choosing one that best meets the demands of a particular clinical situation. The selection of an appropiate wire size and alloy type in turn provides the benefit of optimum and predictable treatment results. The clinician must therefore be conversant with the mechanical properties and the relevant clinical applications of the properties for these wires. It is difficult to gain clinical experience with the possible applications of so many different wires, and clinical judgments of the "feel" of a wire can be particularly misleading with wires that have variable relationships among the basic physical properties of strength, stiffness and range.

The properties of orthodontic wires are commonly determined by means of various laboratory tests. Thus, wires have previously been investigated under tension[3-6] in bending[7-9] and torsion[10,11] tests. Although these tests do not necessarily reflect the clinical situations to which wires are usually subjected, they provide a basis for comparison

of these wires. Tests in bending provide some information on the behavior of wires when subjected to first and second order bends. Similarly, results of torsional tests reflect, to a certain degree, wire characteristics in a third order direction

Several characteristics of orthodontic wires are considered desirable for optimum performance during treatment.[3] These include a large springback, low stiffness, high formability, high stored energy , biocompatibility and environmental stability, low surface friction, and the capability to be welded or soldered to auxiliaries and attachments.

The Need for Esthetic Arch Wires

Advances in the esthetic quality of fixed orthodontic appliances have been dramatic with the introduction of clear orthodontic brackets into the market. All major orthodontic supply companies now offer some sort of esthetic bracket whether it be ceramic or plastic (Allure (GAC), Gem Sapphire (Ormco), Quasar (RMO), Slikon (Am. Orthod.), Starfire (Unitek). The obvious marketability of these appliances has led all major suppliers to develop esthetic bracket product lines. Unfortunately, complementary esthetic arch wires have not yet succesfully entered the market place to a great extent. The only esthetic orthodontic arch wires that are now in the market are:

1) Teflon-coated stainless steel arch wire (White.1989): Has not become too popular because, the diameter of the stainless steel wire must be reduced in order to provide room for the teflon coating. In addition, the teflon coating is known to peel off exposing the stainless steel component of the arch wire.

2) Optiflex esthetic arch wire (Ormco.1990): Is a fiber optic consisting of a glass core and nylon coating used for initial alignment of teeth. Certain limitations should be considered in its use: a) Severe bends producing radii smaller than 1 mm or the use of ligature wire could cause fracture of the inner glass core. Therefore, this wire should

only be ligated with elastic ligatures. b) It will recover to its original shape without any permanent deformation. However, it will take a permanent set at the point of fracture losing its ability to recover at that point.

3) Spectra-Sentalloy: Is a nickel titanium arch wire with a ionized coat of titanium nitrate which gives a whitish or opaque appearance. Its physical properties are optimal but still the esthetic appearance is not solved completely.

The efforts of orthodontic supply companies to market a maximally esthetic appliance is reinforced by some recent investigations that have concentrated on determining patients perspectives on seeking treatment and their concerns about the appearance of the appliance. In a survey of adults attitude toward orthodontic therapy, Tayer [16] found that 74% of those surveyed had indicated they had initial doubts and feeling of hesitation about beginning treatment. One of the two most cited reasons for hesitation was the question of peer reaction. Tayer[16] , included some quotations in his article of people he surveyed to illustrate some of the concerns that patients experienced before deciding to start treatment with fixed appliances: "I was concerned about appearances", "I was afraid of the way people would respond to them...", and "I feared people would focus on my mouth and they would turn off...". The foregoing literature makes a strong case for development of a fixed orthodontic appliance that is as esthetic as possible, if not virtually invisible. The popularity of esthetic brackets with the general public has encouraged their widespread use even in the light of some technical disadvantages such as increased chair time due to bracket failure, enamel wear, and increased appliance cost. The demand for an esthetic appliance must be great in order for patients to endure the negative aspects of the state-of-the-art esthetic brackets.

Gosney[17], in a survey of children from 8 to 17 years old, reported that 23% of the patients in a survey experienced anxiety about the visibility of their fixed appliances. Of the patients surveyed 84% said they were teased about their fixed appliances, and 12% indicated that this teasing was a concern. Gosney[17] , also suggested that general anxiety over fixed appliances were increased with age. Interestingly, 73% of the patients surveyed who said they suffered "lots" of worry over appliance visibility or discomfort would still be willing to undergo treatment if so advised by their dentist. It can be inferred from this data that many patients may undergo orthodontic treatment and still have an underlying anxiety about the visibility of their appliances.

Gosney[18], in a survey of 207 patients and their respective parents assessed the influence various occlusal anomalies and other factors had had in stimulating a desire for orthodontic treatment. From the results obtained it is thought that more attention should be given to the particular occlusal and esthetic deviations which are causing concern to the patient; assumptions based upon the presenting occlusal condition should be avoided. It was shown that for the majority of patients the provision of orthodontic care was dictated largely by esthetics but the general dental practitioner exerted an appreciable influence on patient acceptance of treatment.

As the quality and clinical compatibility of the esthetic orthodontic brackets improves, so will the need for development of complementary esthetic orthodontic arch wires. It is now necessary to elevate the esthetic potential of the orthodontic arch wire by introducing new materials in as much as was the case of the introduction of nickel-titanium, titanium-molibdenum, and multistranded stainless steel wires to the optimization of the clinical mechanical efficacy of the modern metal arch wires.

Recent investigations for the possible use of new "esthetic materials" as a device for new "esthetic arch wires".

Mathew Johnson[13], in partial fulfillment for his master's degree in Orthodontics at Case Western Reserve University, Cleveland, Ohio, researched for synthetic materials that were clear or tooth colored whose physical characteristics were similar to those arch wires existing in the market. The materials tested are listed in table I.

TABLE I

MATERIAL	COMPOSITION
GLASTIC	Uniaxial fiberglass; semitransparent
PEEK (Polyether Etherketone)	Thermoplastic; light brownish color.
PET (Polyethylene Terepthalate)	Plastic; clear color.
Nylon	Transparent color.
Optiflex Esthetic Arch wire	Fiberglass nylon matrix. clear color.

A test protocol was developed to check properties such as modulus of elasticity during tensile and bending tests. To check the efficacy of the testing protocol the most used arch wires in daily practice were chosen such as multistranded stainless steel, nickel-titanium, beta-molibdenum, and others. Once its validity was proved, the testing of the "esthetic materials" was performed. The results are listed in table II.

TABLE II

ARCH WIRE	FLEXURAL E MODULUS
D-RECT .016 x ,022"	0.89 X 10^6 psi
PEEK (Polyether Etherketone)	0.97 x 10^6 psi
MULTISTRANDED RESPOND .0175"	1.64 x 10^6 psi
PET (Polyethylene Terephthalate)	2.64 x 10^6 psi

The flexural E Modulus of the D-Rect. 016 x .022" will compare with the obtained by the PEEK. And the flexural E Modulus obtained by the Multistranded Respond arch wire .0175" will compare with the obtained by the PET material.

The D-Rect. and Multistranded Respond arch wires have shown to be efficient during initial stages of orthodontic treatment, and according to these results there is no reason why the PET and PEEK materials could not have a clinical significance. A brief description will be given from each one.

PET[19] (Polyethylene Terephthalate), is a condensation polymer that has undergone particularly rapid growth in the last few years as a packaging material, not only for carbonated beverages but also for amorphous and crystallized containers and trays. Prior to this, it was used primarily as a food packaging film and for the production of fiber for

textile products and other applications. Within the last five years, reinforced PET and copolyesters have also made great inroads as new polyester products for engineering applications and specialty packaging applications.

The success of PET as a carbonated beverage packaging material is due to its toughness and clarity, its ability to be oriented, favorable economics, and the development of high-speed bottle processing technology. PET beverage containers are lightweight, shatter-resistant, recyclable and exhibit good barrier properties. Filled 2-liter PET beverage bottle weight 24% less than comparable glass bottles; empty, they weigh one-tenth as much as typical glass bottles of the same size, thus providing labor, energy and cost savings throughout the distribution chain, from manufacturer to consumer.

PEEK[19] (Polyether Etherketone), is a family of engineering thermoplastics in which the combination of ketone and aromatic moieties imparts exceptional high temperature properties combined with excellent thermal stability. The most commercially important member of the series is polyaryl ether ether ketone known as PEEK. It has great crystallinity that leads to excellent environmental resistance and low flammability, smoke, and toxic gas emission. Polyketones are well suited to demanding applications such as advanced composites, wire coating, chemical resistant filters, integrated circuit wafer carriers, and motor vehicle bearings.

Johnson[13], concluded that on the basis of comparison with reference values, the uniaxial tensile test and the three point bend test developed at CWRU are highly accurate and have the ability to define the respective mechanical properties of the materials that are tested. Also that it is possible that polymers can deliver clinical efficacy similar to the D-Rect. .016" x .022" and the Respond .0175" multistranded arch wires based solely on the experimental values of the instantaneous flexural modulus of elasticity of the PET polyester monofilaments and PEEK polyether ether ketone monofilaments wires. He also

stated that although the search for esthetic materials should not be limited to polymers only, since such areas as the metal coating industry are rather sophisticated, a clinical testing protocol should be establish to assess the clinical efficacy of the Optiflex arch wire. This arch wire is already on the market and no clinical investigations verifying its clinical efficacy have been published. This clinical testing protocol can also be used to assess the clinical efficacy of new esthetic arch wire materials (such as PEEK and PET), once their mechanical properties and biocompatibility are considered favorable.

Possible Esthetic Substitutes for Metal Alloy Orthodontic Arch Wires

Plastics, or in other words, polymer materials, have great variability in providing products of high esthetic potential. Because dyes and pigments can be incorporated directly into the polymer resins, it is possible to produce an item in an unlimited range of colors both simply and economically. The amorphous polymers, those that have random molecular arrangement, tend to transmit light easily, and are thus transparent. The crystalline polymers, due to an ordered structural arrangement of the molecules, tend to reflect most incident light and are thus opaque [20].

Although there is considerable diversity in the physical properties of various polymers and composite-polymers, plastics as a class are generally lower in strength and stiffness than metals. The development of composite materials, that is the reinforcement of polymers with fiber glass or other minerals, has dramatically increased the strength to stiffness ratio of polymer products to one that is approaching that of die cast metals[20]. The proportion of a polymer that is crystalline not only effects the appearance of the material, but also effects the modulus of elasticity and the melting point. The greater the proportion of crystalline material in the polymer, the higher the modulus of elasticity and the higher

melting point [21]. Tensile strength, solubility, and hardness are also associated with the degree of crystallinity in the polymer[22]. The degree of crystallinity and the morphology of the crystalline materials have great effects on the mechanical properties, and since these factors have a large range of variability, the mechanical properties of crystalline polymers take on a bewildering array of possibilities[23]. The entire family of polymer materials, whether organic or inorganic, are comprised of extremely large molecules, macromolecules. Polymers may be classified as elastomers (rubbers), plastics, and fibers depending on the strength of the intermolecular forces[22]. There is considerable overlap in these broad classifications. Rigid plastics and fibers have the characteristic of high moduli of elasticity, while elastomers have large reversible elongations when a stress is applied. A rigid plastic exhibits a plateau above the yield point on a stress-strain diagram, which in the family of polymers is most similar to that of some metals. Since plastics are viscoelastic, that is, they are complex aggregates of many different elastic and fluid elements, their physical properties are intermediate between crystalline metals and very viscous fluids. When a plastic is loaded, they are subjected to many variables that do not generally affect metals[24] .

Stress-strain curves for plastics vary substantially with the rate of loading and relatively small changes in temperature. Plastics do not have proportional limits as metals, and in theory and practice their stress-strain diagram are curvilinear at ordinary loading rates and use-temperatures. Some rigid plastics have small linear ranges on stress-strain diagrams at room temperature. This linear range is substantial for some highly filled (composite) and rigid thermoset plastic materials, although this stress strain phenomenon is still dependent on test conditions. Yield points for plastics are not sharply defined or do not exist, and as a result this quantity is a very uncertain criteria for product design. Although plastics can be made to rupture in tension, many plastics will not rupture during bending and compression

tests. Because of this, stress-strain testing of plastics frequently can not furnish usable data for maximal loads in bending or compression[24]. Since traditional stress-strain tests are done during short time spans, they do not take in to account the time dependent viscoelastic properties of plastics. The long term behavior of plastics must be evaluated by creep tests where deformation and rupture are measured as functions of time under static tensile, flexural, or compressive loads[24]. Typical stress-strain data tends to grossly overestimate the properties of plastics since time dependent changes are not taken into consideration. The elastic limit of plastics is also dependent on time and temperature. Since the designed equations for metals are based on elasticity and presume elastic constants, such as tensile modulus, the viscoelastic nature of plastics is not well demonstrated with these equations. In order to use these equations with viscoelastic materials, is necessary to modify viscoelastic or creep data by means of curve plotting or equations [24]. Traditional stress-strain data may be useful in obtaining a general or rough estimation of the level of strength and rigidity that a given plastic has compared to other plastics[24]. Ultimate product design requires that the creep properties of a given polymer be well understood. The fatigue characteristics of the polymer also need to be known before the product design can be completed.

Optimal Clinical Applications of orthodontic wires

The practical applications of orthodontic wires can be optimized by carefully selecting the appropiate alloy type and wire size to meet the demands of a specific clinical situation. Kusy[25] and Kusy and Greenberg[26,27] have recommended a sequential use of arch wires selected for optimal use of the mechanical properties of their constituent alloys.

The authors suggest that for initial leveling requiring wide ranging tooth movement, a 0.016" nitinol wire outperforms a 0.0175" multistranded stainless steel wire, and a 0.018"

round nitinol wire is superior to a 0.014" stainless steel wire, as well as a 0.018" square nitinol wire outperforms a 0.014" stainless steel wire. However in a recent report, Kusy and Stevens[28] , noted that a 0.015" multistranded demonstrate a greater working range than either nitinol or beta-titanium wires of similar or greater dimensions. The authors also indicated that multistranded wires compare favorably with titanium wires and may provide a viable alternative to the more expensive titanium wires for initial leveling, for example, where anterior dental crowding is present. The intermediate stages of treatment require closing loops, gable bends, and attachments. Beta-titanium wires meet these demands while providing greater range of activation than stainless steel or Co-Cr wires. In torsion, the formability and stiffness of stainless steel and Co-Cr wires far exceed those of the titanium wires, thereby making these alloys the finishing wires of choice. The lower friction between stainless steel or Co-Cr wires and brackets suggest that these wires may be more suitable than other alloys for movement of teeth along a wire.

Until the recent introduction of new types of orthodontic alloys, increments in wire stiffness during treatment were instituted by progressively increasing the cross-section of stainless steel wires. Burstone[29] refers to this as "variable cross-section orthodontics". The author further states that advances in orthodontic wire alloys have made it possible to control wire stiffness by varying material properties- namely, the modulus of elasticity. This is known as "variable modulus orthodontics".

Burstone[29] formulates his concepts by stating that the overall stiffness of the orthodontic appliance (S) is determined by the wire stiffness (Ws) and design stiffness (As) as represented by:

$$S = Ws \times As$$

Design stiffness (As) is dependent on factors such as interbracket distance and the incorporation of loops and coils into the wire. Changes in wire stiffness (Ws), on the other

hand, can be brought about by altering the cross-sectional stiffness (Cs) and/ or the material stiffness (Ms) as designed by the formula:

$$Ws = Ms \times Cs$$

where the cross-sectional stiffness is determined by a cross-sectional property such as moment of inertia of the wire and the material stiffness is dependent on the modulus of elasticity of the alloy. Therefore, an increase in appliance stiffness (S) can be brought about not only by change in appliance design or increase in cross-sectional thickness of the wire, but also by selecting a material with a higher modulus of elasticity. The relationships of material stiffnesses for stainless steel, cobalt-chromium, nickel-titanium and beta-titanium wires are in the ratio of 1:1.2 : 0.26 : 0.42. Material stiffness for multistranded wires range from 1/25 to 1/5 of that for single-stranded stainless steel wires.

ANTERIOR DENTAL CROWDING

Anterior dental crowding is perhaps the most frequently occuring characteristic of malocclusion; yet the term crowding is one of the most ambiguous terms in the dental vocabulary. Patients, parents, the public and the profession are unquestionably aware of and concerned with dental crowding and avidly seek its correction. Terms such as dental irregularity, overlap, and crowding are subjective, nonquantitative, even emotional terms which can represent a diversity of clinical meaning. Adjectives such as mild, moderate, severe, significant, etc. are descriptively helpful but still allow a wide range of interpretation[45].

An index or score of incisor crowding would be helpful in many respects[45]. Public health and insurance programs are becoming increasingly interested in indices used to establish malocclusion severity as a guide in determining treatment priorities. Epidemiologic studies comparing the presence and amount of various characteristics of

occlusion would benefit from a quantitative measure of the severity of dental irregularity. An index would be valuable in assessing the degree of initial malrelationship as well as in comparing initial crowding with posttreatment and postretention results.

Evidence of progressive instability is often first noted by progressive crowding of mandibular incisors following removal of retaining devices[45]. Whatever the multiplicity of causes for relapse, mandibular incisor irregularity is often the precursor of maxillary crowding, deepening of the overbite, and generalized deterioration of the treated case. Since the status of the six mandibular anterior teeth seems to be a limiting factor in treatment and stability, it would seem logical to develop a diagnostic index that would accurately reflect the mandibular anterior condition[45].

When developing an index a list of minimal requirements should be considered. Jamison and McMillan[30] suggests:

1) It should be simple, accurate, reliable and reproducible.

2) It should be objective in nature and yield quantitative data which may be analyzed by current statistical methods.

3) It must be so designed as to differentiate between handicapping and nonhandicapping malocclusions.

4) The examination required must be one that can be performed quickly, even by examiners without special instruction in orthodontic diagnosis.

5) It should be usable on either patients or study models.

Numerical indices have been developed to rank or score the severity of malocclusion relative to a preconceived orthodontic normal or ideal. Several malocclusion indices are in current use including:

HLD Index[31] (1960)

Draker stated that "Labio-lingual deviation" from a fictitious norm rather than the state of "occlusion" are of epidemiological importance in establishing prevalence rates for physically handicapping orthodontic defects, and degree of the physical handicap. Crowding or "Labio-lingual spread" meaning the deviation of each incisor, in millimeters from a normal arch. For this to be applicable to an index two steps will be needed: 1) A determination of the "norm". 2) A list of those labio-lingual deviations from the "norm" which experience has shown to be grossly handicapping. Out of these considerations, then, would come an index of Handicapping Labio-Lingual Deviations (HLD Index). It may be expected to yield prevalence data if used in screenings. It is believed to be of value also in determining the rating of an individual case.

The Index of the American Association of Orthodontists[32] (1968)

A handicapping malocclusion record form was used to provide a means for establishing priority for treatment of handicapping malocclusion in the individual child according to severity as shown by the magnitude of the score obtained in assessing the malocclusion from dental casts or directly in the oral cavity. Handicapping malocclusion meaning conditions that constitute a hazard to the maintenance of oral health and interfere with the well being of the child by adversely affecting dentofacial esthetics, mandibular function or speech. Salzmann subjectively scored crowding for each tooth as either present or absent, with no distinction made between varying amounts of crowding.

The Occlusal Index [33] (1971)

Summers developed a system to identify and score occlusal disorders due to the lack of a universally acceptable index of occlusion. Nine characteristics were considered for the proper scoring, dental age, molar relation, overbite, overjet, posterior cross-bite, tooth displacement (actual and potential), midline relations and missing permanent teeth. He used a method scoring 1 for cases demonstrating 1.5 to 2 mm of incisor deviation or 35 to 45 degrees of rotation from normal arch alignment and 2 for greater than 2 mm of displacement or greater than 45 degrees of rotation from normal arch form. The main purpose of describing these scoring procedures was to standardize scoring procedures so that comparable results may be obtained among investigators.

The Ackermann-Proffit Rating Scale [34] (1973)

They present a systematic approach to orthodontic treatment planning in complex problems. It is based on the collection of an adequate data base; a quantitative systematic description of the malocclusion, which generates a list of problems and therefore defines the treatment objectives; tentative treatment plan for the individual problems; and generation of a final treatment plan based on interaction among the tentative solutions to the problem. They described a subjective mean of assessing crowding which involved the rating severity on a scale from 0 to 5.

Barrow and White Index[35] (1952)

Barrow and White described crowding in terms of fractions of permanent central incisor width. For example, mandibular crowding of a given case could be described as one third of a lower central incisor for a mild crowding situation while four thirds or more would describe crowding of a more severe nature.

Moorrees and Reed Index[36] (1954)

Moorrees and Reed stated that crowding could be visualized as the numerical difference between mesiodistal crown width, and the space available, an arch length assessment rather than a crowding index.

Van Kirk and Pennel Index[37] (1959)

Van Kirk and Pennel used a method similar to Summers[33] . They suggested a numerical but not a truly quantitative scoring method, with ideal alignment scored zero, less than 45 degrees of incisor rotation or less than 1.5 mm of incisor displacement scored 1, and greater than 45 degrees of rotation or greater than 1.5 mm of displacement scored 2. Grainger[38] employed the same method in the TPI (Treatment Priority Index).

Bjork and colleagues[39] (1964)

Bjork and colleagues modified the Van Kirk method slightly by using 15 degrees as the division between normal and crowded incisors; in this method, crowding was further assessed by recording incisors which are deviated from the "midline of the alveolar process" by more than 2 mm.

Carlos[40] suggested that any index which is to be used for the study of a disease or condition must stand the tests of validity and reliability. To be valid, a test must actually measure what it proposes to measure. Carlos stated that one method of assessing and index, which represents a score of severity, is to obtain index scores and independently compare them with the subjective clinical ranking of severity on a scale of measurement. Computation of the correlation between clinical and index scores would statistically demonstrate index validity.

Reliability (also known as reproducibility or precision) is concerned with the degree or consistency between results of different examiners or the same examiner on different occasions. Several studies have dealt with the reliability of index scores[41-44]. For example, Popovich and Thompson[44] found an association between intraexaminer variation and the degree of malocclusion being assessed, noting greater error in Grainger's Index at the low and medium severity levels than at the higher scores.

Having all these different ways of assessing anterior dental crowding, The Irregularity Index developed by Robert Little[45], is the one used to obtain the data for this particular study. It was chosen because it is simple to use, measures what it purports, is reliable and shows consistent results. Its only major disadvantage that is taken into consideration for this particular study is that tends to exaggerate cases with considerable irregularity but little arch length shortage. In addition, it does not take into account the patients cephalometric pattern, facial esthetics, age, tooth morphology, the effect of habit correction, etc., factors which must be considered in addition when one is assessing a case and formulating a comprehensive diagnosis. This index will be discussed in detail in the Materials and Methods portion.

MATERIALS AND METHODS

The sample was randomly divided into three groups of five patients each. One group was treated with the Optiflex arch wire, the second with PEEK and the third with multistranded arch wires (see table III). The total sample consisted of fifteen boys and girls between the ages of eleven and fifteen years that presented lower anterior crowding.

TABLE III

GROUP No.	ARCH WIRE	SAMP. No.	AGES	SEX
1	Optiflex	5	11 to 15 yrs.	No predilection
2	PEEK	5	11 to 15 yrs.	No predilection
3	Multistranded	5	11 to 15 yrs.	No predilection

Esthetic materials tested.

Johnson[13], searched for transparent or tooth colored materials available in wire form and in dimensions similar to those used in orthodontics. He included Optiflex esthetic arch wire, which is a clear arch wire developed by Ormco Company used for initial alignment of teeth. With the collaboration of the engineering department (Material Science building), a tensile and a three point bending test was performed on the "esthetic materials" chosen, as well as on the most frequently used arch wires in Orthodontics. The laboratory results showed that the "esthetic material" with the best potential to serve as an arch wire was PEEK (Polyether Ether Ketone).

From the "esthetic arch wires" tested by Johnson[13] (1990), only PEEK and Optiflex arch wires were chosen for the clinical study. For the control group, the multistranded (Respond) arch wire was used. It was chosen because it is widely used as an initial alignment arch wire and has shown to be clinically effective. Table IV shows the physical properties of Optiflex, PEEK and multistranded as determined by Johnson[13].

TABLE IV

ARCH WIRE	FLEX. E MODULI	YIELD STRENGTH
Optiflex .020"	0.36 x 10^6 psi	9 x 10^6 psi
PEEK .023"	0.97 x 10^6 psi	17 x 10^6 psi
Multistr. .0175"	1.64 x 10^6 psi	37 x 10^6 psi

Values found by Johnson[13]. Master's thesis: Esthetic Orthodontic Arch Wires.

PEEK[19] (Polyether Etherketone), pertains to a family of engineering thermoplastics in which the combination of ketone and aromatic moieties imparts exceptional high temperature properties combined with excellent thermal stability. Polyketones are well suited to demanding applications such as advanced composites, wire coating, chemical resistant filters, integrated circuit wafer carriers, and motor vehicle bearings.

Presently it is available in a light brownish color. Shakespeare Monofilaments Inc.*, the supplier of PEEK mentioned the possibility of altering its color which would better fit our needs.

*Shakespeare Monofilaments Inc.
P. O. Box 4060, Columbia SC. 29240

Optiflex Esthetic Arch Wire[14], is a fiber optic consisting of a glass core and nylon coating used for initial alignment of teeth. Although it is already being used by some orthodontists, no clinical studies have been conducted to show its efficacy. It has been shown to be very brittle but it is the first true clear or esthetic arch wire and is the most recent one marketed.

Multistranded Arch Wires (Respond), are made of stainless steel and composed of specific numbers of thin wire sections coiled around each other to provide a round or rectangular cross-section. Kusy and Dilley[10] investigated the strength, stiffness and springback properties of multistranded wires in a bending mode of stress. They noted that the stiffness of a multistranded 0.0175" stainless steel arch wire was similar to that of 0.010" single stranded stainless steel wire.

The multistranded arch wire was also 25% stronger than the 0.010" stainless steel wire. The 0.0175" multistranded arch wire and 0.016" nitinol wire demonstrated similar stiffnesses. However, nitinol tolerated more than 50% greater activation than the multistranded wire. The multistranded was also half as stiff as a 0.016" beta-titanium wire.

In more recent investigations, Kusy and Stevens[28] stated that although the elastic properties of multistranded wires vary widely, several of these wires compare favorably with some of the beta-titanium and nitinol wires.

Ingram, Gipe and Smith[49], noted that titanium alloy wires and multistranded stainless steel wires have low stiffnesses when compared with solid stainless steel. The investigators also found that most multistranded wires had a springback similar to that of nitinol, but a larger springback when compared with solid stainless steel or beta-titanium wires. Unlike stainless steel wires, in which springback decreases with increasing thickness, the titanium and multistranded wires have springback properties that are relatively independent of wire size. These findings agree with those made by Kusy and Dilley[10].

ARCH WIRE DIMENSIONS

The arch wires chosen for the study are available in the following diameters (see table V).

TABLE V

ARCH WIRE	DIAMETER
OPTIFLEX	.0175" .0195"
PEEK	.0157" .022"
MULTISTRAND	.0155" .0175" .0195"

The arch wire sizes chosen for the study were:

PEEK - .022 inch.

OPTIFLEX - .0175 inch.

Multistranded (RESPOND) - .0175 inch.

Due to the low stiffness of PEEK the .022" size was chosen for the study to generate adequate force for tooth movement. Once the diameter of the PEEK wire was determined the size of Optiflex and multistranded wires that gave similar force and deflection during activation as PEEK, were chosen.

The deflection of the PEEK .022" wire was checked applying four grams of force with a Dentronix Gauge. The same force (four grams) was applied to the Optiflex (.0175" and .0195") and to the Multistranded (.0175" and .0195"). The deflection shown by the Optiflex .0175" and Multistranded (Respond) .0175" was very similar to that obtained with the PEEK .022".

Johnson[13], reported during the three point bending test a load corresponding to the flexural yield strength at a 0.2% offset and 0.5" span length of 0.16 +/-0.001 lbf. for the PEEK wire .022". The Optiflex esthetic arch wire .0175" required a 0.15 +/- lbf; and the multistranded (Respond .0175) arch wire required a 0.15 +/- lbf. (see table VI).

TABLE VI

ARCH WIRE	FLEXURAL YIELD STRENGTH 0.2%,0.5 Span
PEEK .022"	0.16 +/- 0.001 lbf.
Optiflex .0175"	0.15 +/- 0.002 lbf.
Mutistranded .0175"	0.15 +/- 0.009 lbf.

Considering this results it was decided to use the Optiflex and multistranded (Respond) arch wires in diameters of .0175". If the bigger diameters of Optiflex and multistranded (Respond) arch wires were used there was a possibility of bias since the force produced by the arch wires would be greater than that produced by the PEEK wire.

All erupted teeth in the lower arch were banded/bonded with .022" edgewise brackets. Elastic ligatures were used to secure the wire into the slots.

IRREGULARITY INDEX

The index chosen to measure the crowding before and after the experiment was developed by Robert Little[45] (1975) and is called The Irregularity Index. It was chosen since it is reliable, valid, current and because crowding can be measured directly from models with the same accuracy and without bothering the patient trying to do it intraorally.

This method involves measuring the linear displacement of the anatomic contact points (as distinguished from the clinical points) of each mandibular incisor from the adjacent tooth anatomic point; the sum of these five displacements representing the relative degree of anterior irregularity (Fig. 1).



Fig. 1. Occlussal view of lower model showing anterior irregularity or crowding.

Perfect alignment from the mesial aspect of the left canine to the mesial aspect of the right canine would theoretically have a score of 0, with increased crowding represented by greater displacement and, therefore, a higher index score. Rather than measuring from contact point to ideal arch form or to another subjective point, the actual linear distance between adjacent contact points is determined. Such a measure represents the distance that anatomic contact points must be moved to gain anterior alignment.

As suggested by Peck and Peck[46] , measurements were obtained with an electronic caliper. It was chosen for being accurate, consistent and easy to use. Each of the five measurements was obtained directly from the mandibular cast rather than intraorally, since proper positioning of the caliper is essential for consistent accuracy. The mandibular cast was viewed from above, sighting down onto the incisal edges of the anterior teeth. The caliper was held parallel to the occlusal plane while the beaks were lined up with the contact points to be measured (Figs, 2 and 3). Each of the five measurements represents a horizontal linear distance between the vertical projection of the anatomic contact points of adjacent teeth. Although contact points of anterior teeth can vary in the vertical plane, correction of vertical displacement does not appreciably affect anterior arch length; therefore, all vertical discrepancies of contact points must be disregarded. Care was taken to hold the caliper consistently parallel to the occlusal plane while obtaining each measurement, thereby ensuring the recording of only horizontal displacement.

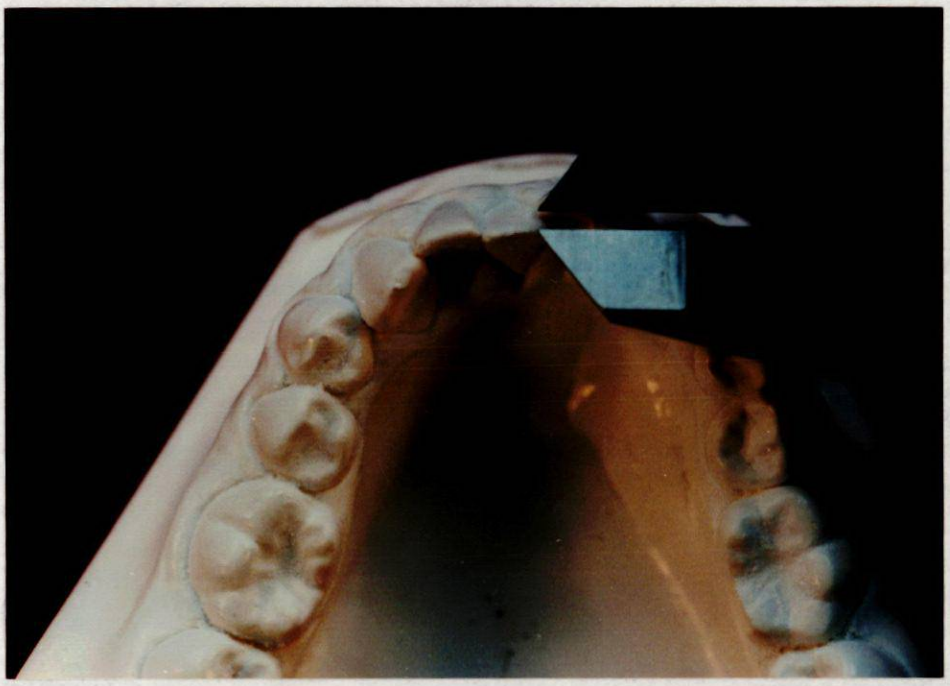


Fig. 2. Occlussal view of lower model and electronic caliper showing measurements of anatomic contact points.

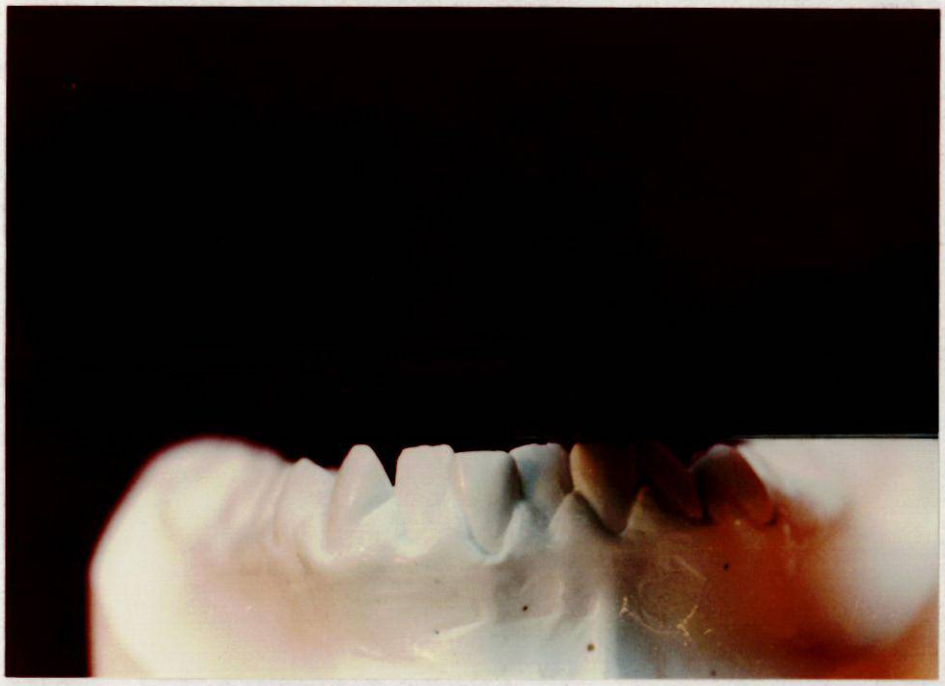


Fig. 3. Labial view of lower model and caliper beaks. The beaks should be parallel to the occlussal plane.

After developing the appropiate protocol and consent form (attached) it was sent to the Human Research Committee for approval. At the same time the faculty and residents of the orthodontic department at C.W.R.U. were contacted and informed of the project to see if they could collaborate with the incoming patients assigned to them. Once the study was approved by the Human Research Committee and the Orthodontic Department at C.W.R.U. it was set as follows:

During the consultation while the resident reviewed the treatment plan with the patient and parents, the study was mentioned and explained either by the resident in charge of the patient or by the person conducting the study (Dr. Wulfran Moron). Once they understood the objectives, advantages and disadvantages, and they decided to participate the consent form was signed by the patient, parents and resident in charge of the treatment. At the bonding and banding appointment a lower impression and intraoral pictures were taken as initial records.

The initial arch wire (either PEEK, Optiflex, or Multistranded Respond), was placed on the lower arch and left in place for eight weeks. The wire was checked every two weeks to record any undesirable effects such as fracture, permanent deformation or other inconvenience that the patient might present. If a wire fractured during the eight week period, it was replaced. While the arch wire was in the mouth the Irregularity Index was applied to the initial models.

Statistical Analysis

An ANOVA test was performed on the initial irregularity scores to see if any bias was present between groups because there was different amount of crowding within them. The results will be discussed later.

After eight weeks the arch wires were removed and final impression and pictures were taken. The Irregularity Index was then measured on the final models. A student t- test was performed to determine significance of the differences between mean change for each treatment.

Scanning Electron Microscopic (SEM) evaluation of PEEK wires.

Once the clinical test was done, a total of six PEEK wires (5 used and 1 not used) were taken to the Department of Chemical Engineer of C.W.R.U. to evaluate changes on the surface and diameter of the wire. The wires were coated with gold to obtain a better image.

Changes in diameter were evaluated at a magnification of 100 times. The wire was measured at the top, middle and bottom portions and a measurement in inches was given. Once this data was recorded an area of each arch wire was chosen for a photographic picture.

The pictures were taken at a magnification of 3200 x. A comparison between the surface of the PEEK wire not used and the surface of the used one's was then established. The data and comparison of this last part will be analyzed in the results and discussion portion.

RESULTS

The distance between the anatomic contact points of each individual tooth and its adjacent was measured with an electronic caliper in a labio-lingual direction. Five initial measurements were taken from each model and then added for a Initial Measurement Total (IMT). This figure represented the Irregularity Index in each individual case. The initial measurements were obtained from the lower initial models and are recorded in Table VII. All measurements were obtained in millimeters.

TABLE VII

Initial Measurements Total (IMT) in mm.

VARIABLE	SAMPLE SIZE	IMT RANGE	IMT MEAN	IMT STD. DEV.
Optiflex	5 patients	3.37 to 11.61	5.576	3.077
PEEK	5 patients	3.00 to 7.03	4.792	1.488
MULTSTRAND	5 patients	1.42 to 12.74	5.722	3.793

All patients were treated by non -extraction. No sex predilection was considered. The age of the patients ranged between 11 to 15 years. Since the crowding varied from individual to individual an ANOVA (analysis of variance) was performed to see if the averages for each treatment group were equal. Table VIII shows the data and results.

TABLE VIII

Initial Measurement Total (IMT) in mm.

VARIABLE	Pt. 1	Pt. 2	Pt. 3	Pt. 4	Pt. 4
OPTIFLEX	5.18	3.96	11.61	3.76	3.37
PEEK	3.85	7.03	4.08	6.00	3.00
MULTISTRAND	3.82	12.74	4.98	5.65	1.42

VARIABLE	SUM IMT	MEAN	STD. DEV.
OPTIFLEX	27.88	5.576	3.077
PEEK	23.96	4.792	1.488
MULTISTRAND	28.61	5.722	3.793

The crowding in the Optiflex group ranged from 3.37 to to 11.61 mm. In the PEEK group it ranged from 3.00 to 7.03 mm. And in the Multistrand group it ranged from 1.42 to 12.74 mm.

There was no significant variation between the means obtained for each group. The analysis of variance showed an f value of 0.01151. The null hypothesis is not rejected at a significance level of 0.01. No bias was found between initial total measurements of the treatment groups.

At the end of eight weeks, final measurements were taken and the irregularity index was then recorded in Table IX. A student t-test was performed to see if there were any significant differences in the changes between the three groups.

TABLE IX

Final Measurement Total (FMT) in mm.

VARIABLE	Pt. 1	Pt. 2	Pt. 3	Pt. 4	Pt. 4
OPTIFLEX	0.82	0.27	5.04	2.32	1.10
PEEK	1.20	4.76	2.39	3.76	2.64
MULTISTRAND	1.42	2.92	5.98	1.95	2.63

The final measurements total in the Optiflex group ranged from 0.27 to 5.04 mm. In the PEEK group it ranged from 1.20 to 4.76 mm. And in the Multistrand group it ranged from 1.42 to 5.98 mm.

Differences between IMT and FMT are shown in table X.

TABLE X

Change in value of Irregularity Index (mm)

(Difference between IMT and FMT)

VARIABLE	Pt. 1	Pt. 2	Pt. 3	Pt. 4	Pt. 5
OPTIFLEX	4.36	3.69	6.57	1.44	2.27
PEEK	2.65	2.27	1.69	2.24	0.36
MULTISTRAND	2.40	6.76	3.03	3.02	-1.50

VARIABLE	MEAN	STD. DEV.
OPTIFLEX	3.67	1.77
PEEK	1.84	0.81
MULTISTRANDED	2.74	2.63

No significant difference was found between the means obtained after treatment. A noticeable standard deviation (S.D.=2.63) was seen in the Multistrand group. This can be attributed to one of the patients in this particular group where the irregularity index increased. The results of the t -test is shown in table XI.

TABLE XI

VARIABLE	t	P VALUE
Optiflex vs PEEK	2.10	.053
Optiflex vs Multistrand	0.65	.276
PEEK vs Multistrand	0.73	.253

The t-test showed no significant difference when comparing Optiflex and PEEK with multistranded arch wires for the correction of crowding. When comparing Optiflex with PEEK some difference was found at a 95% level of confidence.

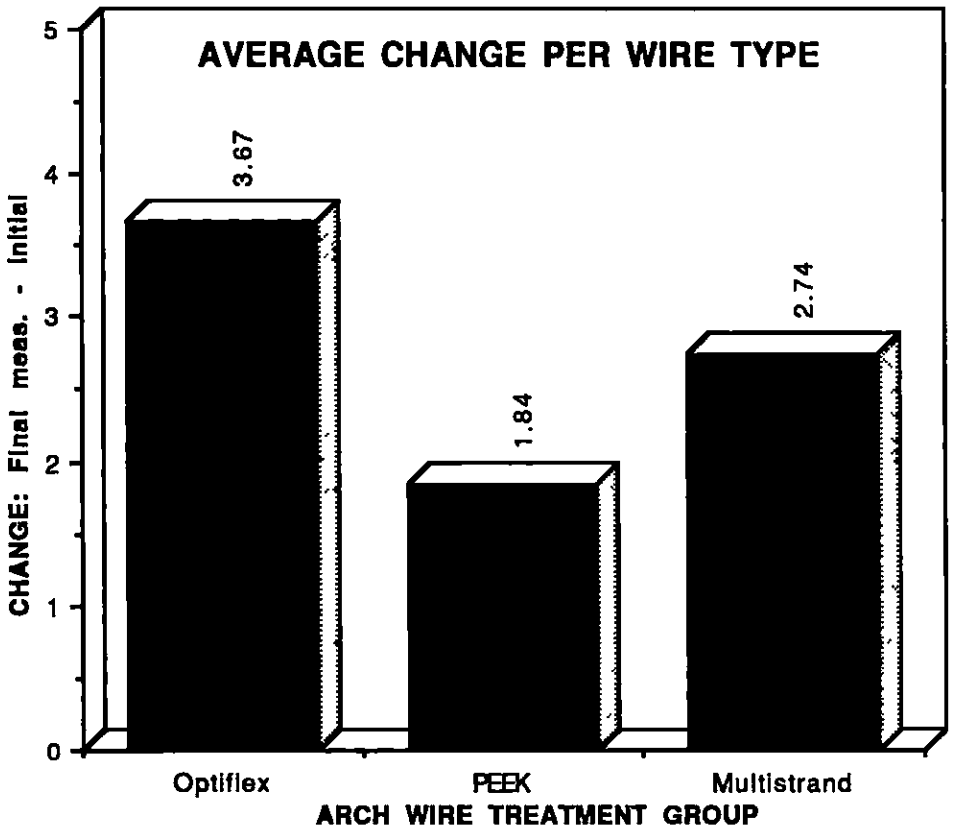


Fig 4. Histogram showing average change per wire type.

PEEK WIRES (SEM)

The PEEK wires were gold coated to obtain a good image in the SEM. The diameters were measured at a magnification of 100x in three different sections of the wire (see table XII).

TABLE XII

Diameters of used and unused PEEK wires in inches.

ARCH WIRE	TOP	CENTER	BOTTOM
Unused	.0244"	.0244"	.0244"
Used #1	.0251"	.0255"	.0259"
Used #2	.0255	.0255"	.0236"
Used #3	.0248"	.0255"	.0255"
Used #4	.0248"	.0244"	.0248"
Used #5	.0256"	.0255"	.0255"

VARIABLE	MEAN	STAND. DEV.
Unused PEEK	.0244"	+/- 0.00
Used PEEK	.0251"	+/- 0.03

According to the measurements obtained with the SEM the initial diameter of .022" listed by the manufacturer was not accurate. The mean average diameter of the unused wire was .0244". The used wires showed a slight increase in diameter with a mean value of .0251".

Polaroid photographs were taken to an area of each PEEK wire. The unused wire showed a smooth surface with some lines or striations following a vertical pattern (Fig. 5). The used wires showed some roughness on the surface but no apparent cracks or fractures were evident (Fig. 6 & 7).

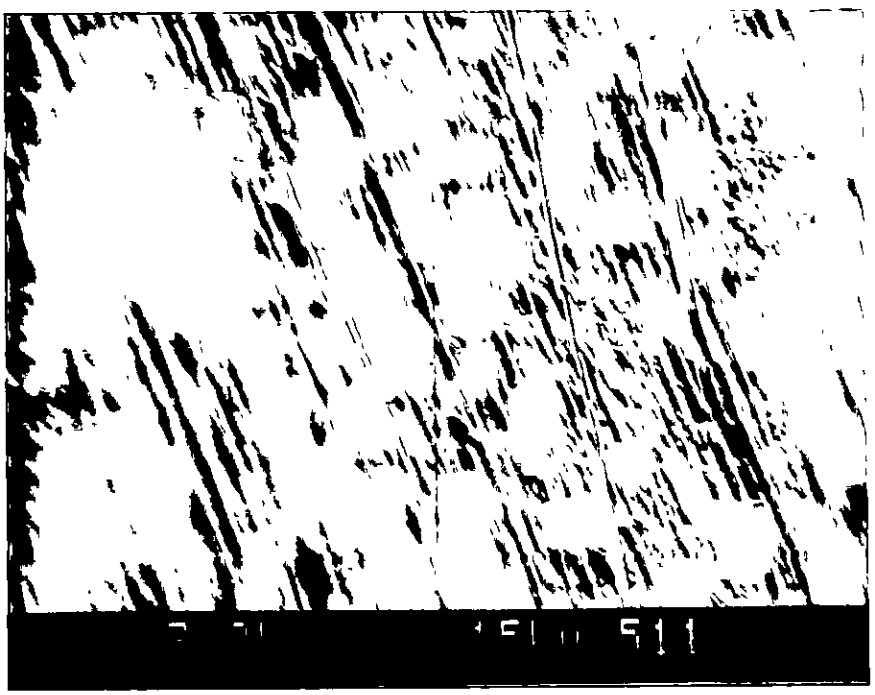


Fig. 5. SEM image of unused PEEK wire. Notice the smooth surface following a vertical pattern.

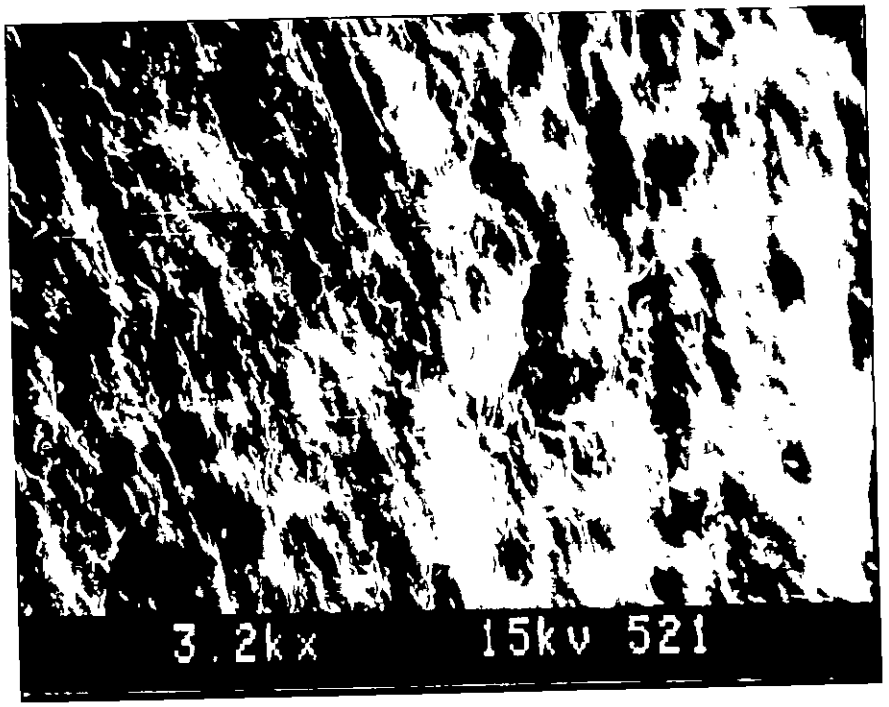


Fig. 6. SEM image of used PEEK wire. Notice the roughness of the surface.

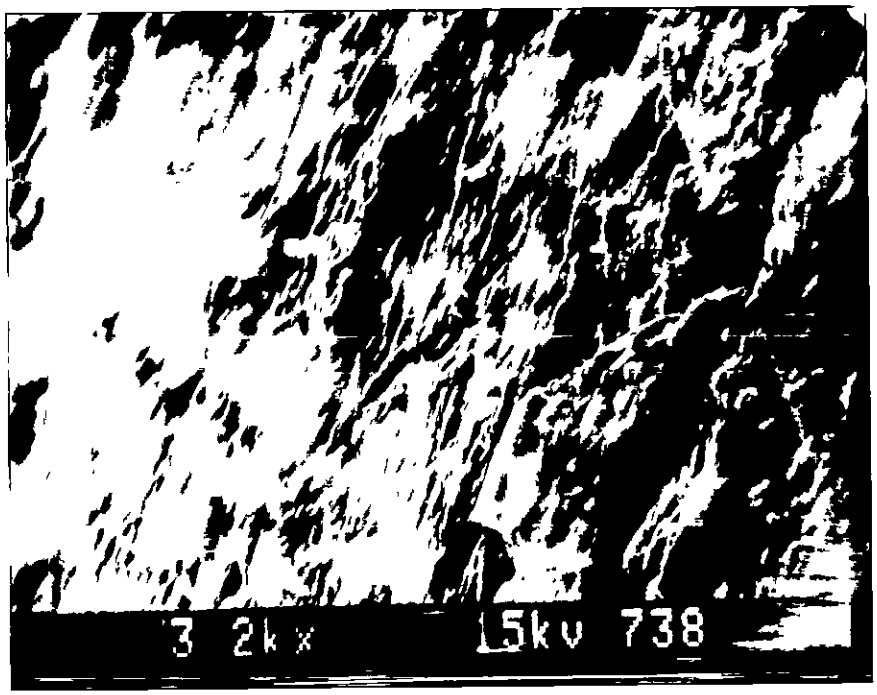


Fig. 7. SEM image of used PEEK wire. Notice the deposits on the surface.

DISCUSSION

A clinical trial was conducted to evaluate the efficiency of two esthetic arch wires used for initial alignment of teeth. One was Optiflex which is made of nylon coated glass fiber and the other was made of polyether ether ketone (PEEK). Comparison was made with a multistranded stainless steel arch wire, which is commonly used as the initial arch wire in orthodontic treatment.

The study was performed on patients between the ages of eleven and fifteen years. Since orthodontic tooth movement in young patients differs from adults. In young individuals a better response has been seen. The tissue elements undergoing changes during tooth movement are primarily the periodontal membrane with its supporting fibers, cells, capillaries, and nerves and secondarily the alveolar bone.

During tooth movement the fiber bundles must elongate. Following stretching of the principal fibers and widening of the periodontal space there is a definite increase in cellular elements. Connective tissue cells produce new fibrils, thus ensuring elongation of periodontal fibers and further movement of the teeth.

In histologic sections of the adult alveolar bone, one may find large marrow spaces, in the apical region on the lingual side of the teeth. However, the bone walls of the middle and marginal region are often quite dense with few marrow spaces. It is in this latter area that the bone changes will occur when the tooth movement is initiated. Lack of marrow spaces implies that bone resorption may take more time.

The bone wall in young persons usually contains large marrow spaces, open clefts, and canals that communicate with the periodontal membrane. Tooth movement is facilitated by

the formation of resorptive cells which increase according to the number of the marrow spaces present[51] .

Validity of Irregularity Index

The Little index was chosen for this study since it has been shown to be valid and reliable. In 1975 Robert Little conducted a study in which seven orthodontists with varying backgrounds and clinical experience evaluated the anterior irregularity present in fifty casts selected to represent a wide range of crowding.

Each cast was subjectively ranked on a scale ranging from 0 to 10. In the second phase of the study five of the same orthodontists used the irregularity index to determine quantitatively the index scores of twenty-five of the same mandibular casts. The examiners determined the irregularity index on two separate occasions, at least one month apart and at least one month after subjectively assessing irregularity.

The data were analyzed as follows:

In the subjective interexaminer variability an analysis of variance rejected the null hypothesis ($P<0.01$) that all judges rated the casts the same.

In the irregularity index intraexaminer variability a t test demonstrated no significant difference between the two trials for six of the seven examiners ($P<0.01$), indicating good consistency between first and second measurements.

Comparison of Initial Irregularity Indices

The amount of lower arch irregularity varied considerably between patients (Table VII). Therefore to avoid any possibility of error due to bias between the groups, an ANOVA test was performed. An F value of 0.1151 showed that the three groups were statistically comparable.

A t -test was performed at the end of treatment to determine if the wires were significantly different in the efficiency to correct crowding. The measurements for Optiflex showed a mean value of 3.67; the PEEK showed a mean value of 1.84; and the multistranded showed a mean value of 2.74. No significant mean difference was found when comparing the Optiflex or PEEK wires with the multristranded (control group). When the Optiflex was compared with the PEEK a P value of 0.05 was observed (Table XI). It can be stated that some significance was found at a 95% level. The Optiflex fiber glass reinforced arch wire seemed to have a better ability to maintain its springback properties after repeated bends as opposed to polymers[13]. One of the reasons for the Optiflex to show a better response could be attributed to its glass component which gives a better springback to the arch wire. During ligation care must be taken in order not to exceed its elastic limit because permanent deformation will occur. This means that low forces are applied to the teeth during activation and deactivation of the arch wire. The arch wire seems to be more resilient and therefore, tooth response is better.

Optiflex arch wire

Although the Optiflex arch wire was statistically significantly better than the PEEK and multistranded for alignment of teeth, it was found to be very brittle. In two patients the arch wire fractured completely twice in each patient in the bicuspid region and had to be replaced. The reason for its fracture seems to be related to its glass component which forms part of its core. The bicuspid region is subjected to several different forces that vary from one individual to another. Continous and concentrated forces applied in this specific area will produce a stress. This repeated stress will create fatigue of the arch wire and once this fatigue propagates the wire fractures. The stress can be related to sharp canine cusps,

habits and different eating patterns. Sometimes the upper canine is too low and when the patient bites its cusp will in this case produce a repeated stress. Habits such as pencil and nail biting are also an example of creating a stress that will eventually produce fracture. And finally, a hard diet would also affect the physical properties of the arch wire.

Apart from complete fractures, when the wire was removed from the mouth a number of permanent sets were also seen along the arch wire. The explanation for not seing a complete fracture was attributed to the nylon matrix which held the glass component. Flexural cycling tests should be done to address the fatigue properties of materials.

Although Optiflex is clear or transparent its brittleness is a disadvantage. Chair time increases if the wire is replaced everytime it breaks. Patients and parents time would also be wasted because the patient will lose more school and the parents will have to quit work to bring the patients into the office. On the other hand, if the patient does not come in until his regular scheduled appointment the treatment time will be increased. If the wire had not been replaced at emergency visits in the patients in this group then most likely this wire would not have compared favorably against the others. Another disadvantage of Optiflex is that due to its brittleness it cannot be ligated with wire ligatures.

PEEK (Polyether Ether ketone) wire

The PEEK wire was available only in .0157" and .022" sizes. The .0157" showed little clinical value when tested on a typodont. It did not show enough springback for tooth movement and it took a permanent set easily. However, in 0.22" diameter it provided sufficient strength and stiffness. Its physical properties compare with the D-Rect. 016 x .022" arch wire as demonstrated by Johnson[13].

Presently, PEEK is available in a light brownish color which is not the ideal color for an esthetic wire. PEEK is a high temperature thermoplastic with a melting temperature of 633°

F and this may make the coloration process difficult with the commonly used polyolefins coloring agents. These coloring agents have a melting temperature of about 340° F [52]. After this point, these agents will degrade and alteration in color will occur.

Another disadvantage is the size of the arch wire (.022") since a number of orthodontists use .018" bracket slot. The manufacturer can produce PEEK in any requested size. In an .018" diameter less force will be exerted by the wire and the force may not be enough for ideal rate of tooth movement. Moreover, the strength of the wire in .018" dimension may not provide adequate strength and prevent against fracture or permanent deformation. It would be advisable to evaluate its clinical efficacy in each specific diameter before using it clinically. Other components such as carbon fibers or others, which have shown excellent physical properties should be added to its composition. Once this is accomplished, it should be tested to evaluate its springback, stiffness and other properties.

It was found that the diameter given by the manufacturer was inaccurate. He claimed the diameter of the PEEK wire to be .022" and according to the measurements obtained in the SEM it was .024". Due to this, deformation of the PEEK wire could be seen during insertion of the wire to the bracket slot. This will create a tight fit which may have decreased the amount of movement due to friction and binding.

PEEK costs about $200/lb. Presently it is sold in spools of 1,270 yards of wire per pound which translates to a cost of about 2.6 cents for a 6" length (Shakespeare Monofilaments catalog, 1990). The great cost advantage of these materials can be seen when compare to the national average of $2.20 for a preformed multistranded Respond (Ormco Co. catalog,1991) and a $3.80 average for a 6" length of Optiflex arch wire.

Of the wires tested if one were going to choose which wire to use for alignment, I would recommend the multistranded arch wires. The constant fracture and other limitations of the Optiflex would create an undesirable situation along treatment. Although PEEK showed

some clinical significance, its color is not ideal for esthetics. This is a big drawback if one is selling "invisible smiles".

Evaluation of the effect of using Optiflex and PEEK wires in ceramic and stainless steel brackets.

Ceramic brackets produce more friction than stainless steel brackets when used with stainless steel wire. In this study, stainless steel brackets were used and good tooth movement was observed when using Optiflex and PEEK wires. Although friction between the different wires and brackets was not tested in this study it is possible that there may be more friction when Optiflex and PEEK wires are used with ceramic brackets. This may hinder tooth movement. Moreover, ceramic brackets tend to have sharp edges. As stated earlier, Optiflex has a glass component which makes the arch wire very brittle. The sharp edges of the ceramic brackets could create stresses along the Optiflex arch wire. This stress concentration on the same spot may cause fracture of the arch wire.

Evaluation of PEEK wire in SEM (Scanning electronic microscope)

Three different areas of the PEEK wire were observed in the SEM to check changes in surface and diameter. A comparison was made between the surface of a original (Fig. 5) and two used wires (Fig. 6,7). The original wire showed an irregular surface with some vertical lines or striations following a parallel pattern. The used wires showed the same vertical pattern. However, in addition Fig. 6 shows a rough surface with evidence of some deposits. Figure 7 shows more clearly the deposits along the surface. No evidence of crack or fracture were seen in any of the wires seen under the SEM.

The roughness of the surface could be associated with saliva components. Saliva is made of inorganic and organic constituents. The inorganic portion is composed of calcium,

phoshorus, phosphate, sodium, magnesium, potassium carbonate, chloride and fluoride. The organic portion is composed of glucose, choloesterol, lecithin, urea, amino acids and proteins[53] . Other type of deposits could be related to food particles that dissolved and stick on the surface.

Table XII shows the different diameters obtained from the unused and used wires. The unused wire showed a constant measurement of .0244" on all surfaces measured. The used wires varied from .0236" to .0259" with a mean value of .0251". According to these measurements the used wires experienced a slight increase in diameter. PEEK has shown excellent resistance to a wide range of liquids. It can be used for thousands of hours in steam or high pressure water without significant property degradation. In common with many polymers, it absorbs low levels of moisture[19]. In this particular study, it is not clear if the change in diameter was produced by the absorption of liquids or the collection of deposits on the surface of the wire.

The measurement of the diameter of the wire under the SEM was found to be different from that specified by the manufacturer (.022"). No definite conclusion could be made about what type of deposits are present, but one can assure that no cracks or fracture are evident.

SUMMARY AND CONCLUSIONS

A clinical evaluation of two esthetic arch wires was conducted. Optiflex which is a fiber optic with a glass core and nylon coating and PEEK which is a thermoplastic made of Polyether etherketone. Results were compared with the multistranded stainless steel arch wires. Statistically, no significant difference was found when comparing the esthetic arch wires with the multistrand wire. Changes in surface and diameter of the PEEK were studied under SEM. Deposits were evident but no sign of crack or fracture were seen. The following conclusions can be drawn from this investigation:

(1) Optiflex, PEEK and multistranded arch wires were all found to be effective in aligning teeth.

(2) Optiflex was found to be the most effective, however its brittleness caused it to fracture on a number of occasions.

(3) The number of visits by the patient are increased with the use of Optiflex due to breakage.

(4) The present color of PEEK is not the most suitable for ideal esthetics.

(5) SEM images showed no significant changes in either the surface or the diameter of the PEEK wires.

The following are suggestions for future work:

(1) Design a protocol to improve or alter the color of PEEK wires.

(2) Design a protocol to evaluate PEEK in smaller diameters (e.g. .018").

(3) It may be necessary to reinforce polymers with carbon or other type of fibers to obtain a better springback.

(4) Evaluate fatigue and creep properties since polymer materials may behave very differently from metals.

(5) Is advisable to obtain SEM images of the Optiflex esthetic arch wire to check areas of fracture and analyze its surface.

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Clinical Evaluation of Esthetic Arch Wires

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The advent of ceramic brackets has improved the appearance of orthodontic appliances considerably. However, the orthodontic wires used currently are still generally not esthetic. The purpose of this study was to: (1) Evaluate the usefulness of a new esthetic synthetic material for use as an initial orthodontic wire. (2) Compare the clinical efficacy of this synthetic material with Optiflex and multistrand wire before and after use. (3) Study the surface of the new synthetic wire (NSW) with scanning electronic microscopy (SEM).

Fifteen boys and girls between the ages of eleven and fifteen years presenting with lower anterior crowding were randomly divided into three groups of five patients each. Group 1 was treated with the new synthetic wire, group 2 with Optiflex and group 3 with multistrand stainless steel arch wire. Models of the lower arch were taken before treatment and after eight weeks of treatment. Lower anterior crowding was measured before and after treatment using the irregularity index as described by Little.

All three wires were found to be effective in aligning teeth. There was no significant difference when comparing the multistrand wire with the new synthetic wire and Optiflex ($p < 0.05$). However, Optiflex fractured in four occasions and had to be replaced, thereby increasing the number of visits by the patient. SEM images of the NSW showed some deposits on the surface after use in the mouth but no cracks or structural faults were evident.

Clinical evaluation of two esthetic arch wires

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A clinical trial was conducted to evaluate the efficiency of two esthetic arch wires used for initial alignment of teeth. One was Optiflex which is a fiber optic with a glass core and nylon coating and the other a synthetic material pertaining to the family of polymers. Results were compared with a multistranded stainless steel arch wire (Respond). Statistically no significant difference was seen between the Optiflex and the synthetic material when compared with the multistranded arch wire. SEM evaluation of the synthetic material showed no changes on the surface but a slight increase in diameter.

The evolution of the appearance of orthodontic appliances has dramatically advanced in the last decade. Before this period, appliances were designed for function only, and appearance was not a criteria for selection of appliances. The patients were usually children; adults rarely accepted treatment because they were embarrassed to be seen wearing appliances that show. Many feared the reaction of social and business acquaintances and although these patients wanted to improve their appearance, the psychological trauma of metal appliances on their teeth was intolerable[1,2,3] . Due to this orthodontic companies developed the so called "esthetic or clear brackets" which are available in a ceramic, plastic or crystalline material.

Even with the advent of "clear" braces a high percentage of patients did not like the arch wire showing in their mouth when smiling. Some products are already available in the market. The teflon coated arch wire (White), which is the same stainless steel arch wire with a teflon coating which tends to peel off during tooth movement. The Optiflex arch wire (Ormco),which is a fiber optic in a glass core and nylon coating which has shown to be brittle. And the Spectra sentalloy (Masel), which is a nickel titanium with a teflon coating giving a whitich appearance.

In recent investigations Johnson[4] , ran a tensile and bending test to several synthetic materials available in wire form. One of the material's physical properties compared favorably with the stainless steel arch wires. Based on his results he concluded that this particular material could be clinically significant during initial alignment of teeth.

The purpose of this study was (1) to evaluate the clinical efficiency of the Optiflex esthetic arch wire; (2) to clinically evaluate the synthetic material; (3) to compare the results with the multistranded (Respond) arch wire; and (4) to evaluate under SEM any changes on surface or diameter of the synthetic material.

METHODS AND MATERIALS

A sample of fifteen boys and girls betweem the ages of eleven to fifteen years were randomly divided into three groups of five patients each. Each patient required to have some lower anterior crowding. One group was treated with Optiflex arch wire, the second with the synthetic material and the third with multistranded (Respond) stainless steel wire.

The Optiflex arch wire is a fiber optic consisting of a glass core and nylon coating used for initial alignment of teeth. Although it is already being used by some orthodontists, no clinical studies have been conducted to show its efficacy. It has been shown to be very brittle but it is the first true clear or esthetic arch wire in the market.

The synthetic material is a plastic or polymer which has shown excellent physical properties. According to Johnson[4] , it can compare clinically with the D-Rect. .016" x .022" arch wire which is regularly used as a initial arch wire. Presently is available in a light brownish color and the possibility of altering its color is being studied.

The multistranded arch wires are made of stainless steel and composed of specific numbers of thin wire sections coiled around each other to provide a round or rectangular cross-section. Kusy and Dilley[5], showed that .0175" multistranded and .016 nitinol have similar stiffness. However, nitinol tolerated more than 50% greater activation than the multistranded wire.

Table I shows the available diameter's of the arch wires chosen for the study.

Table I

ARCH WIRE	DIAMETER		
OPTIFLEX	.0175"	.0195"	
SYNTHETIC MATERIAL	.0157"	.022"	
MULTISTRAND	.0155"	.0175"	.0195"

Due to the low stiffness of the synthetic material the .022" size was chosen for the study to generate adequate force for tooth movement. Once the diameter of the synthetic material was determined the size of the Optiflex and multistranded wires that gave similar force and deflection during activation and deactivation were chosen.

A bending test was simulated in which four ounces of force were applied to the synthetic material, the Optiflex (.0175" and .0195"), and multistranded (.0155", .0175" and .0195"). Their deflection was recorded and compared with each other. The .0175" Optiflex and multistranded showed similar deflection as the .022"

synthetic material. Johnson[4] (1990), reported during the three point bending test of these wires a similar load corresponding to the flexural yield strength (Table II).

Table II

ARCH WIRE	FLEXURAL YIELD STRENGTH 0.2%,0.5 span
OPTIFLEX	0.15 +/- 0.001 lbf.
SYNTHETIC MATERIAL	0.16 +/- 0.002 lbf.
MULTISTRAND	0.15 +/- 0.009 lbf.

Considering this results it was decided to use the Optiflex and multistranded arch wires in diameters of .0175". Edgewise brackets with .022" slot were used in every patient.

The Irregularity index developed by Robert Little[6] (1975), was used to measure the anterior crowding at the begginning and end of treatment. It was chosen for being reliable, valid and crowding could be measure directly from the models.

At the bonding appointment a lower impression was taken for the initial model. The corresponding arch wire was placed and eight weeks later was taken out of the mouth and a final impression was taken. The irregularity index was run on the initial and final models. SEM images were obtained to evaluate the surface of the synthetic material. The diameter was evaluated at a magnification of 100 x. Three measurements were taken: top, middle and bottom portions. Means and standards deviations were then recorded.

An ANOVA test was performed on the initial irregularity scores to see if any bias was present between groups because there was different amount of crowding within them. A student t test was performed to determine significance between mean changes for each treatment.

RESULTS

The means and standard deviations of the total initial measurements obtained when the irregularity index was run are shown in table III.

Table III
(Total initial measurements (IMT) in mm.)

VARIABLE	IMT RANGE	MEAN	STD. DEV.
OPTIFLEX	3.37 to 11.61	5.576	3.077
SYNTH. MATERIAL	3.00 to 7.03	4.792	1.488
MULTISTRANDED	1.42 to 12.74	5.722	3.793

The ANOVA showed an f value of 0.01151. No bias was found between initial total measurements between treatment groups.

The difference between initial and total measurements, means and standard deviations are shown in table IV.

Table IV
Change in value of Irregularity Index (mm)
(Difference between IMT and FMT)

VARIABLE	Pt. 1	Pt. 2	Pt.3	Pt. 4	Pt. 5
OPTIFLEX	4.36	3.69	6.57	1.44	2.27
SYN. MAT.	2.65	2.27	1.69	2.24	0.36
MULTIST.	2.40	6.76	3.03	3.02	-1.50

VARIABLE	MEAN	STD. DEV.
OPTIFLEX	3.67	1.77
SYN. MAT.	1.84	0.81
MULTIST.	2.74	2.63

The P values for Optiflex, the syntheetic material and multistranded wires are shown in table V.

Table V

VARIABLE	P VALUE
OPTIFLEX	.053
SYNTHETIC MATERIAL	.276
MULTISTRAND	.253

The t test showed no significant difference when comparing the Optiflex and the synthetic material with the multistranded arch wires. When comparing Optiflex with the synthetic material some difference was found at a 95% level of confidence.

According to the measurements obtained with the SEM the initial diameter of .022" listed by the manufacturer for the synthetic material is not accurate. Table VI shows the means and standard deviations for the unused and used wires.

Table VI

VARIABLE	MEAN	STD. DEVIATION
UNUSED	.0244"	+/- 0.03
USED	.0251"	+/- 0.09

Polaroid photographs obtained from a area of the synthetic material wire showed a smooth surface for the unused wire. The used wires showed some roughness but no apparent crack or fracture line was evident.

DISCUSSION

The study was performed over a group of individuals that were considered still to be growing. Orthodontic tooth movement in young patients differ from adults. The tissue elements undergoing changes during tooth movement are primarily the periodontal membrane with its supporting fibers, cells, capillaries and nerves and secondarily the alveolar bone[7] . During tooth movement the fiber bundles must elongate. Following stretching of the principal fibers and widening of the periodontal space there is a definite increase in cellular elements. Connective tissue cells produce new fibrils, thus ensuring elongation of periodontal fibers and further movement of teeth[7].

The crowding in the sample chosen for this study varied considerably from individual to individual. The ANOVA test showed no bias between initial total measurements between treatment groups (f value=.01151). No significant mean differences were found when comparing initial and final measurements. The t test showed no significant difference when comparing the Optiflex and synthetic material with the multistranded. But some significance was found when comparing the Optiflex with the synthetic material. This could be due to the presence of the glass component in the Optiflex which gives a better springback to the arch wire.

Although the Optiflex showed clinical significance during alignment of teeth, it was found to be very brittle. In two patients the arch wire fractured completely twice in each patient in the bicuspid region and had to be replaced. The reason for its fracture seems to be related to its glass component which forms part of its core. The bicuspid region is subjected to several different forces that vary from one individual to another. Continous and concentrated forces appliled in this specific area will produce a stress. This repeated stress will create fatigue of the arch wire and once this fatigue propagates the wire fractures. The stress can be related to sharp canine cusps, habits and different eating patterns. Sometimes the upper canine is to low and when the patient bites, its cusp will in this case produce a repeated stress. Habits such as pencil and nail biting is also an example of creating a stress that will eventually produce fracture. And finally, a hard diet which is common among different individuals could had also affect the physical properties of the arch wire. Although this arch wire is transparent its brittleness is a disadvantage. Chair time increases if the wire is replaced everytime it breaks. It can only be ligated with elastic ligature.

The synthetic material was available only in .0157" and .022". The .0157" showed little clinical value when tested on a typodont. It did not show enough springback for tooth movement and it took a permanent set easily. However, in .022" diameter it provided sufficient strength and stiffness. Presently is available in a light brownish color which is not the ideal for an esthetic wire. This material has a melting point of 633° F and this may make the coloration process difficult with the commonly used polyolefins coloring agents. These coloring agents have a melting point of about 340° F (Riddle, 1990)[8] .

Presently, the synthetic material is available in spools of 1.270 yards of wire per pound. Each pound is about $200 which translates to a cost fo about 2.6 cents for a 6" length (Riddle,1990). The great cost advantage of these materials can be seen when compared to the national average of $2.20 for a preformed multistranded Respond (Ormco, 1991) and a $3.80 average for a 6" length of Optiflex arch wire.

Three different areas of the PEEK wire were observed in the SEM to check changes in surface and diameter. According to the measurements obtained the used wires experimented a slight increase in diameter. This material has shown to be resistant to a wide range of liquids. It can be used for thousands of hours in steam or high pressure water without significant property degradation. In common with many polymers it can absorb low levels of moisture[8]. In this particular study it is not clear if the change in diameter was produced by the absorption of liquids or if the wire has been coated with some type of tissue. Being a foreign body in the oral cavity a covering is expected, but the only way to determine if deposits are present is by the means of EDS. This method will accurately describe any deposits on the surface of the wire if present. Innacuracy was found in the diameter described by the manufacturer (.022"). Unused wires were measured and diameters ranged from .0236" to .0259". This can be explained by the factor that this wires are not actually made for orthodontic purposes. So an exact diameter is not taken into consideration when fabricated. A comparison was made between the surface of a original (Fig. 1) and two used wires (Fig. 2,3). The original showed an irregular surface with some vertical lines or striations following certain parallel pattern. The used one's showed the same vertical pattern. Fig 2 shows a rough surface with evidence of some sort of deposits. Fig. 3 shows more clearly the rests or deposits along the surface. Apparently no evidence of crack or fracture were seen in either one.

The roughness of the surface could be associated with organic or inorganic components of saliva. No definite conclusion could be made about what type of deposits were present, but one can assure that no cracks or fracture are evident.

SUMMARY AND CONCLUSIONS

A clinical study was conducted to evaluate the efficiency of two esthetic wires. One the Optiflex and the other a synthetic material. Results were compared with the multistranded stainless steel arch wire. Statistically no significant difference was found when comparing the esthetic arch wires with the multistrand. SEM evaluation of the synthetic material showed some roughness of the surface but no signs of fracture was seen. The following conclusions have been drawn from this investigation.

1. Optiflex arch wires and the synthetic material showed clinical value during initial alignment of teeth when compared to multistranded stainless steel arch wires.
2. Optiflex arch wires showed tp be brittle and is considered a disadvantage in private practice.
3. Color in the esthetic material could compromise esthetics.
4. The available diameter in the synthetic material limits its use.
5. SEM images of the synthetic material showed no significant changes in surface or diameter.

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