THE TITANIUM STAPLE IMPLANT : A CLASSIFICATION OF THREE-DIMENSIONAL PROFILES OF THE ANTERIOR IMPLANT-BEARING AREA OF HUMAN MANDIBLES

by

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DECLARATION

I, Johannes Theodorus Potgieter hereby declare that the work contained in this thesis is my own original work and has not previously in its entirety or in part been submitted at any University for a degree.

J T POTGIETER

9th day of August 1993

The work reported in this thesis was carried out in the Biostereometric Unit of University of Cape Town at Cape Town, RSA and the Faculty of Dentistry, University of Stellenbosch, Tygerberg, RSA.

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ABSTRACT

The purpose of this study was to establish standards (norms), based on three-dimensional stereomicroscopic surveys of the anterior implant-bearing area of severely-resorbed human edentulous mandibles. Such standards could possibly be applied towards the development of a series of transmandibular implants which would have wide applications in a broad spectrum of patients.

The sample consisted of forty five severely-resorbed human edentulous mandibles eminating from people of various ages, both genders and several ethnic groups. Only 28 specimens were accompanied by pertinent details about the deceased. Measurements were made in the anterior mandibular area bounded by the mental foramina. Menton, Gnation and the inferior point of the base of the lower genial tubercle were used as reference points. Measurements included mandibular width and the angular relationships of the superior crest of the mandibular ridge to an established baseline.

The restricted nature of this sample made it impossible to establish any correlation between mandibular morphology, age, gender or ethnic group. Moreover, analysis of the results showed that they could not be used towards designing a "universal" transmandibular implant with baseplate width and angulation of its transmandibular components such that it would be applicable to a broad spectrum of patients.

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OPSOMMING

Die doel van hierdie studie was die daarstelling van standaarde (norme), gebaseer op driedimensionele stereomikroskopiese opmetings van die anterior inplantaat-draende area van erg resorbeerde, tandlose, menslike mandibulas. Dié standaarde kan moontlik gebruik word vir die ontwikkeling van 'n reeks transmandibulêre inplantate wat bruikbaar sou wees vir 'n breë spektrum pasiënte.

Vyf-en-veertig, erg-resorbeerde, tandlose menslike mandibulas vanuit 'n breë spektrum van die bevolking was vir hierdie studie gebruik. Slegs 28 monsters het volledige besonderhede ten opsigte van ouderdom, geslag en etniese herkoms, van die oorledenes besit. Die anterior gebied tussen die mentale foramina het gedien as opmetings area. Menton, Gnation en die inferior punt van die basis van die inferior geniale tuberkel was as verwysingspunte gebruik. Die opmetings het onder andere die mandibulêre breedte en angulêre verhouding tussen die superior kruin van die mandibulêre rif en 'n verkose basislyn ingesluit.

Daar kon geen verband tussen mandibulêre morfologie, ouderdom, geslag of bevolkingsgroep aangedui word as gevolg van die beperkte aantal monsters. Die analisering van die resultate het ook aangedui dat daar nie 'n "universele" transmandibulêre inplantaat met 'n spesifieke basisplaat breedte en angulasie van die transmandibulêre onderdeel kan ontwerp word, wat bruikbaar sou wees vir 'n breë spektrum pasiënte, nie.

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INTRODUCTION

Historical background

Prosthetic treatment of the edentulous mouth developed during the nineteenth and twentieth centuries to the extent that a well-fitting and occluding complete denture became an acceptable alternative to natural teeth, as long as the residual alveolar structures provided adequate support and retention. There has, however, always been a small percentage of individuals who fail to become accustomed to dentures, without sufficient anatomical support of the tissues. Progressive resorption of the alveolar support of the dentures tends to undermine retention and stability with increased potential for trauma and discomfort of the underlying tissues. This process can cause functional and psychosocial problems (Tallgren, 1972).

Since the days of the Phoenicians and Etruscans, man has endeavoured to replace lost teeth. Earliest attempts involved the use of gold wire or gold strip bridges (Woodforde, 1968). The concept of an intrabony implant to support a tooth developed at the turn of the sixteenth century when the transplantation of human teeth was referred to by Paré in 1564 as cited by Woodforde (1968).

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The history of dental implants as recorded by Maggiolo in *Manuel de l'art Dentaire* dates back to 1809 (Natiella et al, 1972). These root-shaped implants, were made of gold. Harris (1887) and Berry (1888) suggested the use of lead for root shaped implants, while Scholl (1905) studied porcelain as the implant material of choice; Casto (1914) reported the use of iridio-platinum roots. In Germany, Ehricke (1920) and Schneider (1937) described the utilization of ivory roots to replace lost teeth and in America, Strock (1939) suggested Vitalium[1] as the alloy of choice.

Implant materials

The use of acrylic teeth as replacements for lost natural teeth was described by Hegedus and Inke (1957), Hodosh et al, (1964; 1967; 1968), Brown, Neff and Tylenda (1969) and Hamner,

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[1] Austenal Dental, 5101 S Keeler Ave, Chicago, IL, USA

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Reed and Hand (1970). Dogs, monkeys and baboons were used as research animals. The researchers reported on various criteria for success and concluded that the encouraging results merited further investigation. On the other hand, Boucher and Surwillo (1968) found that acrylic roots implanted in the jaws and soft tissues of rabbits produced an unfavourable tissue reaction; they concluded therefore that acrylic was not a suitable implant material. Iswaschenko (1957), Hodosh (1960), Hodosh et al, (1964) and Lam and Poon (1968) documented clinical cases with varying results. Hodosh et al, (1968) theorized about a fibre support system which would simulate the periodontal ligament. The histological reports of Lam and Poon (1968) demonstrated epithelial tissue encapsulating the implant; this finding supported the results of Boucher and Surwillo (1968). Balogh (1964) suggested a gold platinum alloy for root shaped implants supporting dentures.

The earliest cobalt based alloy utilized in subperiosteal implants was Vitallium and consisted of 30% chromium, 7% tungsten, 0,5% carbon and 62,5% cobalt. The tungsten was soon replaced with 5% molybdenum resulting in improved ductility (Smith 1974). Further changes in the constituents of this material yielded various other alloys. Currently-available surgical Vitallium has a composition of cobalt 62%, chromium 28%, molybdenum 6%, carbon 3,5% maximum, manganese 1% maximum and silicon 1% maximum (Weisman, 1970). The alloy used for conventional dental castings has less carbon, more silicon and manganese for improved elongation and castability (Fitzpatric 1968). Goldberg and Gershkoff (1949) utilized Vitallium screws to stabilize implants, whereas Linkow (1954; 1958) developed a different design and relied on fibrous encapsulation to achieve implant stability. Wimmer (1979) utilized surgical-grade Vitallium to avoid the possibility of impurities entering the metal during casting procedures.

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Marziani (1954) preferred tantalum as an implant material because of its ductility and malleability which facilitated the manufacturing process. The implants could be placed during a single surgical procedure which was an advantage over the more conventional two-stage cast implant.

Pedersen, Haanaes and Faehno (1979) described the failure of porous ceramic subperiosteal transmucosal implants due to unfavourable tissue response. Experimental work in dogs by

Evaskus, Rostoker and Laskin (1980) was based on the use of sintered titanium fibre composite. This material was covered by the periosteal membrane and mucosa and left unloaded. There was no evidence of subperiosteal bone formation over the implant.

Homsy (1970) investigated the biocompatibility of materials utilizing in vitro techniques to predict quantity and cytotoxicity of moieties released by the implant materials. To verify his assessment that vitreous carbon implants could be used in humans, limited animals studies was suggested. Grenoble and Voss (1977) did a longitudinal analysis of vitreous carbon endosseous implants. The negative results could be attributed to the great number of variables introduced into this study. Kent and Bokros (1980) described the use of two types of pyrolytic carbon-coated metallic dental implants in baboons and dogs. Clinical mobility, periodontal sulcus depth, periapical radiographs and histological analysis were performed. They came to the conclusion that the implant with a flared neck was superior and the results of this study formed the basis for clinical trials in human subjects. Schnitman and Shulman (1980) prepared a paper for the Harvard National Institute of Dental Research Consensus Development Conference, using a literature review based on vitreous carbon implants by James (1980) and the experimental findings of the Harvard Tooth Implant-Transplant Research Unit. They recommended that because of the high morbidity rate, vitreous carbon root implants could no longer be used as free-standing implants in the absence of interdental splinting.

Hulbert, Morrison and Klawitter (1972) evaluated the biocompatibility of porous calcium aluminate, calcium titaniate and calcium zirconiate and observed no histological signs of rejection or of toxic or carcinogenic responses in the soft tissue of rabbits. Davis et al, (1972) found that because of corrosion and toxicity, lead and arsenic-selenium-sulphur glasses were not suitable materials for implantation. Young (1972) demonstrated the experimental success of calcium aluminate ceramics as tooth root replicas in dogs. Hamner, Reed and Greulich (1972) and Hamner and Reed (1973) showed similar results in baboons. McLean (1967) studied aluminous porcelain and propagated its use as a biocompatible implant, given its similarity to natural dentine in respect of physical properties.

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The use of titanium in implantology is well-known, but little has been published in the literature. Parr, Gardner and Toth (1985) and Taira, Moser and Greener (1989) described titanium and its alloys and proposed its use as a dental implant material, as a result of its biocompatibility and excellent physical properties.

Pure titanium and its alloys are most commonly utilized for implants. The most popular alloy contains aluminium and vanadium which serve as stabilizers and strengtheners. Casting of titanium is technically sensitive due to its high chemical reactivity with oxygen at elevated temperatures. The casting techniques demands highly sophisticated equipment with the result that titanium and its alloys are used mainly in machine-wrought form.

Surgical implantation involves trauma and the bone response is similar to that of a healing fracture. In respect of implants the trauma is more controlled and the phagocytosis phase much more rapid. This results in the faster proliferation of fibroblasts in the surrounding tissues in an attempt to lay down connective tissue and heal the site of implantation. This fibroblastic proliferation and deposition of collagen fibres lead to the formation of a fibrous tissue plug which fills the bone-implant interface. This process is normally completed within fourteen days. In the absence of bacterial infection and toxic or allergenic reaction, the connective tissue is eventually replaced by bone (Atkinson and Witt 1982). Earlier research with endosseous and subperiosteal implants demonstrated fibrous encapsulation of the implant bone interface. This led to the postulation that tissue reaction to an implant would result in the formation of a suspensionary sling around the implant as a result of the occlusal stresses placed on it. However this reaction jeopardizes the integrity of the implant.

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Bränemark (1983) has reviewed the underlying principles of osseointegration and its application to root-form endosseous implants. Osseointegration can be defined as a direct and functional connection between ordered living bone and the surface of a load-carrying implant. The creation and maintenance of osseointegration depends on a fundamental understanding of and regard for tissue healing and the reparative and remodelling capacities of bone. In 1952 Bränemark and co-workers did their initial work on rabbits and beagle dogs. Meticulous surgical techniques, augmented by intravital microscopy, were used to establish osseointegration between unloaded implants and bone. (Bränemark, Zarb and

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Albrektsson, 1985). They came to the conclusion that pure titanium was the most suitable biocompatible material available and extended the study to include human subjects (Albrektsson et al, 1981 and Carlsson et al, 1986). The crux of the healing process is for bone and marrow to heal as highly differentiated tissue in the absence of scar tissue due to trauma caused by surgery, bacteria and occlusal loading. After an initial healing period of three to four months in the absence of occlusal forces, the mucoperiosteal flap could be prepared for joining of abutments and further prosthetic treatment.

Implant systems

The implant systems that were developed and suggested were as varied as the earlier materials of choice. The following discussion of implants will be based on the classification suggested by English (1990).

1. ENDOSSEOUS
    a) Ramus frame
    b) Pins
    c) Discs
    d) Plateform
    e) Cylindrical or root-form

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2. SUBPERIOSTEAL
3. TRANSOSSEOUS

1. ENDOSSEOUS

Endosseous implants are those that are surgically placed in the jawbone and protrude only at one point through the cortical bone to support a prosthetic device. They can be metal of non-metal origin.

a) Ramus frame (Fig. 1)

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Fig. 1: Three ramus frame implants

The ramus frame implant was developed and described by Roberts and Roberts (1970) as a posterior support for mandibular fixed partial dentures where the existing mandibular width and height were insufficient. Nelson (1974) described it as a one piece tripodal endosseous implant that derived support for the complete mandibular denture from the symphysis region and the ascending rami of the mandible. Kerley et al. (1981) reported a success rate of 91% over a period of twenty-six months for fifty-six patients. The most common complication was paraesthesia of the inferior alveolar nerve and early failure of the unsuccessful implants.

b) Pins (Fig. 2)

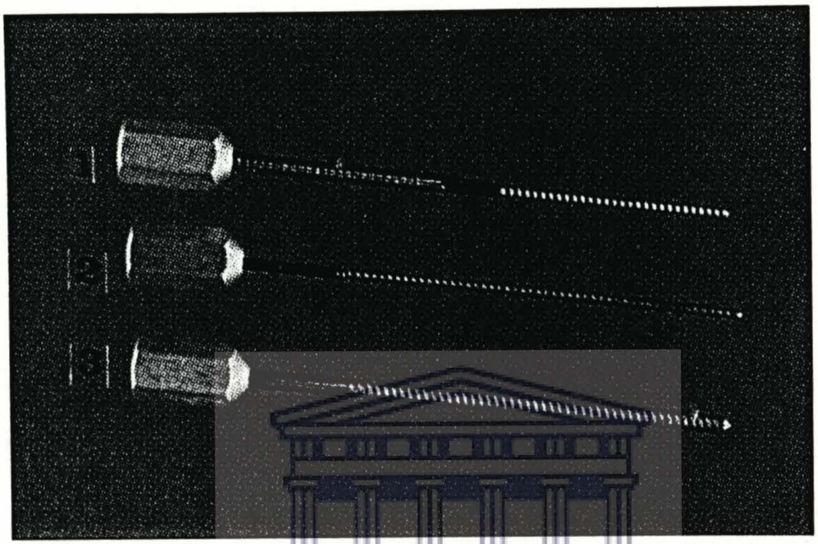

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Fig. 2: Three different sized pins used as endodontic implants

Pins were proposed by Scialom (1963) as endodontic stabilizers. The implant protruded through the apex into the jaw bone. Orlay (1960) utilized endodontic splinting to stabilize compromised periodontal teeth. Complications included penetration of the maxillary sinuses or floor of the nose, and injury to larger vessels and nerves. Shaykin (1962) reported a degree of success with endodontic implants over a period of fourteen months. Radiographic criteria were advanced to evaluate success or failure of the implant. The cytotoxicity of the materials used to cement the implants could have contributed to the lower success rate.

c) Discs (Fig. 3)

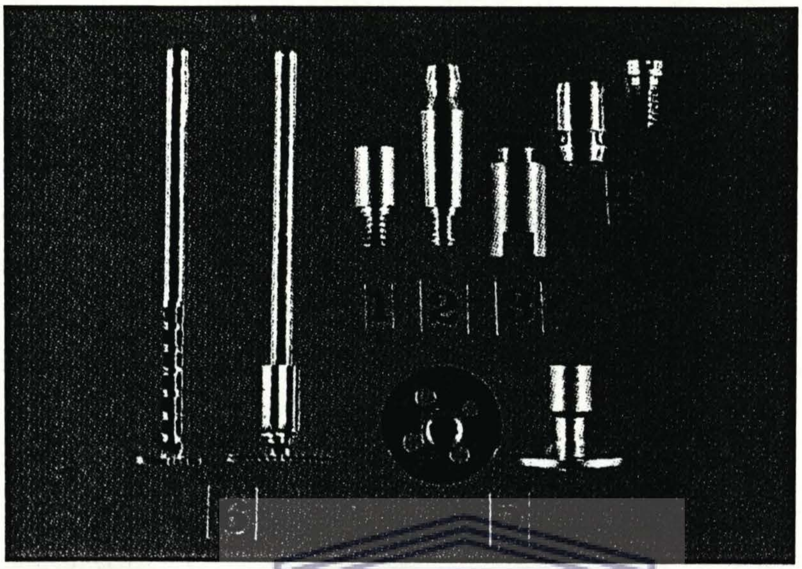

Fig. 3: Various components of disc implant system

This implant originated with Scorteci in the mid-1970's (English 1990). The implant had a unique two stage design with buccal or facial placement in special osteotomy cases. The implant design resembled an eighteenth century candle-stick.

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d) Plateform (Figs. 4 and 5).

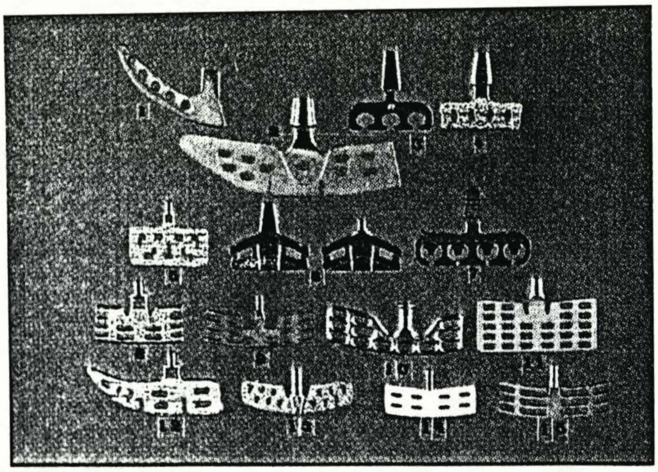

Fig. 4: Various mandibular plateform implants

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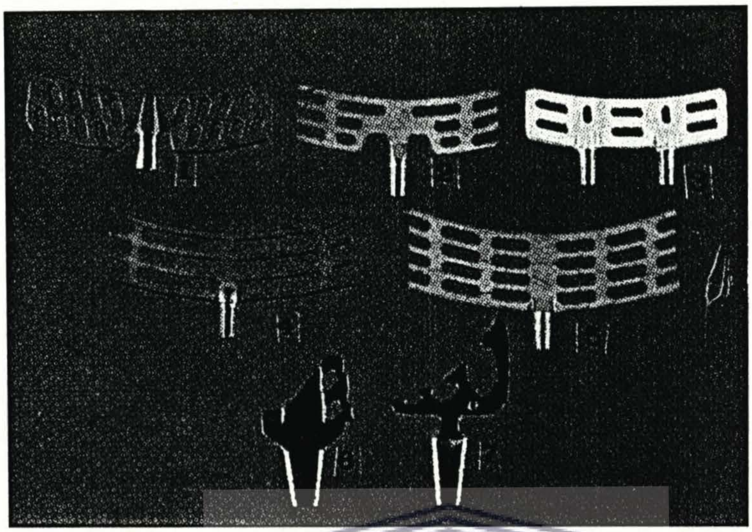

Fig. 5: Various forms of maxillary plateform implants

This concept was initially proposed by Robert and Roberts as reported by English (1990), and was developed by Linkow (1964; 1970). It consisted of a flat anteroposterior surface with a thin buccolingual dimension and a blade-like inferior border. Open circular ventilations were incorporated in the blade to encourage bone ingrowth for additional anchorage. Many designs are commercially available and include a two stage type which allows for a healing period before occlusal loading of the implant.

e) Cylindrical or root-form

This was one of the earliest designs and is the most popular one in use. The bulk of current research focusses on this concept, which can be subdivided into four different categories:

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i) Cylindrical bullet, e.g. Integral[2] (Fig. 6)

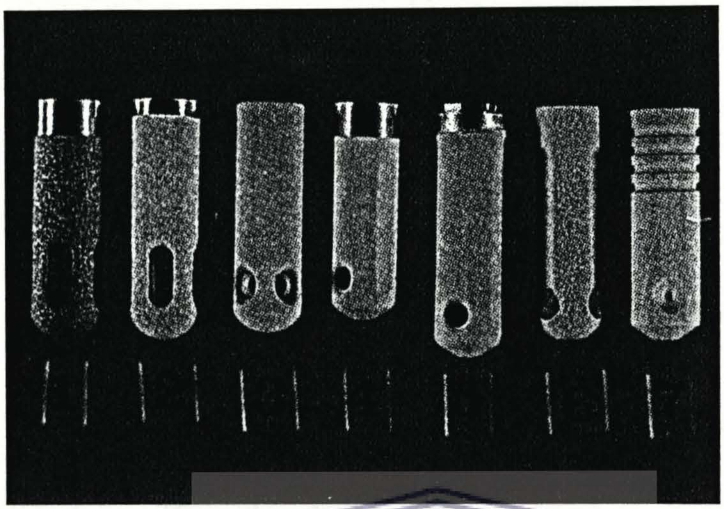

Fig. 6: Selection of cylindrical bullet implants

ii) Cylindrical basket e.g. Core-vent[3] (Fig. 7)

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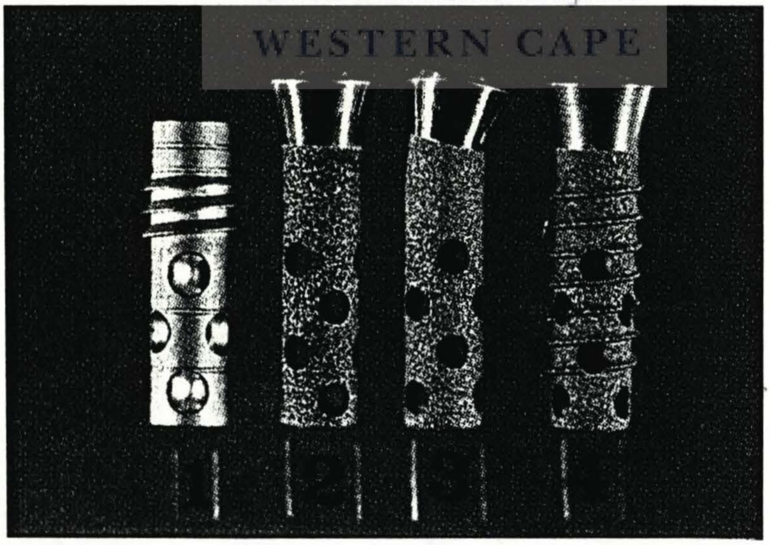

Fig. 7: Various cylindrical basket implants

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[2] Calcitek, Inc. 2320 Faraday Ave. Carlsbad, CA 92008, USA

[3] Core-vent Corp. 15821 Ventura Blvd, Encion, CA 91436, USA

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iii) Cylindrical screw, e.g. Bränemark[4] (Fig. 8)

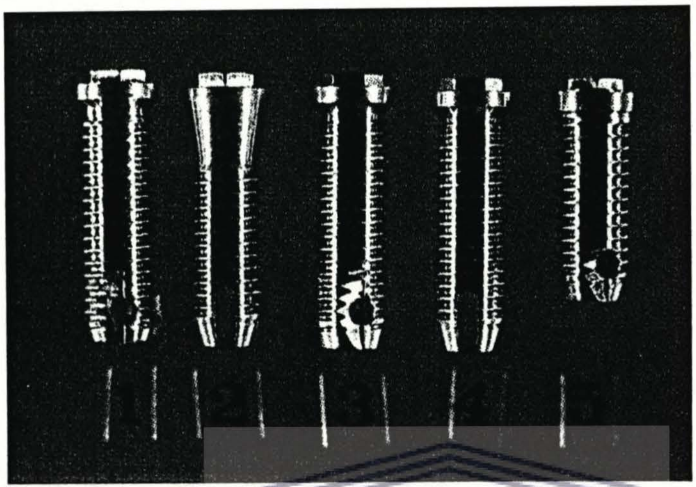

Fig. 8: Various cylindrical screw implants

iv) Cylindrical fin, e.g. Stryker Precision[5] (Fig. 9)

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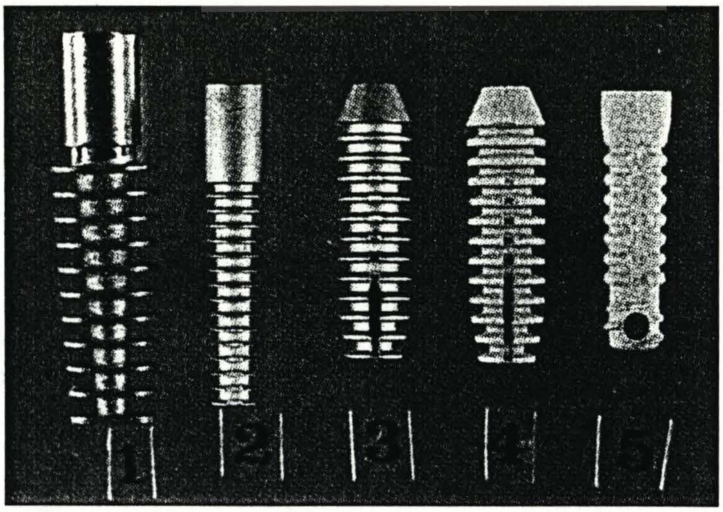

Fig. 9: Various cylindrical fin implants

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[4] Nobelpharma USA, Inc. 5101 S Keeler Ave, Chicago, IL. USA

[5] Stryker Dental, 420 Alcott Street, Kalamazo MI. USA

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All the above-mentioned have the same basic cylindrical design. The cylindrical bullet has a rounded apical shape whereas the basket has a flat apical area. The cylindrical screw has the same tapered apical area as the bullet design but also has a screw thread on the axial sides, while the fin design embodies a flat apical area and instead of a screw thread, parallel fins are mounted onto the centre core.

2. SUBPERIOSTEAL (Figs. 10 and 11)

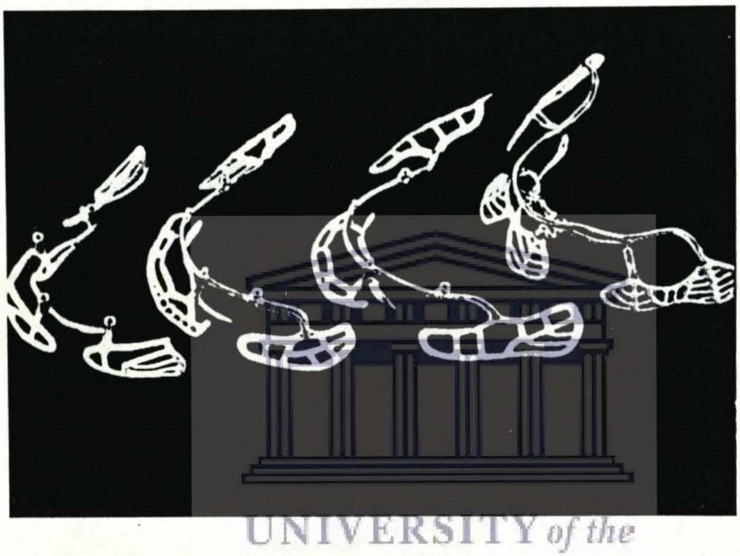

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Fig. 10: Various designs of bilateral subperiosteal implants

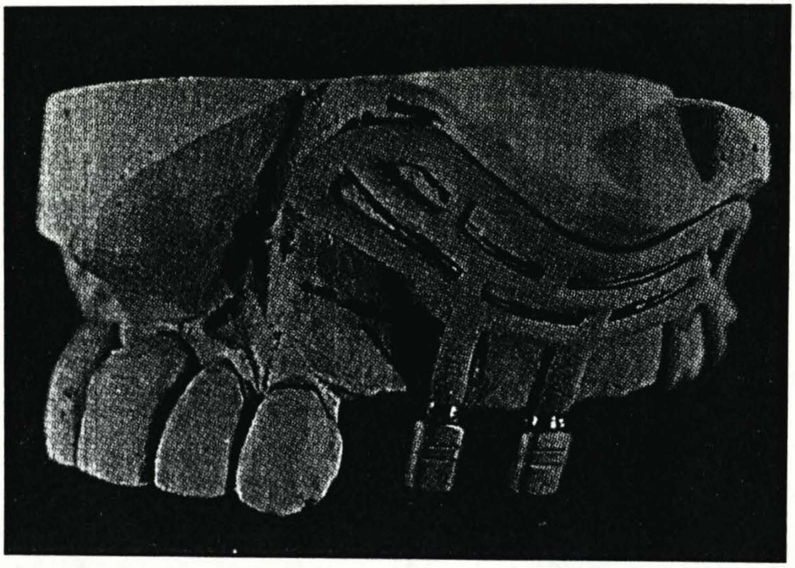

Fig. 11: Unilateral maxillary subperiosteal implant

The full-arch subperiosteal implant originated with and was developed by Dahl (1956). Designs varied from unilateral partialframes (Weber 1966) to bilateral and full-arch frames for edentulous patients. Cranin and Cranin (1966) described a simplified full arch subperiosteal implant. The clinical problems experienced with subperiosteal implants have often been associated with the prescribed two-stage procedure: the surgical site had to be exposed twice, and a sensitive technique was required to provide an accurate substructure to support the prosthetic device.

Linkow (1967) reported a ten-year retrospective study based on his unilateral subperiosteal design and reported that it had a definite place in dentistry if used in the correct clinical situations.

3. TRANSMANDIBULAR IMPLANT (Fig. 12)

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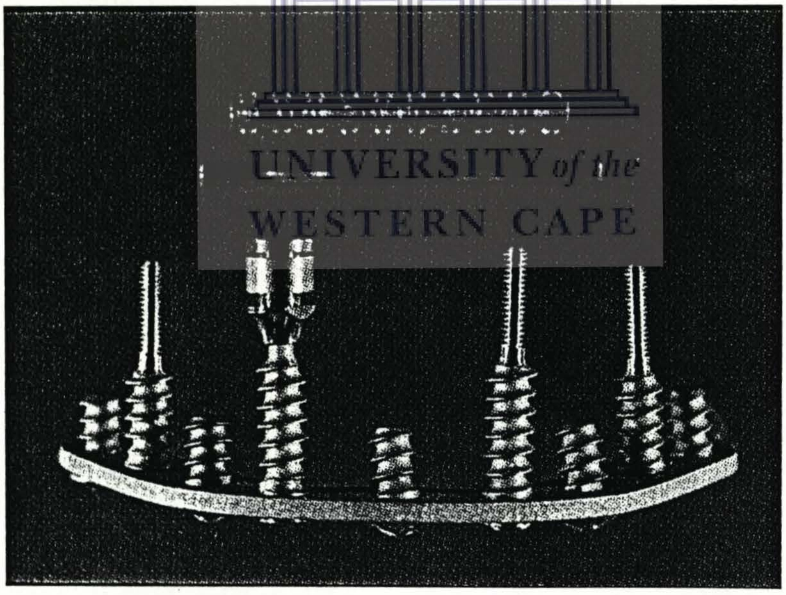

Fig. 12: Transmandibular implant

The transmandibular implant has been recommended for patients with extensive mandibular alveolar bone loss who have problems wearing conventional complete dentures (Unger and Crabtree, 1991).

The basic design consists of a base plate and two transosseal pins that penetrate the mandible mesial to the mental foramina and incorporate self-tapping retention screws. Small and

Kobernick (1969) designed the stainless steel staple implant and utilized dog studies to test its possible clinical application. Small (1975; 1979; 1986; 1990) developed the design to meet the demands of clinical application. Bosker and Van Dijk (1989) and other researchers developed similar implants to support and retain overdentures or small fixed dentures.

In 1968 Small and Kobernick commenced clinical trials based on their earlier work. The implants used were fabricated from an alloy consisting of 90% titanium, 6% aluminium and 4% vanadium. Small (1980) presented his results at the NIH-Harvard Consensus Development Conference on Dental Implants which was held in 1978. He showed the results of 109 staple implants which had been in place for five years and claimed a success rate of 95%. Helfrick, Topf and Kaufman (1982) published an independent report of 250 patients who received staple implants at Sinai Hospital, Detroit over a period of seven years. Criteria for success or failure were: evidence of implant mobility, bone loss, gingival and mucosal health, function, aesthetics, presence of infection, discomfort, paraesthesia, anaesthesia, the patient's emotional and psychological attitudes and satisfaction with the treatment received. The overall success rate was 96.8% with a total of 89.2% without postoperative complications. They concluded that the staple implant could be an effective method where indicated for prosthetic reconstruction in cases of atrophy, congenital or traumatic deformities, and tumour resections of the mandible.

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Kent et al, (1984) did a retrospective evaluation of 160 patients over a seven-year period and demonstrated a cumulative success rate of 90.9%. The staple bone implants used were similar to those utilized by Small (1978). Criteria for evaluation were based on the standards for dental implants established by the National Institute of Dental Research at the Harvard Consensus Development Conference.

Meyer and Kotwal (1986) evaluated the success of staple bone implants over a six- to thirty-month period. Bosker and Van Dijk (1989) used a staple implant made of 18-carat 5% gold alloy. The implant included a baseplate, four transosseal posts and five cortical screws. They showed an overall success rate of 97,8% in a group of 185 patients who had received implants over a period of five to ten years.

Maxon, Powers and Scott (1990) and Unger and Crabtree (1991) described further sucessful use of the transmandibular implant to provide patients with an implant supported denture to avoid the disadvantages of a mixed implant-tissue supported prosthesis.

There appear to be no reports in the literature about titanium transmandibular implants that would allow for a period of osseointegration without occlusal loading from a prosthetic appliance. The design of such an implant would require a thorough survey of the relevant parts of the human mandible. The development of a series of implants that could be placed surgically in a single procedure would allow for a period of osseointegration, prior to mucosal penetration and occlusal loading of the implant.

Denissen, Veldhuis and Van Faasen (1984) made a morphological study of eighteen atrophic mandibles. They divided the mandible into four sections. Section one constituted the ramus from condyle to mandibular foramen; the distances from the latter to the lateral surface and the anterior border of the ramus were recorded. Section two included the area of the angle of the mandibula where the lengths from the medial wall of the mandibular canal to the medial cortical plate of the ramus were measured. Section three was the body distal to the mental foramen. On this section the distances from mandibular canal to the crest of the alveolar process, the lateral surface and the medial surface were recorded. Section four was the area between the mental foramen to the midline. Here they measured the mental foramen - midline distance and the vertical and horizontal thicknesses of the mandible. They came to the conclusion that in atrophic mandibles the only area suitable to receive implants was the anterior part of the mandible between the two mental foramina.

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OBJECTIVES

The purpose of this study was to make a three-dimensional survey of severely-resorbed edentulous human mandibles in the area bounded by the mental foramina with the inferior point of the base of the lower genial tubercle, Menton and Gnation serving as additional reference points. The results would be used to test the feasibility of developing a series of transmandibular implants and structural features which would make them suitable for insertion in a wide spectrum of patients. Implants would be left unloaded until healing and osseointegration had taken place.

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MATERIALS AND METHODS

Forty five severely resorbed edentulous mandibles were utilized for this study. They came from people of various ages and both genders. The average biological age of the specimens was 70.7 years and the criterion for selection of the mandibles was the absence of a residual alveolar ridge. The mandibles were to be sectioned at the mesial border of the mental foramina and it was therefore decided to use a replication technique which would allow sectioning of the mandibular models. Adams, Jooste and Thomas (1991) demonstrated the accuracy of a replication technique utilizing a polyvinylsiloxane addition cured impression material[1] and die stone[2] models for biostereometric analysis. A difference of 0.25% was found and confirmed the accuracy of this replication system.

Impressions of the mandibles were taken with polyvinylsiloxane addition cured impression material for duplication in die stone. Lower anatomical impression trays[3] of a size suited to the different mandibles were used. The trays were coated with adhesive solution and left for twenty minutes before appropriate amounts of putty were placed in them and the impression of the lower half of the mandible taken. A period of twenty minutes at room temperature was allowed for the material to set.

The impression thus obtained was eased and filled with a low-viscosity polyvinylsiloxane impression material to obtain the final impression of the lower half. A releasing agent[4] was applied to this impression prior to the taking of a similar impression of the rest of the mandible. These impressions of the mandible included an area which extended 2 cm distal to the mental foramina.

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[1] President Coltene Inc, CH-9450 Altsätten/Switzerland

[2] TM, Columbus Dental, USA

[3] Inox, West Germany

[4] Vaseline

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Impressions thus obtained were stored for 24 hours before being cast in die stone. The die stone was mixed according to manufacturers instructions with a vacuum mixing[5] and investing technique and the cast models were left overnight at room temperature. The polyvinylsiloxane impressions were then separated and these models were stored at room temperature until they were subjected to a biostereometrical survey with a reflexmicroscope [6] (Fig. 13).

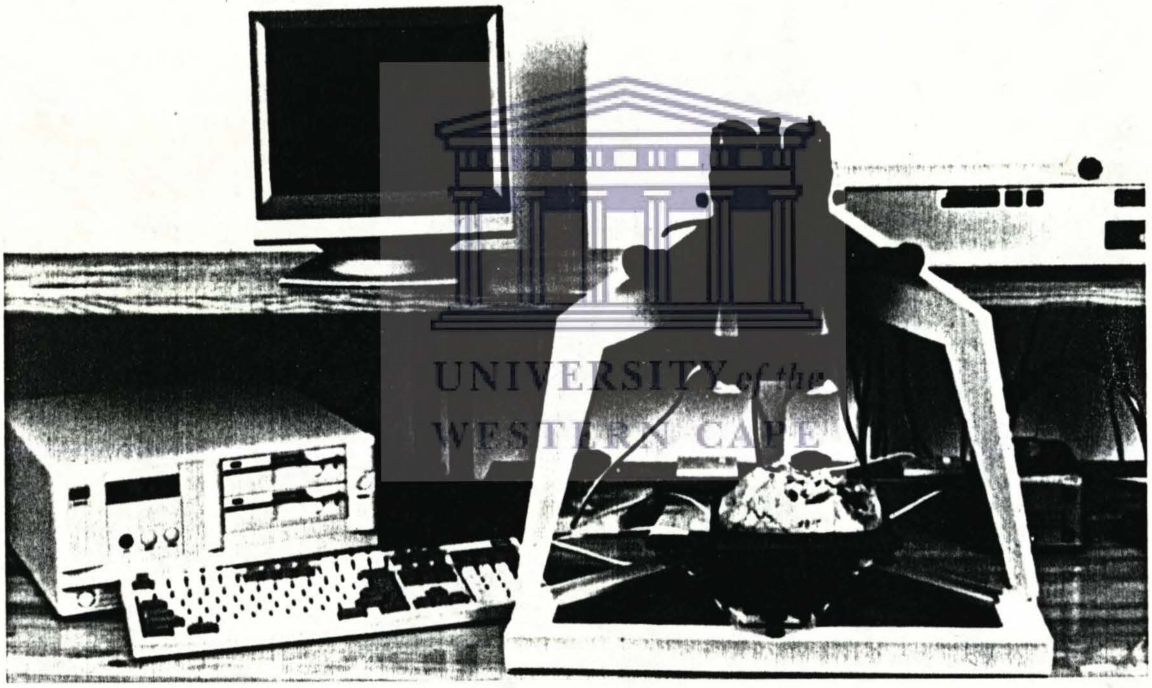

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Fig. 13: Reflexmicroscope, personal computer and monitor

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[5] Whipmix Corporation, Model D, Louisville, USA

[6] Reflex Measurements Ltd., Whitehall Park, London, D193TS

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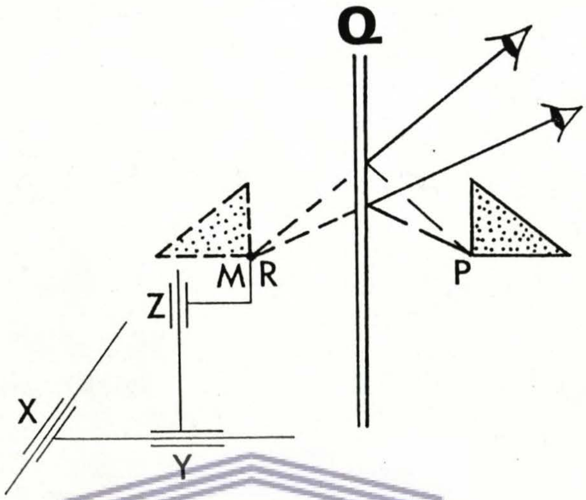

Fig. 14: Reflexmicroscope principle where **Q** is the mirror and **P** a point on an object; **R** is the reflected object; points **P** and **M** measuring points. **X,Y** and **Z** represent three-dimensional coordinates of point **P**

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The reflexmicroscope was developed by Scott (1981) according to the principle attributed to Abdel-Aziz. The principle is illustrated in Figure 14. The object on the right is reflected in a semi-silvered mirror Q. An object point P creates an image of itself at R, where PR is normal to the mirror and P and R are equidistant from it. The virtual image is thus seen to contain all the three-dimensional properties of the original object. An observer looking at R will be able to see through the mirror to a measuring mark M and when M coincides with R, there will be no visual parallax. The observer can thus move M about the image, taking measurements as required without obstruction from the object. The object itself must be stationary during the measuring while the platform to which it is fixed can move 100 mm by 100 mm in X and Y axis while the microscope moves in the Z axis.

Biostereometric analysis depends upon the observation of the X, Y and Z coordinates which are encoded on an X, Y and Z slide system. The Z-value is susceptible to variation given the individual perception of stereoscopic depth (Wright 1954). Adams and Wilding (1988) found that inter- and intra-observer value differences were negligible and from their research they concluded that single measurements of X or Y coordinates are accurate to ± 2 µm and those for Z coordinates to between 4 and 8 µm, depending on the visual acuity of the observer.

The area of the inferior border of the cast models to be observed was demarcated as the surface between the mental foramina. Gnation, Menton and the inferior point of the base of the lower genial tubercle were chosen as reference points to demarcate the area to be observed. A mathematical designed perpendicular line to Menton was identified as line AB, illustrated in Figure 15. A line perpendicular to AB from Gnation bisected AB at X. A similar line from the inferior point of the base of the lower genial tubercle bisected AB at X_1.

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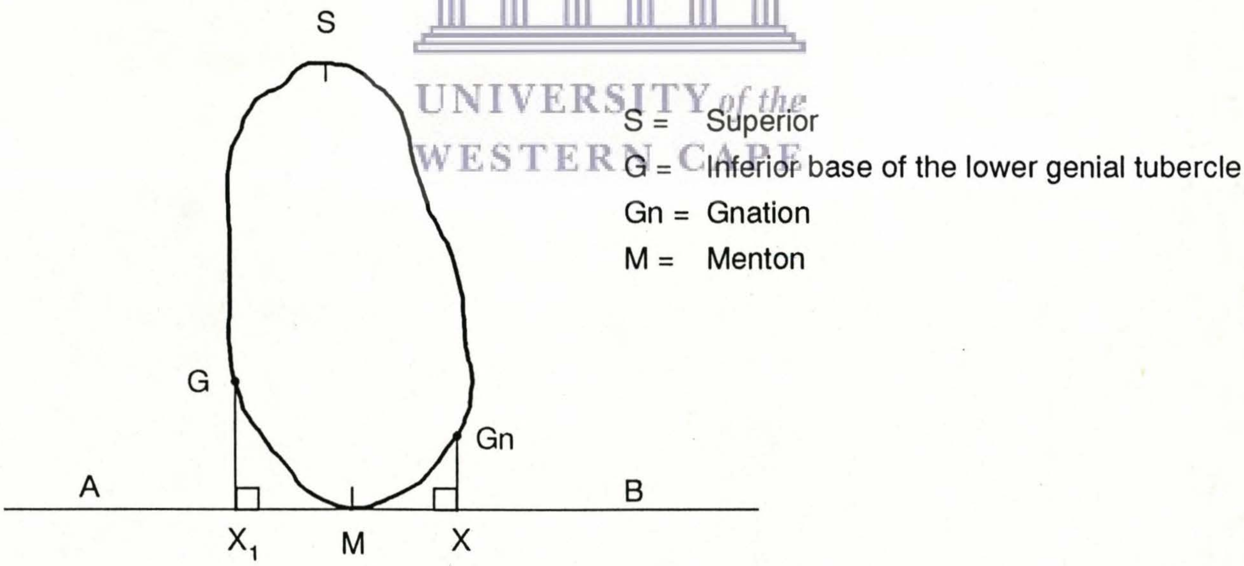

Fig. 15: Sectioned vertical plane of mandible, illustrating Gnation, Menton and inferior point of base of lower genial tubercle, reference points used to create observation grid.

To delineate the observation grid on the inferior surface of the models a jig was constructed

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utilizing the above model. The distances of each model from X to Gnation and X_1 to the inferior point of the base of the lower genial tubercle were calculated. With the aid of the distances thus acquired a stainless steel pin of adjustable length with a diameter of 1,5 mm and a sharpened end was mounted perpendicular to a polymer base[7] by means of a milling machine[8] and a spirit level[9] The polymer base was secured to the foot plate of the milling machine. The spirit level was used to position the milling machine and the polymer base at the same level to the horizontal. A drill of 1,5 mm diameter was used to drill a hole through the polymer base to receive the stainless steel pin as portrayed in Figure 16.

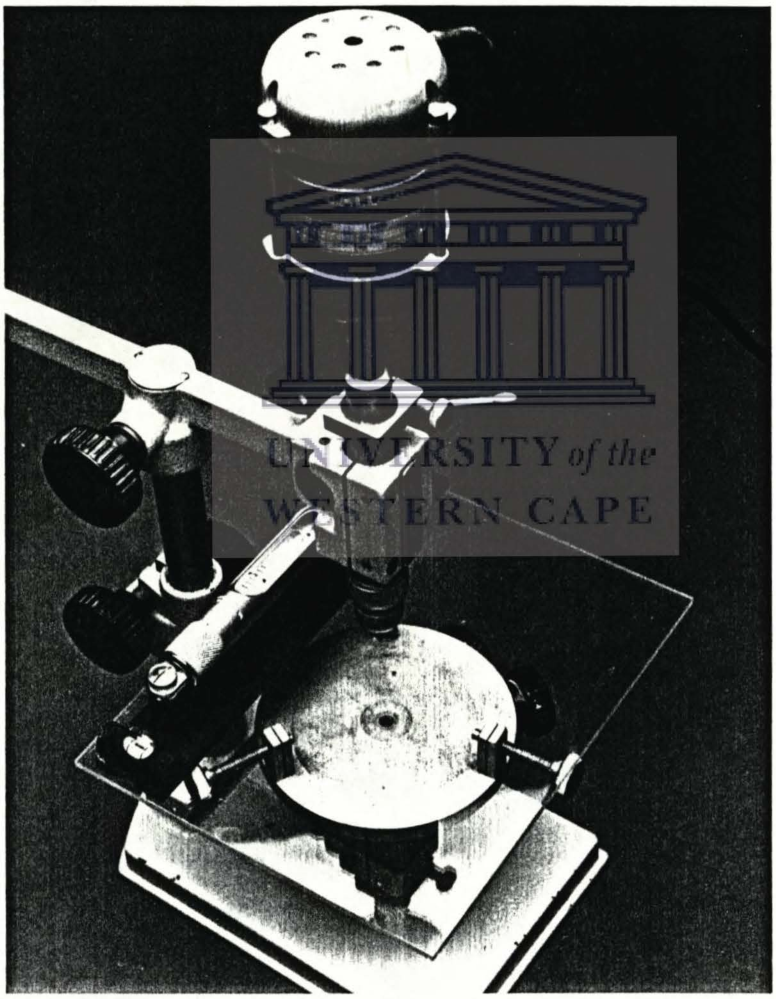

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Fig. 16: Base, milling machine and spirit level

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[7] Perspex

[8] Gallioni, S Colombano al Milano

[9] Starrett Level, Grand Vail and Cross Test Level, no. 198, 8 inc, L.S. Starrett Co. Ltd., Jedburg, Scotland.

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The jig thus constructed was employed to delineate the buccal and lingual peripheral border of the observation grid by placing the inferior surface of the model on the polymer base, and rotating the model to delineate the border line as demonstrated in Figures 17 and 18.

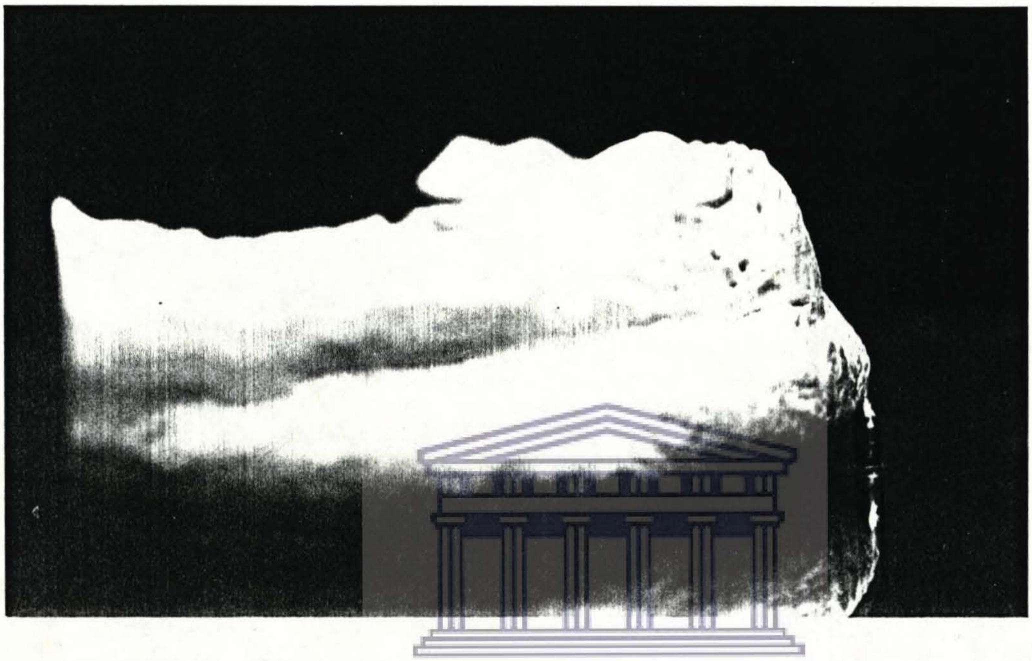

Fig. 17: Jig and demarcation of buccal surface at point Gnation

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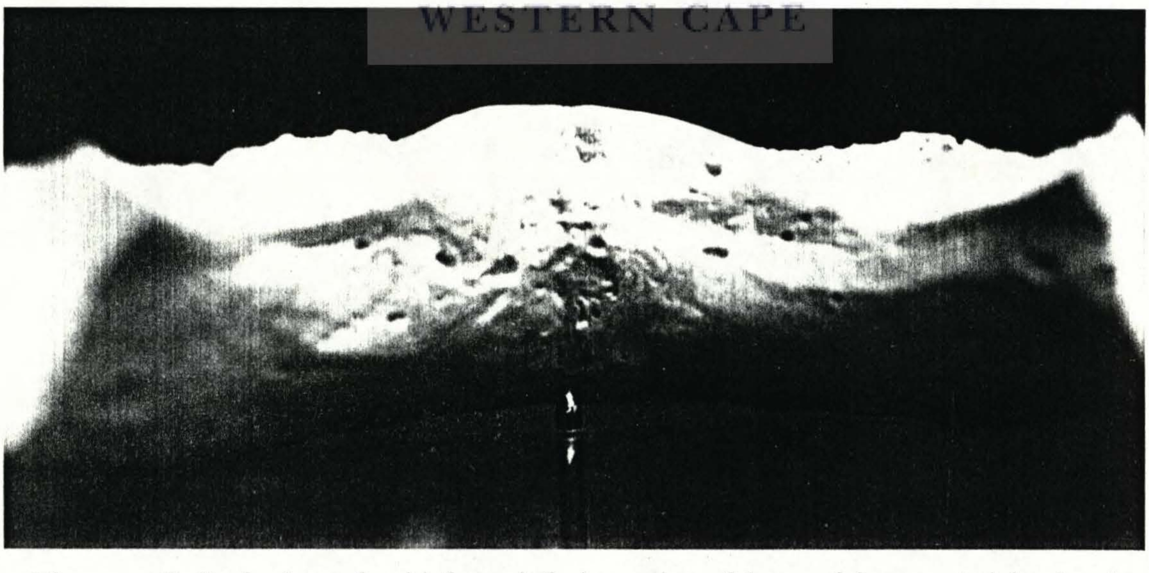

Fig. 18: Delimitation of grid from inferior point of base of lower genial tubercle as reference point

The 27 point grid was determined by halving the mandibles at Gnation, Menton and the inferior point of the base of the lower genial tubercle. These two halves were successively halved to produce quarters, eighths and finally a sixteen-block grid. The first observation point was positioned at the right lingual side of the model. The rest of the grid intersections were allocated in a counter clockwise fashion. In Figure 19, points 20-27 and 10 indicates the inferior mandibular crest.

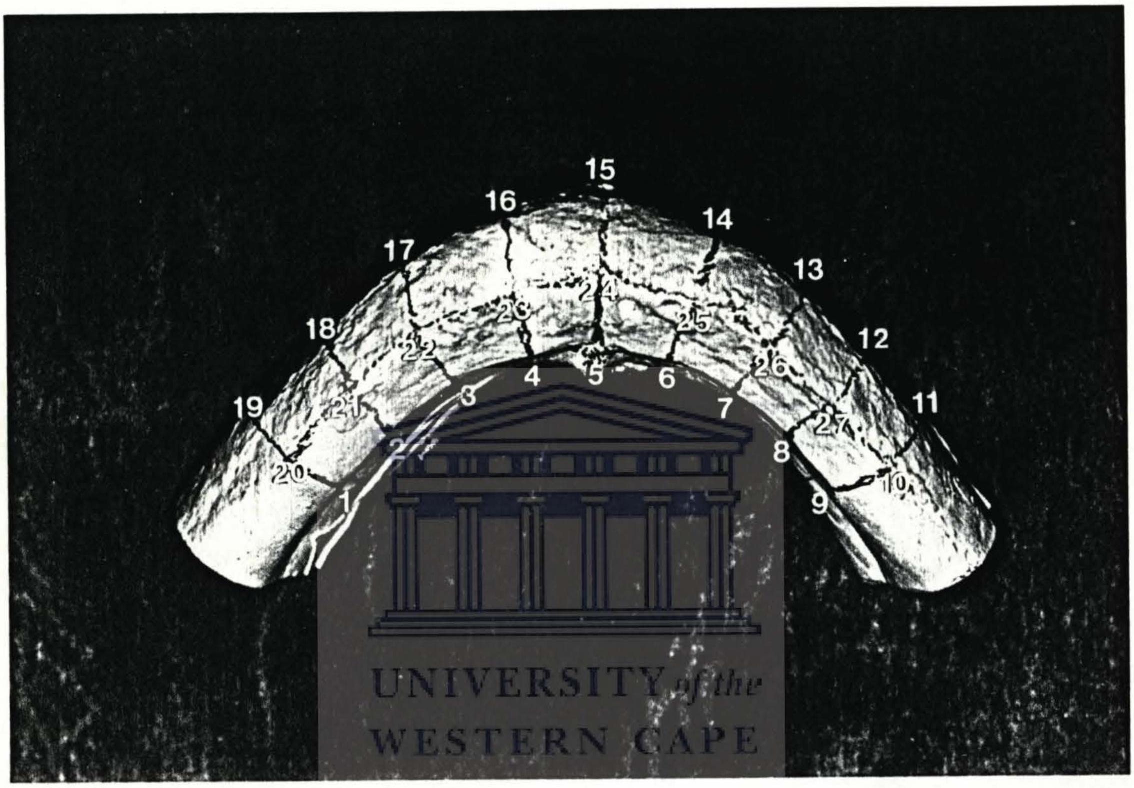

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Fig. 19: 27-point grid on inferior border between mental foramina

To produce a graphical contour of the mandibles the outline as well as random points within the grid were observed. The observation points on the grid were approximately 1 mm apart. X, Y and Z co-ordinates were recorded as well as three reference points; an algorithm embodying Caley's formula and the Rodriques parameters was used to form an orthogonal rotation matrix for transformation of the co-ordinates into a common system (Thompson 1969). All co-ordinates were processed by means of a contour interpolation computer-package[10] to produce contour plots and computer-generated three-dimensional representations of the relevant mandibular surfaces.

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[10] Saclant Graphics Package, (Run on the University of Cape Town Vax Main Frame)

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The accuracy of coordinates was assured by random observations made by a control observer for each cast. Repeatability was controlled by using a software program with the ability to compare current and initial readings of the observed contours.

The analysis of these observation points produced the following data.

a) Buccolingual contour distances as shown in Figure 20. This distance was measured from the lingual to buccal aspect of the grid following the curvature of the specimen. This line connects all the points between the buccal, inferior and lingual aspects of the grid.

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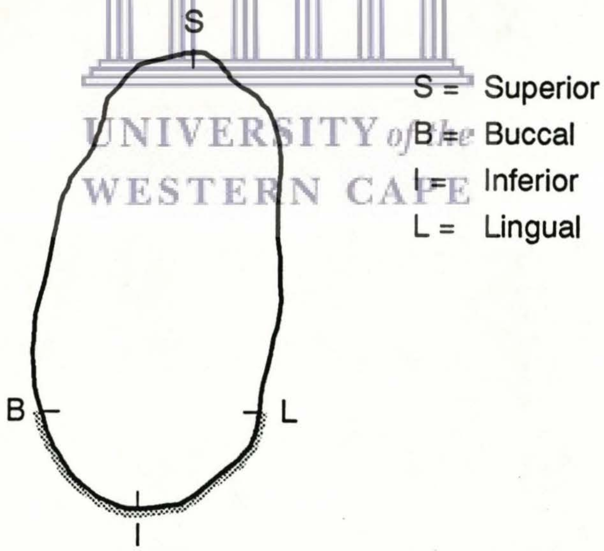

Fig. 20: Buccolingual contour following shape of inferior border of mandible

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b) Direct distance between the buccal and lingual points of the grid (Figure 21).

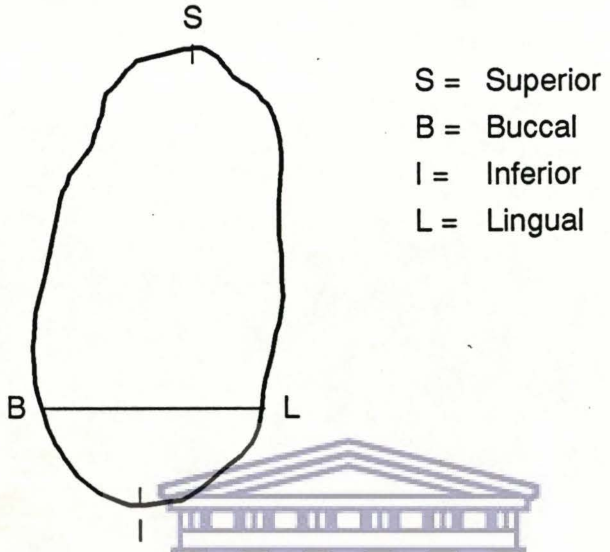

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Fig. 21: Distance (BL) from buccal (B) to lingual (L) observation points on grid

By means of STATGRAPHICS[11] a multiple range analysis for contour distance by contour site as well as the buccolingual distance by bucco-lingual site was executed to find homogeneous groups.

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[11] Statistical Graphics Corporation, STSC, Inc. Rockville, Maryland, USA

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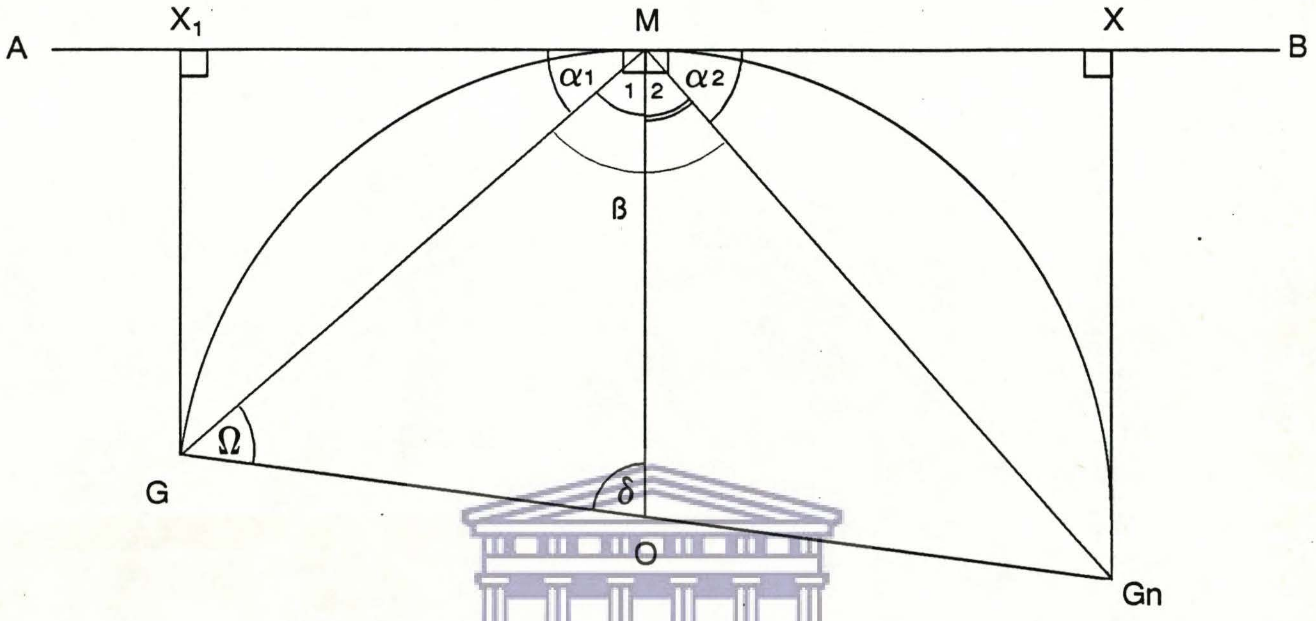
c) The distance MO was calculated by application of the mathematical principles as shown in Figure 22.



G = Inferior base of the lower genial tubercle
M = Menton
Gn = Gnation

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Fig. 22: Mathematical model used to calculate distance **MO**

A perpendicular line to AB from point M bisects line GnG at O.
X_1 and X were determined by means of perpendicular lines to AB from the inferior point of the base of the lower genial tubercle (G) and Gnation (Gn). Using the observation points G (inferior point of the base of the lower genial tubercle), M (Menton) and Gn (Gnation) the distances X_1G, MG, MGn, XGn and GnG could be measured. Mathematical principles were used as follows to calculate distance MO for each specimen.

Distances required to calculate MO are X_1G, XGn, GnG, MG, GnM. Angles required to calculate MO are α_1, α_2, ß, Ω, ß, ∂.
All the required distances could be measured from the observation points on the grid of each model.

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The angle sizes were calculated by means of the Sin E rule (Thompson 1969).

$$\sin \alpha_1 = \frac{X_1G}{MG}$$

$$\sin \alpha_2 = \frac{XGn}{GnM}$$

$$ß = 180° - (\alpha_1 + \alpha_2)$$

because AB is a straight line.

To calculate Ω the sine rule was applied

$$\frac{\sin \Omega}{GnM} = \frac{\sin ß}{GnG}$$

$$\sin \Omega = \frac{(\sin ß \ . \ GnM)}{GnG}$$

MG, ß, Ω and ∂ are known

$$\Omega = \arc \sin\left(\frac{\sin ß \ . \ GnM}{GnG}\right)$$

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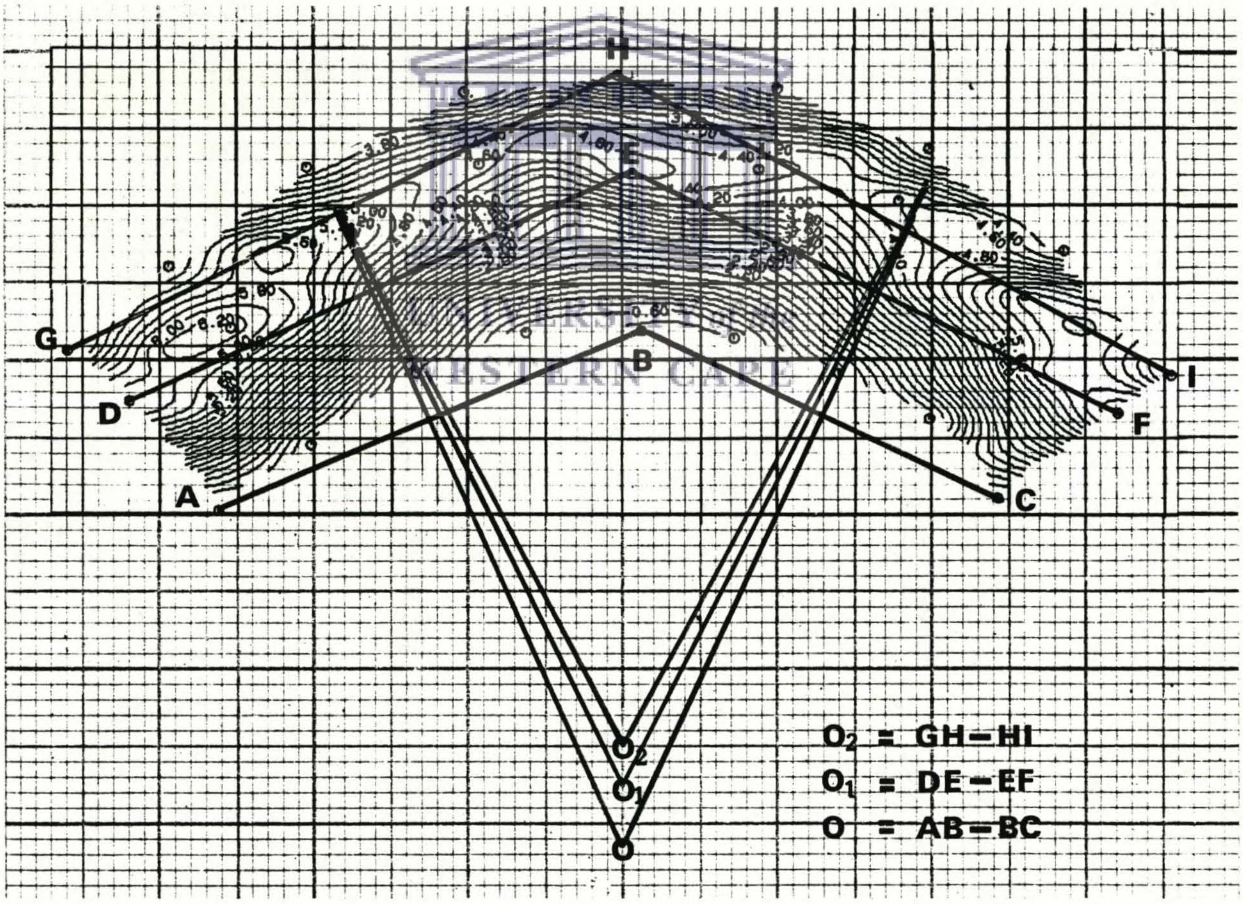
Using sine rule again

$$\frac{MO}{\sin \Omega} = \frac{MG}{\sin \delta}$$

$$MO = \frac{MG \, . \, \sin \Omega}{\sin \delta}$$

d) The appearance of the observation points on the contour plots, as shown in Figure 23, led to the hypothesis that the grid observation points could be located on the circumference of three arcs of circles of different radii for each mandible observed.



(Scale 3:1)

Fig. 23: Graphic contour reproduction depicting observation points, chords AB, BC, DE, EF, GH and HI as well as radius centre points O, O_1 and O_2. This tested the hypothesis that points A,B,C,D,E,F,G,H and I are situated on the circumference of a circle.

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The theorem that a perpendicular bisector of a chord passes through the centre of a circle was then applied. Figure 23 is a graphic contour reproduction of a mandibular model. Points A, B, C, D, E, F, G, H and I are the hypothetical points on the circumference of three circles described as lingual, crestal and buccal. Points A, B and C are connected to form chords AB and BC. Lines drawn perpendicular to AB and BC meet at O. If AO, BO and CO are equal, A, B and C are on the circumference of a circle. By means of a written computer programme observation, points 1-9 of the observation grid were incorporated to form a matrix of radii for the lingual circle. The average standard error of these observation points to the circumference of the circle was 0,14 mm. The same theorem was tested on points D,E,F, and G,H,I. To compute the crestal radius, points 20-27 and 10 were used and points 11-19 formed the basis for computing the buccal radius. The average standard error to the circumference of the crestal circle was 0,21 mm per observation point and for the buccal circle 0,18 mm. The standard error in each case was negligible and the hypothesis was thus accepted.

The different observation points (Fig. 19) were connected on the grid and allocated an alphabetical symbol which represented the section through that particular part of the mandible. The different points on the grid and alphabetical symbols of the sections are given in Table 1 and illustrated in Figure 24.

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Table 1: Alphabetical symbols represents sections through mandibles at specific observation points on grid.

1-20-19 = A
2-21-18 = B
3-22-17 = C
4-23-16 = D
5-24-15 = E
6-25-14 = F
7-26-13 = G
8-27-12 = H
9-28-11 = I

Fig. 24: Symbols illustrating inferior contour sites of mandible

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The mandibles were sectioned at planes A, E and I and the following points on the planes thus formed were observed. The upper observation marks were the most superior points (S) of the sectioned mandible whereas the buccal (B), lingual (L) and inferior (I) marks were the same points utilized for the grid as shown in Figures 25, 26, 27.

These observation points produced the following data:

e) The mathematical superior-inferior distance in plane A illustrated in Figure 25.

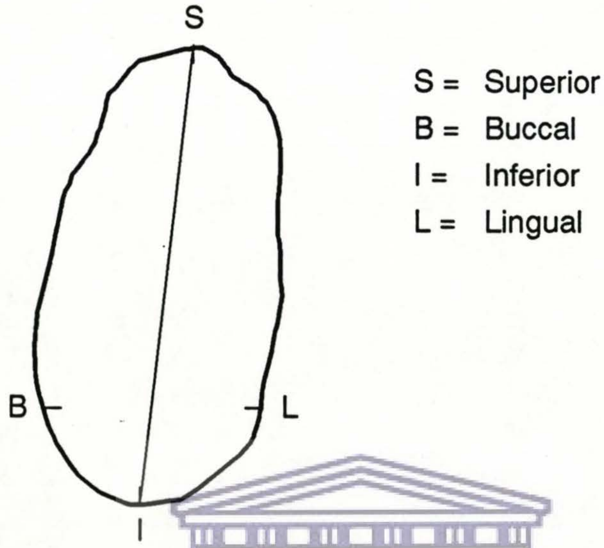

Fig. 25: Superior (S) to inferior (I) distance

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f) The angle of the superior inferior dimension to the buccolingual dimension represented in Figure 26 by α.

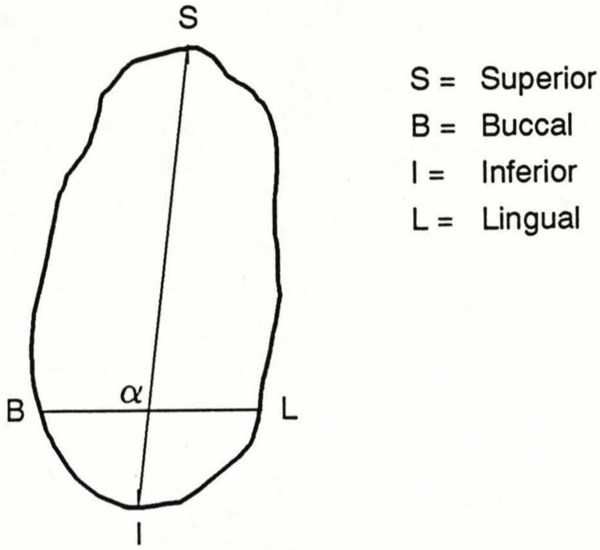

Fig. 26: Angle (α) formed at intersection of lines representing superior-inferior dimension (SI) and buccolingual dimension (BL)

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g) The buccolingual dimensions of the specimens were divided into three groups based on the following ranges:

Group 1: 4 mm to < 8 mm
Group 2: 8 mm to < 11 mm
Group 3: 11 mm to < 14 mm

h) The lengths of the inferior buccolingual border profiles (Fig. 20) of planes A, C, E, G and I were placed in one of the three categories established for Groups 1, 2 and 3, these were superimposed in a graphical manner.

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RESULTS

a) The measurements of the contours A, B, C, D, E, F, G, H and I (Fig. 24) of the individual specimens observed are recorded in Table 2 while Table 3 summarizes the means and standard deviations of measurements made.

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Table 2: Individual lengths (mm) of buccolingual contours of each specimen

SPEC NO	**B/L CON** A	**B/L CON** B	**B/L CON** C	**B/L CON** D	**B/L CON** E	**B/L CON** F	**B/L CON** G	**B/L CON** H	**B/L CON** I
1	5.5	6.2	6.0	6.3	6.2	6.3	5.6	5.2	5.6
2.	10.0	11.0	10.8	11.5	12.0	12.0	13.1	12.4	10.1
3.	9.2	9.2	8.9	10.1	8.6	8.9	8.9	8.8	9.8
4.	7.5	8.8	10.1	10.5	11.0	9.4	7.0	6.5	5.9
5.	8.0	8.3	7.8	7.4	6.8	8.1	7.6	7.6	7.6
6.	9.7	9.9	10.4	12.2	12.2	12.2	9.3	9.1	8.8
7.	9.0	10.3	10.6	10.8	10.4	11.4	12.5	10.4	10.5
8.	10.9	11.2	10.5	11.1	11.1	10.0	10.1	10.4	10.1
9.	11.0	11.0	11.2	12.2	9.4	10.6	10.6	10.6	9.9
10.	11.3	12.2	13.0	12.2	10.6	12.3	12.9	12.4	13.1
11.	12.9	12.7	12.8	11.8	11.0	12.0	11.6	12.3	12.0
12.	8.1	8.4	8.7	10.6	10.0	8.9	8.2	7.8	7.7
13.	8.6	8.0	9.4	9.2	8.4	8.7	7.4	8.0	7.3
14.	8.5	9.0	11.2	11.0	9.5	10.8	10.5	7.6	7.2
15.	11.1	11.8	12.9	14.5	15.2	14.6	12.8	11.4	11.4
16.	12.4	12.3	12.6	12.3	11.8	13.4	13.1	12.5	11.8
17.	9.2	9.6	10.0	10.3	10.4	10.7	9.8	9.5	8.3
18	9.2	9.6	9.0	8.9	7.6	9.1	9.1	10.1	9.9
19.	11.8	12.5	12.2	13.0	13.1	13.6	12.0	11.8	11.9
20.	8.5	7.9	7.7	7.0	8.3	6.9	6.5	6.4	6.9
21.	10.0	10.2	11.7	12.4	11.1	10.9	10.0	9.9	9.6
22.	7.4	7.7	8.1	9.1	7.1	7.7	7.4	6.2	6.3
23.	7.8	6.9	6.7	6.8	7.5	7.1	7.3	7.2	7.4
24.	9.5	10.1	11.3	12.4	12.4	12.1	11.5	9.0	9.8
25.	11.0	13.3	14.3	15.4	14.7	15.4	14.6	14.0	12.7
26.	10.8	11.3	11.8	12.9	13.2	12.6	11.9	11.7	11.4
27.	9.2	9.7	10.5	10.9	9.9	9.0	9.5	9.0	9.7
28.	10.7	11.0	10.7	11.5	12.3	10.5	9.8	10.4	11.7
29.	10.2	8.4	8.1	8.6	9.4	9.0	8.1	8.0	8.8
30.	10.3	9.8	11.5	12.0	11.5	12.7	11.6	9.9	10.6
31.	6.9	8.2	8.0	7.5	7.1	8.5	9.1	9.4	8.4
32.	9.4	9.5	8.9	9.2	7.3	7.1	7.1	7.3	7.7
33.	7.5	8.3	9.6	11.5	10.9	11.4	9.1	9.2	9.4
34.	9.9	9.7	10.2	11.0	10.3	11.0	9.3	9.0	9.3
35.	7.4	7.5	8.4	8.6	10.4	9.6	8.7	9.1	8.9
36.	8.6	9.2	11.2	11.6	12.7	11.7	11.0	10.6	9.0
37.	10.4	11.8	12.8	14.2	13.7	14.5	13.2	12.8	9.6
38.	9.3	10.1	9.8	9.9	9.4	9.5	10.1	10.4	9.9
39.	10.2	10.9	11.9	12.6	14.0	13.4	13.4	12.4	11.4
40.	8.9	8.7	7.0	7.1	7.6	6.6	6.6	7.9	8.3
41.	9.0	9.6	11.8	11.3	10.3	11.1	10.3	9.9	9.9
42.	11.6	16.8	16.2	15.4	12.7	18.1	18.5	17.4	8.2
43.	9.1	10.4	11.8	12.6	12.2	12.8	11.6	11.1	9.5
44.	10.1	11.4	10.7	12.3	12.7	11.7	11.1	10.0	9.5
45.	9.7	10.1	11.2	10.4	10.2	9.5	10.2	11.0	10.1

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Table 3: Means and standard deviations of buccolingual contour lengths (mm)

POSITION	MEAN MILLIMETRES	STANDARD DEVIATION ±
BL/CON A	9.49	1.50
BL/CON B	10.01	1.91
BL/CON C	10.44	2.06
BL/CON D	10.89	2.20
BL/CON E	10.53	2.23
BL/CON F	10.74	2.50
BL/CON G	10.21	2.50
BL/CON H	9.85	2.29
BL/CON I	9.39	1.76

Table 4 reflects the groupings obtained from multiple range analysis of the results summarized in Table 3.

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Table 4: Results of multiple range analysis, showing homogeneous groupings of mean different lengths of observed contours

		MILLIMETRES
BL/CON A	-	9.49**
BL/CON B	-	10.01***
BL/CON C	-	10.44***
BL/CON D	-	10.89 *
BL/CON E	-	10.53***
BL/CON F	-	10.74 **
BL/CON G	-	10.21***
BL/CON H	-	9.85***
BL/CON I	-	9.39*

* Indicates the vertical homogeneous groupings of the 95% confidence levels.

Buccolingual contours A, B, C, E, F, G and I form a homogeneous width group. A random sample from this group would result in a 95% chance that the specimen would be within the same parameters. Any specimen from buccolingual contour group D would not be included within the parameters of the abovementioned tabulation, while buccolingual contours B, C, D, E, F and H form a homogeneous group to which the 95% confidence level test applies.

Buccolingual contour F does not fall within the 95% confidence level of the first-mentioned tabulation but is within the parameters of the second group.

b) The direct distances (BL) between the buccal (B) and lingual (L) points of the grid (Fig. 21) are shown in Table 5.

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Table 5: Individual direct buccolingual distances (mm) of each specimen in each plane for all mandibles

SPEC NO.	STR A	STR B	STR C	STR D	STR E	STR F	STR G	STR H	STR I
1	4.5	4.7	4.8	5.2	6.0	5.0	4.5	4.4	4.7
2.	6.2	6.2	7.0	7.9	9.6	8.1	7.0	7.1	7.3
3.	6.5	6.8	7.2	6.9	6.4	6.8	7.2	7.3	8.0
4.	5.4	5.6	6.5	8.6	9.0	6.9	4.6	5.0	4.4
5.	6.8	6.6	6.7	6.4	6.0	7.0	6.5	6.6	6.3
6.	8.1	8.4	8.8	11.3	11.3	10.8	7.9	7.6	7.6
7.	6.6	7.6	8.6	8.9	8.5	9.6	9.5	8.1	7.8
8.	8.0	8.8	8.6	9.6	9.8	8.8	8.3	8.1	8.0
9.	8.4	9.2	10.0	11.0	9.1	9.7	9.3	8.9	7.9
10.	8.7	9.2	9.3	10.1	10.7	10.8	10.8	10.1	8.2
11.	11.0	10.9	10.7	10.7	10.4	10.5	9.8	10.5	10.4
12.	6.3	7.0	7.8	9.8	9.4	8.5	7.3	6.8	6.2
13.	6.9	7.1	7.9	7.7	8.2	7.6	6.2	7.1	6.4
14.	6.7	7.0	9.5	10.6	9.2	10.5	8.9	6.4	6.1
15.	9.7	10.3	11.4	12.9	12.6	13.1	11.1	10.0	9.6
16.	10.2	10.7	10.9	11.1	10.5	11.4	10.8	10.5	9.7
17.	7.1	7.8	8.3	8.9	8.8	9.3	8.0	7.3	6.5
18.	7.7	8.2	7.6	8.0	6.9	8.0	7.9	8.3	8.1
19.	9.0	9.8	10.7	11.9	11.9	12.0	10.3	8.7	8.7
20.	7.0	6.8	6.3	6.0	7.9	5.8	5.5	5.7	6.1
21.	8.2	9.1	10.3	11.0	10.1	9.8	8.5	7.9	7.7
22.	6.0	6.3	7.1	7.8	6.5	6.7	6.2	5.2	5.4
23.	6.7	6.3	5.9	5.7	6.6	6.4	6.7	6.4	6.6
24.	7.7	8.4	9.4	10.9	10.7	10.6	9.3	8.0	7.5
25.	9.7	11.1	12.4	13.9	13.1	13.6	12.2	11.1	10.2
26.	9.4	9.5	10.5	11.0	11.2	10.9	10.3	10.2	9.8
27.	6.4	6.9	7.8	8.8	8.0	7.6	7.3	6.3	6.6
28.	7.9	8.1	8.2	9.3	10.5	9.0	8.1	7.7	8.4
29.	8.9	7.3	6.8	6.8	8.6	7.1	6.6	7.0	7.6
30.	7.8	7.9	8.7	9.6	9.3	9.9	8.7	8.0	8.0
31.	5.8	6.8	6.6	6.5	6.6	7.0	7.7	7.8	7.2
32.	7.7	7.7	7.4	8.1	7.1	6.6	6.2	6.4	6.4
33.	6.5	6.6	7.7	9.3	9.4	6.9	6.9	6.8	7.2
34.	7.7	7.8	8.9	9.5	8.8	9.8	7.9	7.4	7.3
35.	8.7	9.2	9.3	10.1	10.7	10.8	10.8	10.1	8.2
36.	7.1	7.2	8.3	9.7	10.4	9.6	8.4	8.0	7.1
37.	7.2	8.6	10.3	12.6	12.0	12.7	10.6	9.4	7.7
38.	7.7	8.0	7.7	7.9	7.9	7.8	7.8	8.2	8.1
39.	8.3	9.2	10.5	11.0	12.1	11.9	11.7	10.1	9.3
40.	7.0	6.9	5.6	5.2	6.7	5.5	5.2	6.9	7.0
41.	8.0	8.5	10.3	10.2	9.7	9.7	8.8	8.2	8.0
42.	6.2	6.9	7.5	6.2	5.4	5.8	8.1	7.7	6.8
43.	7.9	9.2	10.9	11.5	10.8	11.5	10.5	9.4	8.2
44.	7.0	8.2	8.4	9.7	9.7	9.2	8.2	7.6	6.8
45.	8.1	8.4	8.9	9.0	8.8	8.4	8.7	8.8	8.0

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The means and standard deviations of the direct buccolingual dimensions of the mandibles are

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shown in Table 6 while Table 7 reflects the results of the multiple range analysis of these distances.

Table 6: Means and standard deviations of direct buccolingual dimensions

POSITION	**MEAN** **MILLIMETRES**	**STANDARD DEVIATION** **±**
STR A	7.56	1.68
STR B	7.97	2.00
STR C	8.53	2.89
STR D	9.21	2.09
STR E	9.17	1.92
STR F	9.0	2.15
STR G	8.32	1.80
STR H	7.89	1.55
STR I	7.53	1.30

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Table 7: Homogeneous groups derived from multiple range analysis of buccolingual distances by buccolingual sites

		MILLIMETRES
STR A	-	7.56*
STR B	-	7.97*
STR C	-	8.53**
STR D	-	9.21 *
STR E	-	9.17 *
STR F	_	9.00 *
STR G	-	8.28**
STR H	-	7.89*
STR I	-	7.53*

* Signifies the 95% confidence average for the homogeneous groupings.

The direct buccolingual distance at planes A, B, C, G, H and I form a homogeneous width group, while planes C, D, E, F and G form another homogeneous width group with a wider width parameter. The direct buccolingual distances at planes C and G are the only two groups that show the same width parameters for both groups.

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c) The distances MO, XGn and X_1Gn (Fig, 22) are summarized in Table 8 while Table 9 reflects their corresponding means and standard deviations.

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Table 8: Distances MO, X_1G and XGn (mm)

SPEC. NO.	MO	X_1G	XGn
1.	0.8	0.6	3.2
2.	2.6	2.5	2.6
3.	2.8	3.5	2.3
4.	3.2	3.8	2.1
5.	1.6	1.0	2.2
6.	2.3	2.2	2.3
7.	2.9	3.8	2.3
8.	2.6	2.2	2.8
9.	2.6	2.5	2.6
10.	1.7	0.4	3.1
11.	1.9	1.3	2.4
12.	1.4	0.4	1.7
13.	1.0	0.1	2.6
14.	1.1	1.7	0.3
15.	4.2	4.1	4.3
16.	2.7	2.8	2.5
17.	2.8	2.4	3.2
18.	1.4	0.7	2.9
19.	2.8	2.4	3.0
20.	1.0	0.5	2.8
21.	2.3	2.0	2.6
22.	1.4	1.0	2.1
23.	1.8	1.4	2.0
24.	3.2	2.9	3.4
25.	3.2	2.8	3.6
26.	3.4	4.5	2.7
27.	2.9	2.4	3.5
28.	3.0	3.1	3.0
29.	1.8	0.6	4.0
30.	3.4	3.3	3.4
31.	1.2	0.7	2.3
32.	0.9	0.4	1.6
33.	2.8	3.2	2.5
34.	2.7	2.8	2.7
35.	2.1	0.5	4.1
36.	3.7	3.6	3.7
37.	3.3	3.3	3.4
38.	2.6	2.4	2.8
39.	3.4	4.6	2.7
40.	1.7	0.6	3.9
41.	1.8	0.9	2.7
42.	0.4	0.8	1.2
43.	2.8	2.5	3.0
44.	4.1	5.0	3.4
45.	2.5	4.4	1.3

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Table 9: Means and standard deviations of distances MO, XGn and X_1G

POSITION	**MEAN** **MILLIMETRES**	**STANDARD DEVIATION** **±**
MO	2.35	0.92
XGn	2.19	1.37
X_1G	2.72	0.79

d) The radii of the lingual, crestal and buccal circles (Fig. 23) are noted in Table 10. The mean radii for the lingual, crestal and buccal circles were 19.8 mm, 22.2 mm and 24.7 mm respectively. The respective mean standard error of each observation point on the circumference of the circles was 0.14 mm for the lingual, 0.21 mm for the crestal and 0.18 mm for the buccal.

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Table 10: Lingual, crestal and buccal radii distances (mm)

SPEC NO	RAD LINGUAL	RAD CRESTAL	RAD BUCCAL
1	20.5	22.9	23.9
2	19.0	21.5	23.0
3	18.3	19.8	25.9
4	18.7	20.1	21.2
5	17.3	19.3	22.5
6	22.0	21.2	24.8
7	17.6	20.3	23.1
8	21.0	21.3	26.5
9	18.8	23.0	25.4
10	15.8	23.2	25.1
11	18.1	21.2	27.9
12	21.2	18.2	22.5
13	21.6	25.6	25.6
14	16.1	17.6	19.6
15	26.3	29.0	28.1
16	19.8	25.0	28.0
17	18.9	1.5	22.4
18	15.3	18.8	22.1
19	21.6	20.0	25.5
20	17.2	20.0	22.5
21	19.9	22.4	25.2
22	22.7	25.5	27.5
23	16.6	18.6	22.0
24	21.0	23.5	24.3
25	21.3	26.5	24.6
26	22.5	26.4	28.9
27	16.6	17.9	20.5
28	20.3	21.0	25.1
29	17.6	19.6	25.2
30	18.8	22.6	24.6
31	21.5	30.3	28.1
32	20.4	22.3	26.4
33	21.6	21.2	24.4
34	19.1	20.2	23.7
35	17.1	18.4	21.9
36	19.3	21.6	23.4
37	26.9	27.1	26.8
38	19.5	23.1	27.2
39	22.8	22.7	27.2
40	18.1	20.9	24.8
41	21.0	24.8	25.6
42	19.1	23.2	23.8
43	22.6	23.7	25.6
44	19.7	21.5	24.0
45	19.0	24.4	25.9

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e) The distances from the superior crests to the inferior crests of the mandibles, as measured in planes A, E and I (Figs. 24 and 25) are recorded in Table 11.

Table 11: Superior-inferior distances (mm) are reflected as S/I A for plane A; S/I E for plane E and S/I I for plane I

SPEC NO.	**S/I A**	**S/I E**	**S/I I**
1	8.83	16.23	9.53
2	11.99	14.45	13.46
3	17.00	19.75	14.03
4	18.53	23.77	19.30
5	15.48	20.45	14.10
6	17.50	19.80	14.64
7	15.65	18.30	15.08
8	15.67	16.43	15.03
9	16.27	17.46	12.47
10	19.49	16.72	16.93
11	18.06	16.95	9.28
12	13.86	20.79	13.87
13	20.15	19.88	18.83
14	18.43	18.65	17.66
15	18.45	18.28	12.03
16	15.17	18.97	16.17
17	15.40	17.51	15.47
18	15.30	20.35	17.20
19	12.46	17.05	14.00
20	19.40	17.91	16.53
21	10.13	14.21	13.37
22	11.46	19.64	14.66
23	13.71	18.56	12.65
24	13.24	19.27	18.22
25	14.68	18.21	14.40
26	12.17	13.55	10.84
27	13.03	17.91	12.22
28	10.79	14.42	15.10
29	9.16	11.07	6.89
30	17.85	17.85	16.40
31	15.55	18.77	14.91
32	8.18	8.85	10.19
33	15.67	17.38	12.81
34	12.79	11.40	9.77
35	16.19	16.29	14.54
36	14.38	19.19	15.96
37	18.51	22.45	17.82
38	14.08	18.00	12.33
39	13.63	17.56	15.27
40	15.30	18.51	14.60
41	14.73	16.70	15.46
42	11.79	18.07	13.62
43	10.78	14.49	9.96
44	15.6	21.48	14.92
45	17.11	17.04	16.21

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The means of the superior-inferior distance of these planes were:

Plane A	14.7mm
Plane E	17.6mm
Plane I	14.4mm

The means of the buccolingual contour distance of these planes were:

Plane A	9.49mm
Plane E	10.53mm
Plane I	9.39mm

The means of the direct buccolingual width of these planes were:

Plane A	7.56mm
Plane E	9.17mm
Plane I	7.53mm

f) Table 12 reflects the size of the angles (α) at the bisection of the lines representing the superior-inferior (SI) and buccolingual (BL) dimensions (Fig. 26).

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Table 12: Angles at intersection lines SI and BL in respect of planes A, E and I.

SPEC NO.	ANGLE AT A	ANGLE AT E	ANGLE AT I
1	94.4	97.5	83.9
2.	98.9	106.7	108.0
3.	101.3	112.7	96.1
4.	82.4	111.5	97.7
5.	69.6	105.2	80.2
6.	99.0	119.0	104.0
7.	98.2	114.7	120.9
8.	99.0	109.4	98.1
9.	87.4	97.5	94.8
10.	101.2	115.1	114.3
11.	95.6	113.5	87.4
12.	91.6	114.7	92.7
13.	94.5	105.4	101.2
14.	96.8	121.1	106.7
15.	99.6	105.9	105.4
16.	110.6	112.2	118.3
17.	89.5	112.0	96.8
18.	80.6	98.5	87.1
19.	76.7	119.2	92.1
20.	89.5	77.8	79.0
21.	112.2	115.8	98.7
22.	99.6	111.8	100.6
23.	76.4	117.8	75.1
24.	101.8	106.6	97.6
25.	120.2	106.4	115.9
26.	143.1	121.3	108.4
27.	108.3	112.5	101.4
28.	78.6	98.2	107.9
29.	72.1	78.4	67.7
30.	89.0	117.5	105.3
31.	117.0	116.2	120.8
32.	93.5	86.3	96.3
33.	96.4	120.5	79.9
34.	100.1	115.8	87.2
35.	75.6	90.1	81.5
36.	91.7	116.7	107.5
37.	113.3	111.5	115.4
38.	92.3	109.5	102.6
39.	82.4	103.5	87.0
40.	105.2	111.4	104.6
41.	96.8	130.4	111.8
42.	104.4	111.8	113.1
43.	95.0	109.5	107.7
44.	92.9	107.4	109.9
45.	98.7	106.2	110.5

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The means and standard deviations of the angles at planes A, E and I were:

	MEAN DEGREES	STANDARD DEVIATION ±
Plane A	95.8°	13.6
Plane E	108.9°	10.7
Plane I	99.5°	12.8

g) Table 13 depicts the distribution of the direct buccolingual dimensions (BL) at planes A, E and I relative to the three established ranges or width categories describe under item g), on page 32. The distribution for the buccolingual contour distances (BIL) at the same planes and for the same establish ranges or groups, are shown in Table 14.

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Table 13: Groups of direct buccolingual measurements at planes A, E and I.

BL Dimensional groups 1, 2 and 3

SPEC. NO.	(Group 1)4 to <8MM			(Group 2)8 to <11MM			(Group 3)11 - 14MM		
	A	E	I	A	E	I	A	E	I
1.	4.5	6.0	4.7						
2.	6.2		7.3		9.6				
3.	6.5	6.4		8.0					
4.	5.4		4.4		9.0				
5.	6.8	6.0	6.3						
6.			7.6	8.1				11.3	
7.	6.6		7.8		8.5				
8.				8.0	9.8	8.0			
9.			7.9	8.4	9.1				
10.				8.7	10.7	8.2			
11.					10.4	10.4	11.0		
12.	6.3		6.2		9.4				
13.	6.9		6.4		8.2				
14.	6.7		6.1		9.2				
15.				9.7		9.6		12.6	
16.				10.2	10.5	9.7			
17.	7.1		6.5		8.8				
18.	7.7	6.9				8.1			
19				9.0		8.7		11.9	
20.	7.0	7.9	6.1						
21.			7.7	8.2	10.1				
22.	6.0	6.5	5.4						
23.	6.7	6.6	6.6						
24.	7.7		7.5		10.7				
25.				9.7		10.2		13.1	
26.				9.4		9.8		11.2	
27.	6.4		6.6		8.0				
28.	7.9				10.5	8.4			
29.			7.6	8.9	8.6				
30.	7.8				9.3	8.0			
31.	5.8	6.6	7.2						
32.	7.7	7.1	6.4						
33.	6.5		7.2		9.4				
34.	7.7		7.3		8.8				
35.				8.7	10.7	8.2			
36.	7.1		7.1		10.4				
37.	7.2		7.7		12.0				
38.	7.7	7.9		8.1					
39.				8.3		9.3		12.1	
40.	7.0	6.7	7.0						
41.				8.0	9.7	8.0			
42.	6.2	5.4	6.8						
43.	7.9				10.8	8.2			
44.	7.0		6.8		9.7				
45.				8.1	8.8	8.0			

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Table 14: Groups of contour measurements at planes A, E and I

BIL Dimensional groups 1, 2 and 3

SPEC	(Group 1)4 to < 8mm			(Group 2)8 to < 11mm			(Group 3)11 - 14 mm		
NO.	A	E	I	A	E	I	A	E	I
1.	5.5	6.2	5.6						
2.				10.0		10.1		12.0	
3.				9.2	8.6	9.8			
4.	7.5		5.9					11.0	
5.		6.8	7.6	8.0					
6.				9.7		8.8		11.1	
7.				9.0	10.4	10.5			
8.				10.9		10.1		11.0	
9.					9.4	9.9	11.0		
10.					10.6		11.3		13.1
11.							12.9	11.0	12.0
12.			7.7	8.1	10.0				
13.			7.3	8.6	8.4				
14.			7.2	8.5	9.5				
15.							11.1	15.2	11.4
16.							12.4	11.8	11.8
17.				9.2	10.4	8.3			
18.		7.6		9.2		9.9			
19.							11.8	13.1	11.9
20.			6.9	8.5	8.3				
21.				10.0		9.6		11.1	
22.	7.4	7.1	6.3						
23.	7.8	7.5	7.4						
24.				9.5		9.8		12.4	
25.							11.0	14.7	12.7
26.				10.8				13.2	11.4
27.				9.2	9.9	9.7			
28.				10.7				12.3	11.7
29.				10.2	9.4	8.8			
30.				10.3		10.6		11.5	
31.	6.9	7.1				8.4			
32.		7.3	7.7	9.4					
33.	7.5				10.9	9.4			
34.				9.9	10.3	9.3			
35.	7.4				10.4	8.9			
36.				8.6		9.0		12.7	
37.				10.4		9.6		13.7	
38.				9.3	9.4	9.9			
39.				10.2				14.0	11.4
40.		7.6		8.9		8.3			
41.				9.0	10.3	9.9			
42.						8.2	11.6	12.7	
43.				9.1		9.5		12.2	
44.				10.1		9.5		12.7	
45.				9.7	10.2	10.1			

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h) The lengths of the inferior buccolingual profiles of planes A, C, E, G and I are grouped according to the three established ranges of width categories described under item g) page 32. These profiles are shown in Figures 27 - 41 and are included in the appendix pages 62-77.

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DISCUSSION

The object of this study was to undertake a three-dimensional survey of severely-resorbed edentulous mandibles in the area bounded by the mental foramina, using the inferior point of the base of the lower genial tubercle, Menton and Gnation, as reference points. These results would demonstrate the feasibility of designing a series of titanium transmandibular implants that would be suitable for the use in two-stage procedures performed in a wide spectrum of patients, allowing time for osseointegration to occur prior to abutment connection and loading.

Due to the lack of information, it was not possible to demonstrate any correlation between size, age, gender and ethnic group. The results of the profile measurements of the inferior mandibular border were too inconsistent to design a contoured baseplate for the majority of cases, and were discarded. To accommodate a flat baseplate the inferior border of the mandible would have to be surgically contoured by removal of an average of 2.3 mm of bone.

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In designing a universal baseplate the narrowest area would determine the width so as not to impinge on the soft tissues. These results demonstrated that the width at the mental foramina would determine the width of the base plate. Thirty-three mandibles in the sample fell within Group 1. The average width was 6.65 mm with a median of 6.6 mm and mode of 6.4 mm. However the minimum value was 4.4 mm and, therefore, to accommodate all the specimens the baseplate would have to have a width of 4.4 mm. Group 2 consisted of 12 mandibles from the sample, with an average width of 8.85 mm, a median of 8.5 mm and a mode of 8 mm; however, minimum width was 8 mm and the width of the baseplate in this category would therefore be 8 mm.

Application of trigonometric principles to the analysis of maxillary casts have led to the formulation of a theory that the anterior maxillary arch lies on the circumference of a circle (Oblak, 1975). Stereophotogrammetry analysis of maxillary and mandibular alveolar ridges by Adams (1976) lent support to the circle theory. This study confirms the finding of these two earlier workers. The results show that the mandibular arc lies on the circumference of a circle; that the majority of mandibular arches have a common centre point; and that the wider the buccolingual dimension the greater the circumference of the circle. The 4 mm to < 8 mm group had a width of 4.4 mm and a common radius of 17.6 mm whereas the 8 mm to < 11 mm group had a 8 mm baseplate width and a common radius of 21 mm.

In Group 1, 18,18% of specimens and in Group 2, 15,15% of specimens had shorter radii than those of the mean. Given the relative dimensions of the arc angle and radius length, the difference is negligible and would accommodate all the specimens.

Ideally the vertical components of the transmandibular implant should emerge at the crest of the alveolar ridge. The mean angles and variance at planes A, E and I demonstrated in this study do not indicate that a universal design could suit the majority of clinical situations. The means of the angles at planes A, E and I was 95.8°, 108.9° and 99.5° respectively. If the transmandibular components at planes A and I were angled at 97° to the base plate they would emerge at the immediate region of the alveolar crest. A shortened intramandibular component at plane E would provide additional stabilization and enhanced osseointegration and stabilization.

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The division of the specimens into width categories ensured that all the specimens were accommodated. Group 1 contained 73.3% of the specimens while 26.7% were accommodated in Group 2.

CONCLUSION

The restricted nature of this sample made it impossible to establish any correlation between mandibular morphology, age, gender or ethnic group. Moreover, analysis of the results showed that they could not be used towards designing a "universal" staple transmandibular implant with baseplate width and angulation of its transmandibular components such that it would be applicable to a broad spectrum of patients, however using these results it would be possible to design a series of staple transmandibular implants that would be applicable to most clinical situations.

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REFERENCES

Adams, L.P. (1976) Palatal analysis by a stereophotogrammetric method. The South African Survey Journal 15(93), 35-49.

Adams, L.P., Jooste, C.H. & Thomas, C.J. (1991) Accuracy of a replication technique for biostereometric evaluation of clinical tooth wear. Journal of the Dental Association of South Africa, 46, 363-364.

Adams, L.P. & Wilding, R.S.C. (1988) A stereometric technique for measuring residual alveolar ridge volumes. Journal of Prosthetic Dentistry, 60, 388-393.

Albrektsson, T., Bränemark, P.I., Hansson, H.A. & Lindström, J. (1981) Osseointegrated Titanium implant requirements for ensuring a long-lasting, direct bone-to-implant anchorage in man. Acta Orthopedica Scandinavica, 52, 155-170.

Atkinson, P.J. & Witt, S. (1982) Characteristics of Bone Biocompatibility of Dental Materials Ch 4, 95-131, London, Cleveland, Ohio, Florida, CRC Press. Ed Smith, D.C. & Williams D.F.

Balogh, K. (1964) Support of lower denture prosthesis by implanted metal roots. Dental Digest, 70, 312, cited by Natiella et al, (1972).

Berry, A. (1888) Lead roots on teeth for implantation. Ohio State Journal of Dental Science, 6, 549, cited by Natiella et al, (1972).

Bosker, H. & Van Dijk, L. (1989) The transmandibular implant : A 12 year follow-up study. Journal of Oral Maxillo-Facial Surgery, 47, 442-450.

Boucher, L.J. & Surwillo, E.J. (1968) The effects of plastic implants on the jaws and adjacent tissues of the rabbit. Journal of Prosthetic Dentistry, 19, 514-522.

UNIVERSITY of the
WESTERN CAPE

http://etd.uwc.ac.za/

Bränemark, P.I. (1983) Osseointegration and its experimental background. Journal of Prosthetic Dentistry, 50, 399-410.

Bränemark, P.I., Zarb, G.A. & Albrektsson, T. (1985) Tissue-integrated Prosthesis. Osseointegration in Clinical Dentistry, Ch. 1, pp. 11-76, Chicago, London, Rio de Janeiro and Tokyo: Quintessence Publishing Company.

Brown, B.H., Neff, P.A. & Tylenda, A. (1969) Acrylic resin tooth implants in rhesus monkeys: A preliminary report. Journal of Prosthetic Dentistry, 22, 367-370.

Carlsson, L., Röstlund, T., Albrektsson, B., Ablrektsson, T. & Bränemark, P.I. (1986) Osseointegration of titanium implants. Acta Orthopaedica Scandinavica, 57, 285-289.

Casto, T.D. (1914) Results of 3 iridio-platinum roots implanted. Dental Cosmos, 56, 493, cited by Natiella et al, (1972).

Cranin, A.N. & Cranin, S.L. (1966) Simplifying the subperiosteal implant denture technique. Oral Surgery, Oral Medicine and Oral Pathology, 22, 7-20.

Dahl, G. (1956) Subperiosteal implants and superplants. Rass Trimest Odontoiatr, 37, 25 cited by Natiella et al, (1972).

Davis, S.D., Gibbons, D.F., Martin, R.L., Levitt, S.R., Smith, J. & Harrington, R.V. (1972) Biocompatibility of ceramic implants in soft tissue. Journal of Biomedical Materials Research, 6, 425-449.

Denissen, H.W., Veldhuis, H.A. & Van Faassen, F. (1984) Implant placement in the atrophic mandible : An anatomic study. Journal of Prosthetic Dentistry, 52, 260-263.

Ehricke, A. (1920) Die Odontoplastik im Lichte der Plantationslehre. Berlin Sammlung Meusser, Part 12, cited by Natiella et al, (1972).

UNIVERSITY of the WESTERN CAPE

English, C. (1990) An overview of implant hardware. Journal of the American Dental Association, 121, 360-368.

Evaskus, D.S., Rostoker, W. & Laskin, D.M. (1980) Evaluation of sintered titanium fibre composite as a subperiosteal implant. Journal of Oral Surgery 38, 490-498.

Fitzpatric, B. (1968) A comparative study of some implant material: Part II. Australian Dental Journal, 13, 422-434.

Goldberg, N.I. & Gershkoff, A. (1949) The implant lower denture. Dental Digest, 55, 490-494.

Grenoble, D.E. & Voss, R. (1977) Analysis of five years of study of vitreous carbon endosseous implants in humans. Oral Implantology, 6, 509-525.

Hamner, J.E. & Reed, O.M. (1973) Implantable ceramic teeth. Journal of Biomedical Material Research Symposium, 7(4), 217-234.

UNIVERSITY of the
WESTERN CAPE

Hamner, J.E., Reed, O.M. & Greulich, R.C. (1972) Ceramic root implantation in baboons. Journal of Biomedical Materials Research Symposium, 6(3), 1-13.

Hamner, J.E., Reed, O.M. & Hand, A.R. (1970) Clinical, radiographic, histologic and electron microscopic observations of plastic tooth implantations in baboons. Oral Surgery, Oral Medicine and Oral Pathology, 30, 555-570.

Harris, L.M. (1887) An artificial crown on a leaden root. Dental Cosmos, 55, 433, cited by Natiella et al, (1972).

Hegedus, Z. & Inke, G. (1957) Implantation of tooth roots made of methylmethacrylate. Schweil Monatsshr Zahnheikunde, 67, 29, cited by Natiella et al, (1972).

http://etd.uwc.ac.za/

Helfrick, J.F., Topf, J.S. & Kaufman, M. (1982) Mandibular staple bone plate : Long term evaluation of 250 cases. Journal of the American Dental Association, 104, 318-320.

Hodosh, M. (1960) Implants of plastic teeth. Journal of the American Dental Association, 60, 123-124.

Hodosh, M., Montagna, A.B., Povar, M., Providence, R.I. & Shklar, G. (1964) Implants of acrylic teeth in human beings and experimental animals. Oral Surgery, Oral Medicine and Oral Pathology, 18, 569-579.

Hodosh, M., Povar, M. Providence, R.I. & Shklar, G. (1967) Plastic tooth implants with root channels and osseous bridges. Oral Surgery, Oral Medicine and Oral Pathology, 24, 831-836.

Hodosh, M., Povar, M., Providence, R.I. & Shklar, G. (1968) The anatomic anorganic bone polymethacrylate endosteal dental implant. Oral Surgery, Oral Medicine and Oral Pathology, 25, 883-888.

UNIVERSITY of the
WESTERN CAPE

Homsy, C.A. (1970) Bio-compatibility in selection of material for implantation. Journal for Biomedical Material Research, 4, 341-356.

Hulbert, S.F., Morrison, S.J. & Klawitter, J.J. (1972) Tissue reaction of three ceramics of porous and non-porous structures. Journal of Biomedical Materials Research, 6, 347-374.

Iswaschenko, G.M. (1957) On the possibility of implanting acrylic teeth and roots. Stomatologia (Moskva), 36, 52, cited by Natiella et al, (1972).

Kent, J.N. & Bokros, J.C. (1980) Pyrolytic carbon and carbon-coated metallic dental implants. Dental Clinics in North America, 24, 465-485.

Kent, J.N. Misiek, D.J. Silverman, H. & Rotskoff, K. (1984) A multicenter retrospective review of the mandibular staple bone plate. Journal of Oral Maxillo-Facial Surgery, 42, 421-428.

Kerley, T.R., Phillips, R.M., Mulherin, D.R., English, J. & Schow, C.E. (1981) The ramus frame implant. Journal of Oral Surgery, 39, 415-420.

Lam, R.V. & Poon, K.Y. (1968) Acrylic resin root implants : A preliminary report. Journal of Prosthetic Dentistry, 19, 506-513.

Linkow, L.I. (1954) Unilateral implant. Dental Digest, 60, 302-306.

Linkow, L.I. (1958) An evaluation of the unilateral implant : a five year report. Dental Digest, 64, 383-387.

Linkow, L.I. (1964) Intra-osseous implants utilized as fixed bridge abutments. Journal of Oral implantology and transplant Surgery, 10, 17-23.

Linkow, L.I. (1967) Re-evaluation of mandibular unilateral subperiosteal implants : A 12 year report. Journal of Prosthodontics, 17, 509-514.

UNIVERSITY of the
WESTERN CAPE

Linkow, L.I. (1970) Endosseous blade-vent implant. Journal of Prosthetic Dentistry, 23, 441-448.

Marziani, L. (1954) Dental implants and implant dentures. Their theory; history and practice. International Dental Journal, 4, 459-481.

Maxon, B.B., Powers, M.P. & Scott, R.F. (1990) Prosthodontic considerations for the transmandibular implant. Journal of Prosthetic Dentistry, 63, 554-558.

McLean, J.W. (1967) High alumina ceramics for bridge pontic construction. British Dental Journal, 123, 571, cited by Natiella et al, (1972).

Meyer, J.B. & Kotwal, K.R. (1986) Clinical evaluation of ramus frame and staple bone implants. Journal of Prosthetic Dentistry, 55, 87-92.

http://etd.uwc.ac.za/

Natiella, J.R., Armitage, J.E., Greene, G.W. Jr. & Meenaghan, M.A. (1972) Current evaluation of dental implants. Journal of the American Dental Association, 84, 1358-1372.

Nelson, R.W. (1974) The ramus frame implant for stabilzing impossible lower dentures. Oral Implantology, 4, 475-503.

Oblak, P. (1975) Trigonometric method of analysis of the upper part of the mouth cavity. Journal of Maxillo-Facial Surgery 3, 88-93.

Orlay, H.G. (1960) Endodontic splinting. Treatment in periodontal dissease. British Dental Journal, 108, 118-121.

Parr, G.R., Gardner, L.K. & Toth, R.W. (1985) Titanium: The mystery metal of implant dentistry. Dental Material aspects. Journal of Prosthetic Dentistry, 54, 410-414.

Pedersen, K.N., Haanaes, H.R. & Faehno, O. (1979) Subperiosteal transmucosal porous ceramic titanium implants: clinical experience from three cases. International Journal of Oral Surgery, 8, 349-355.

Roberts, H.D. & Roberts, R.A. (1970) The ramus endo-osseous implant. Quintessence International, 10, 33, cited by Natiella et al, (1972).

Schneider, H. (1937) Ober Aseptische Implantation einer neuen Kunstlichen Zahn wurzel. Acta Stomatology, 12, 806, cited by Natiella et al, (1972).

Schnitman, P.A. & Shulman, L.B. (1980) Vitreous carbon implants. Dental Clinics of North America, 3, 441-463.

Scholl, C.R. (1905) Implantation of a porcelain tooth. Dental Cosmos, 47, 157, cited by Natiella et al, (1972).

UNIVERSITY of the WESTERN CAPE

Scialom, J. (1963) La Selle fite et les risques de infiltration. L'Evolution Odonto Implantogique, 1, 3, cited by Natiella et al, (1972).

Scott, P.J. (1981) The reflex plotters : measurement without photographs. Photogrammetric Record, 10, 435-446.

Shaykin, J.B. (1962) An endodontic splint for partial denture support. Journal of the American Dental Association, 65, 846-847.

Small, I.A. & Kobernick, S.D. (1969) Implantation of threaded stainless steel pins in the dog's mandible. Journal of Oral Surgery, 27, 99-109.

Small, I.A. (1975) Metal implants and the mandibular staple bone plate. Journal of Oral Surgery, 33, 571-585.

Small, I.A. (1979) Use of the mandibular staple bone plate in the deformed mandible. Journal of Oral Surgery, 37, 26-30.

Small, I.A. (1980) Benefit and Risk of Mandibular Staple Bone Plates. In Dental Implants: Benefits & Risk. An NIH-Harvard Consensus Development Conference, ed. Schmitman, P.A. & Schulman, L.B., pp 139-150 Bethesda: National Institute of Health.

Small, I.A. (1986) The mandibular staple bone plate : Its use and advantages in reconstructive surgery. Dental Clinics of North America, 30, 175-187.

Small, I.A. (1990) The fixed mandibular implant : Its use in reconstructive prosthetics. Journal of the American Dental Association, 121, 369-374.

Smith, D.C. (1974) Materials used for construction and fixation of implants. Oral Science Reviews, 5, 23-55.

UNIVERSITY of the
WESTERN CAPE

Strock, A.E. (1939) Experimental work on a method for the replacement of missing teeth by direct implantation of a metal support into the alveolus. American Journal of Orthodontics, 25, 467, cited by Natiella et al, (1972).

Tallgren, A. (1972) The continuing reduction of the residual alveolar ridges in complete denture wearers: A mixed-longitudinal study of covering 25 years. Journal of Prosthetic Dentistry, 27, 120-132.

Thompson, E.H. (1969) An Introduction of the Algebra of Matrices with Some Applications, 1st ed., pp 153-157, London: JCL Press Ltd.

Taira, M., Moser, J.B. & Greener, E.H. (1989) Studies of Ti-alloys for dental castings. Dental Materials, 5, 45-50.

Unger, J.W. & Crabtree, D.G. (1991) The transmandibular implant : prosthodontic treatment considerations. Journal of Prosthetic Dentistry, 66, 660-664.

UNIVERSITY of the
WESTERN CAPE

Weber, S.P. (1966) Unilateral subperiosteal implants : Elimination of solid fixation. Journal of Implant and Transplant Surgery, 12, 17, cited by Natiella et al, (1972).

Wimmer, J. (1979) Laboratory procedures for subperiosteal implant dentures. Journal of Oral Implantology, 4, 629-642.

Wright, W.D. (1954) Stereoscopic vision applied to Photogrammetry. Photogrammetric Record, 1, 29-49.

Woodforde, J. (1968) The strange story of false teeth. Ch. 2, pp 8 - 13; Ch. 13, pp 81 - 86, London. Routledge & Kegan Paul Limited, Special edition in association with Reckitt & Sons Ltd. Hull.

Weisman, S. (1970) The skeletal structure of metal implants. Oral Implantology, 1, 69, cited by Natiella et al, (1972).

http://etd.uwc.ac.za/

Young, F.A. (1972) Ceramic tooth implants. Journal of Biomedical Materials Research Symposium, 6(2), 281-296.

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APPENDIX

The lengths of the inferior buccolingual planes of planes A, C, E, G and I are grouped according to the three established ranges or width categories described under item g) page 32. These profiles are shown in Figures 27 - 41 and are included in pages 63 - 77.

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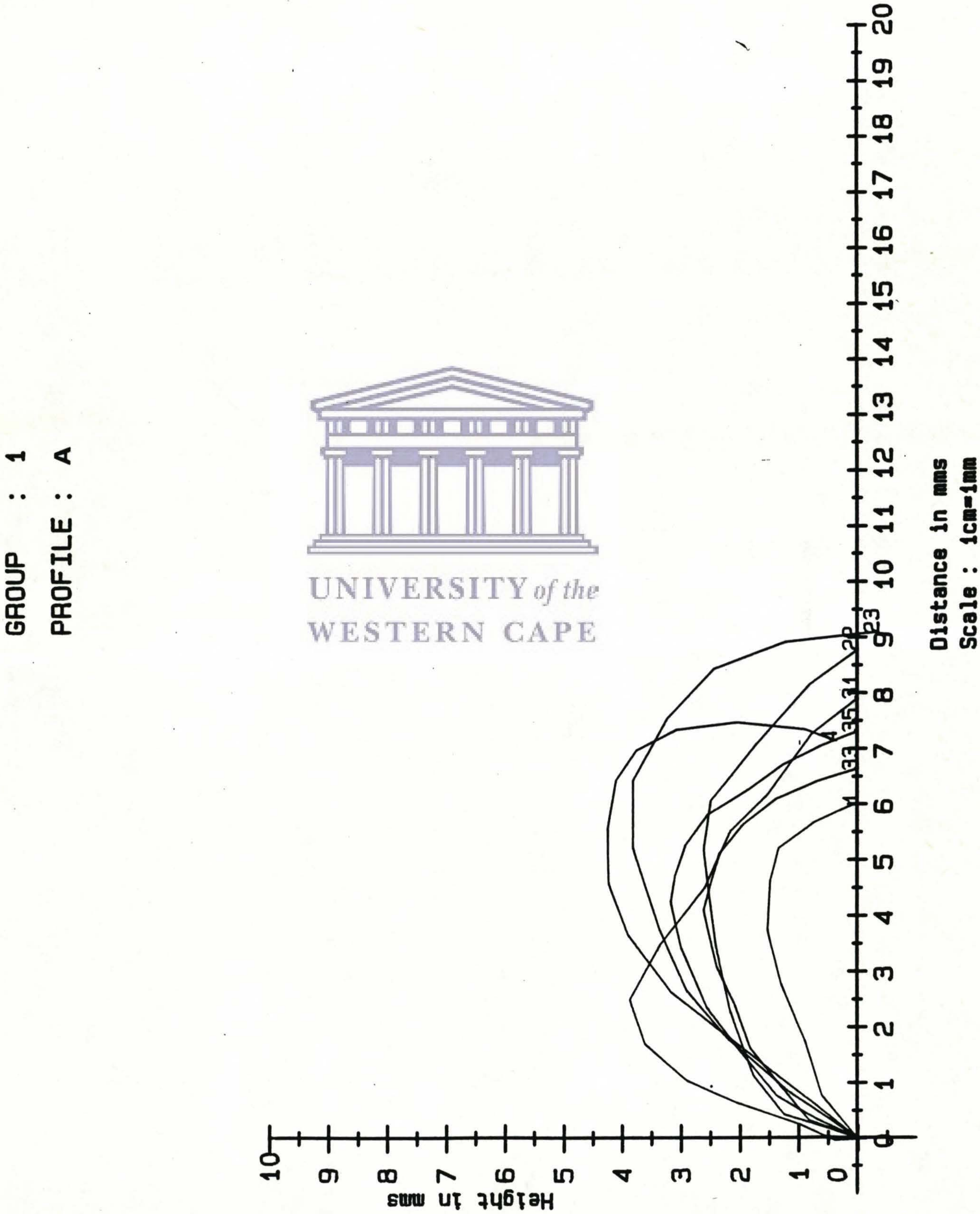

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FIGURE 27

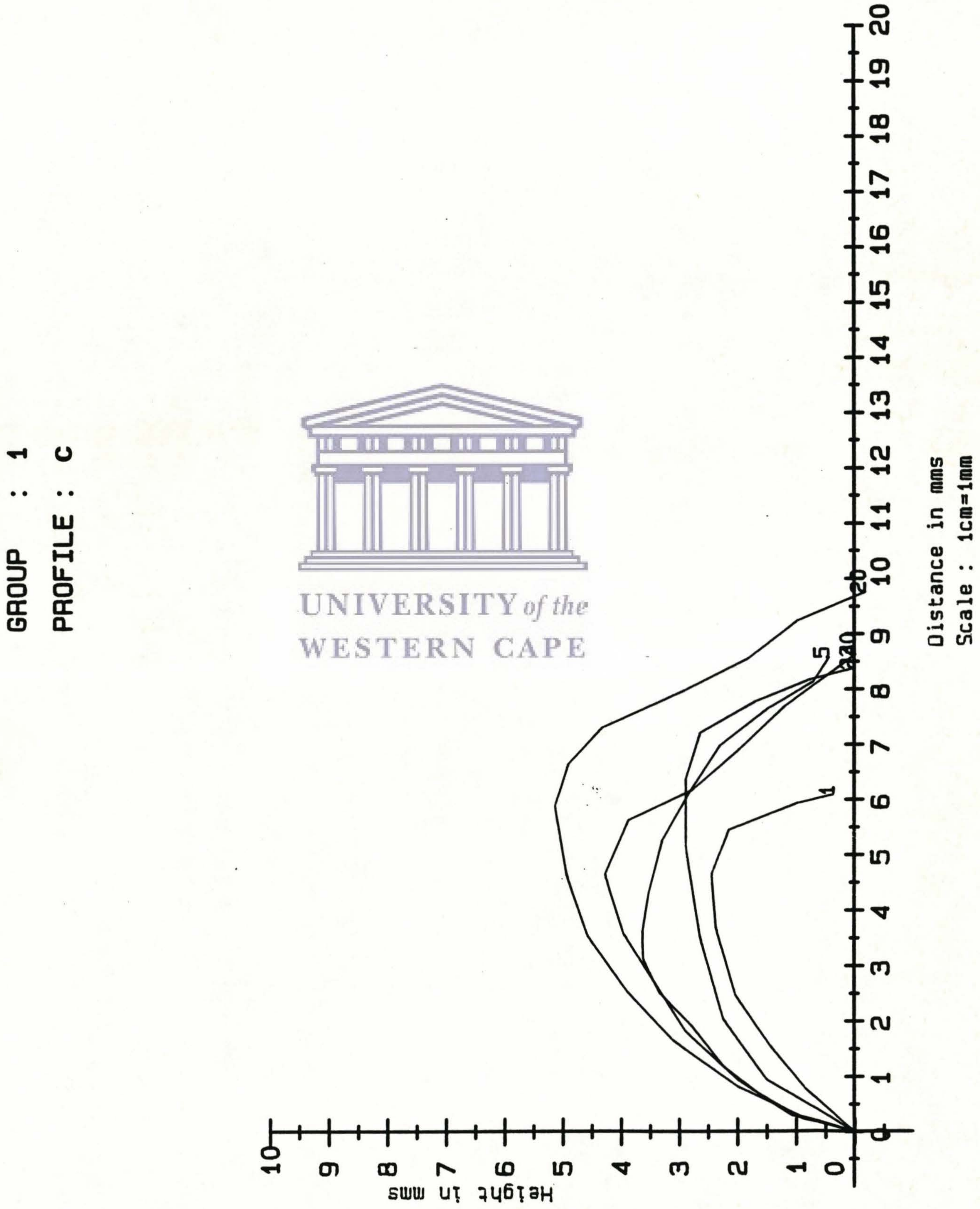

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FIGURE 28

GROUP : 1
PROFILE : E

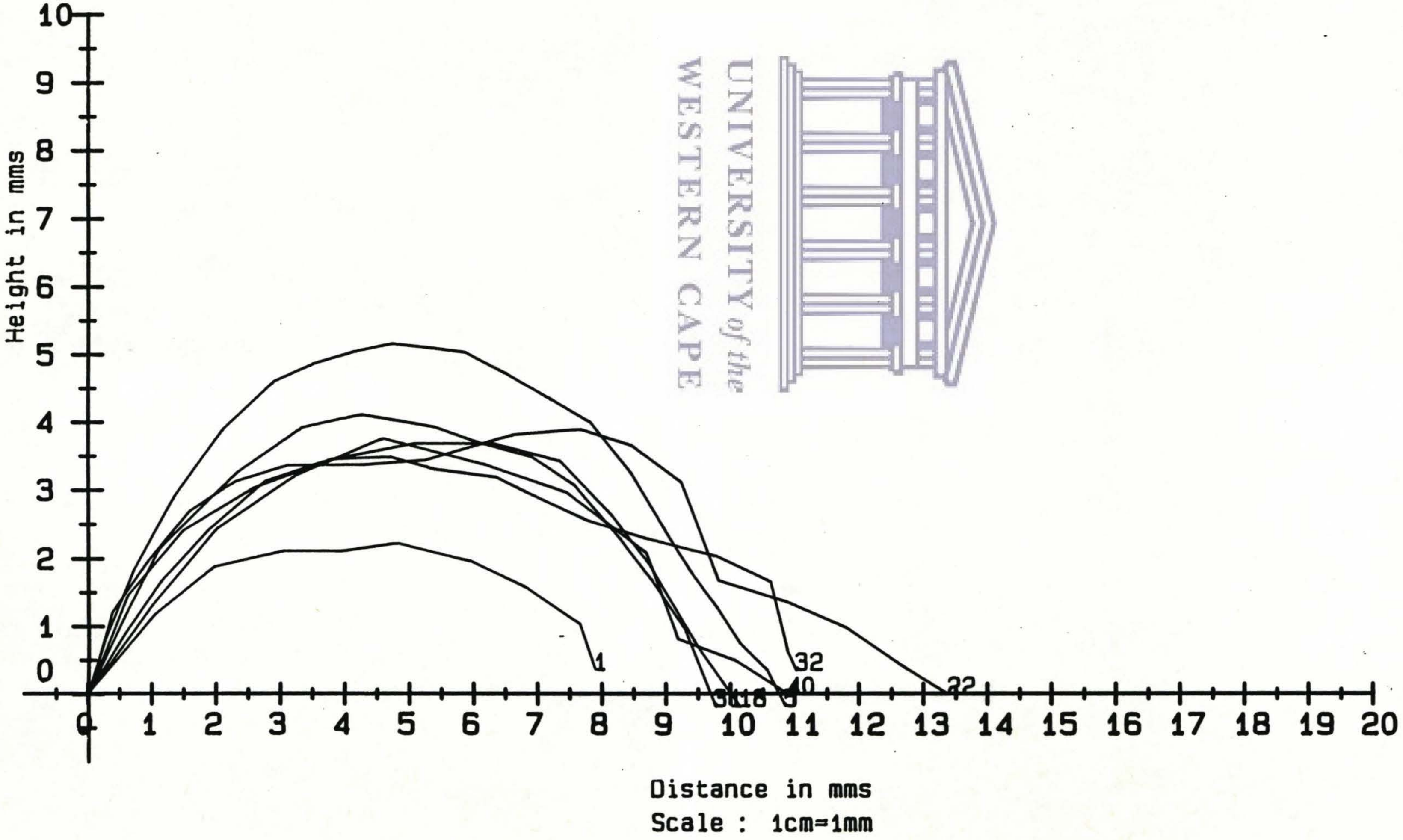

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FIGURE 29

GROUP : 1

PROFILE : G

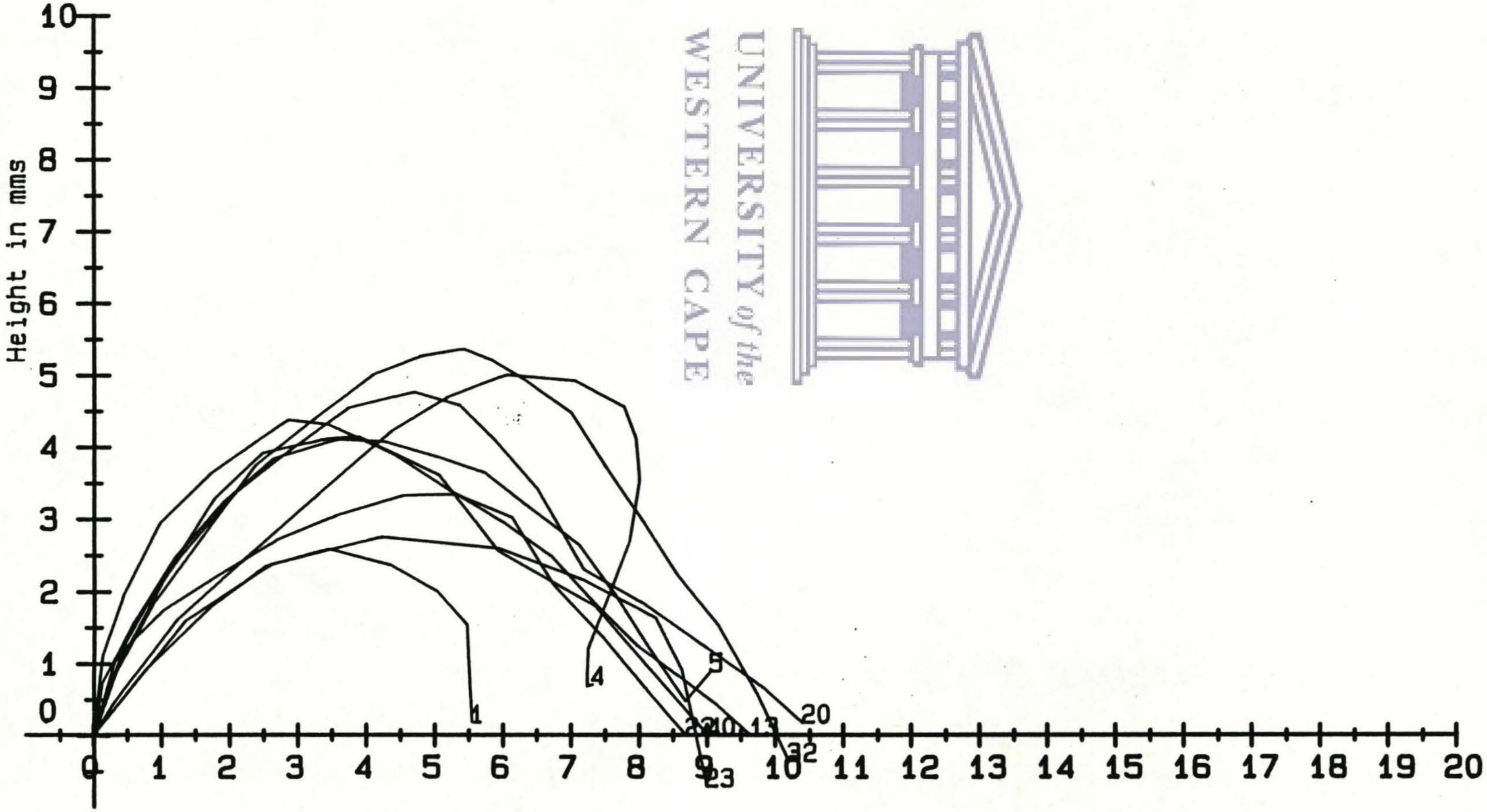

FIGURE 30

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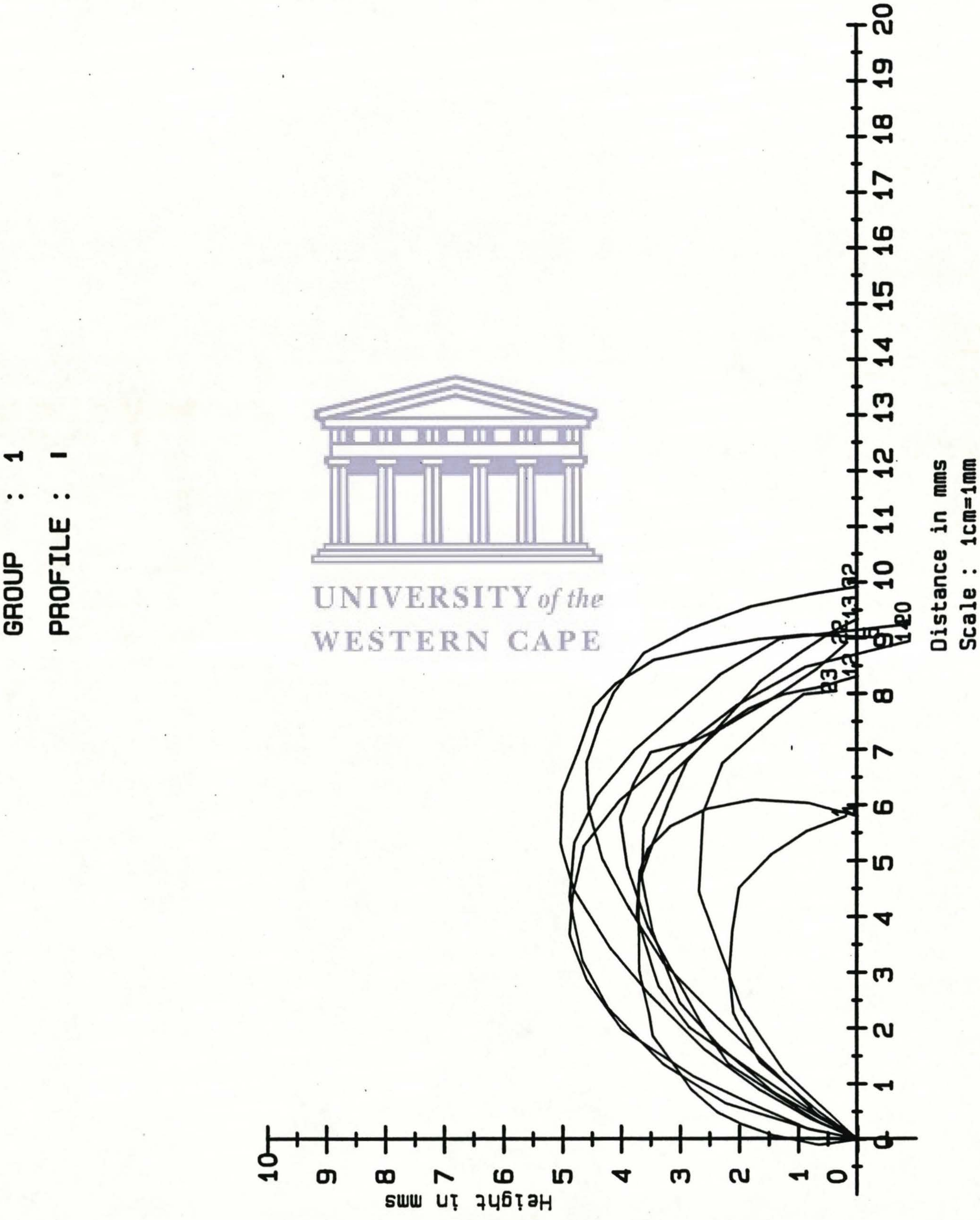

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FIGURE 31

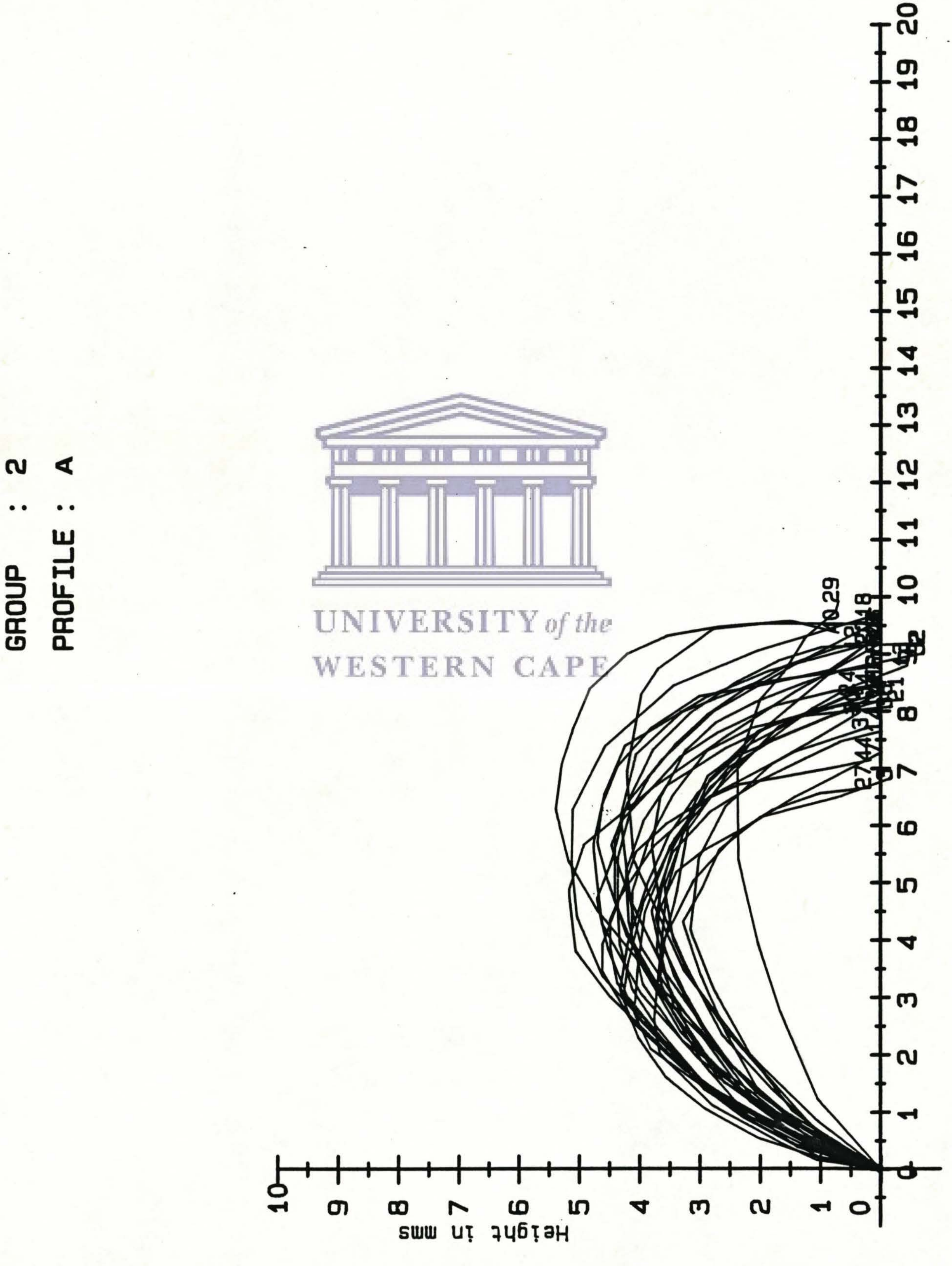

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FIGURE 32

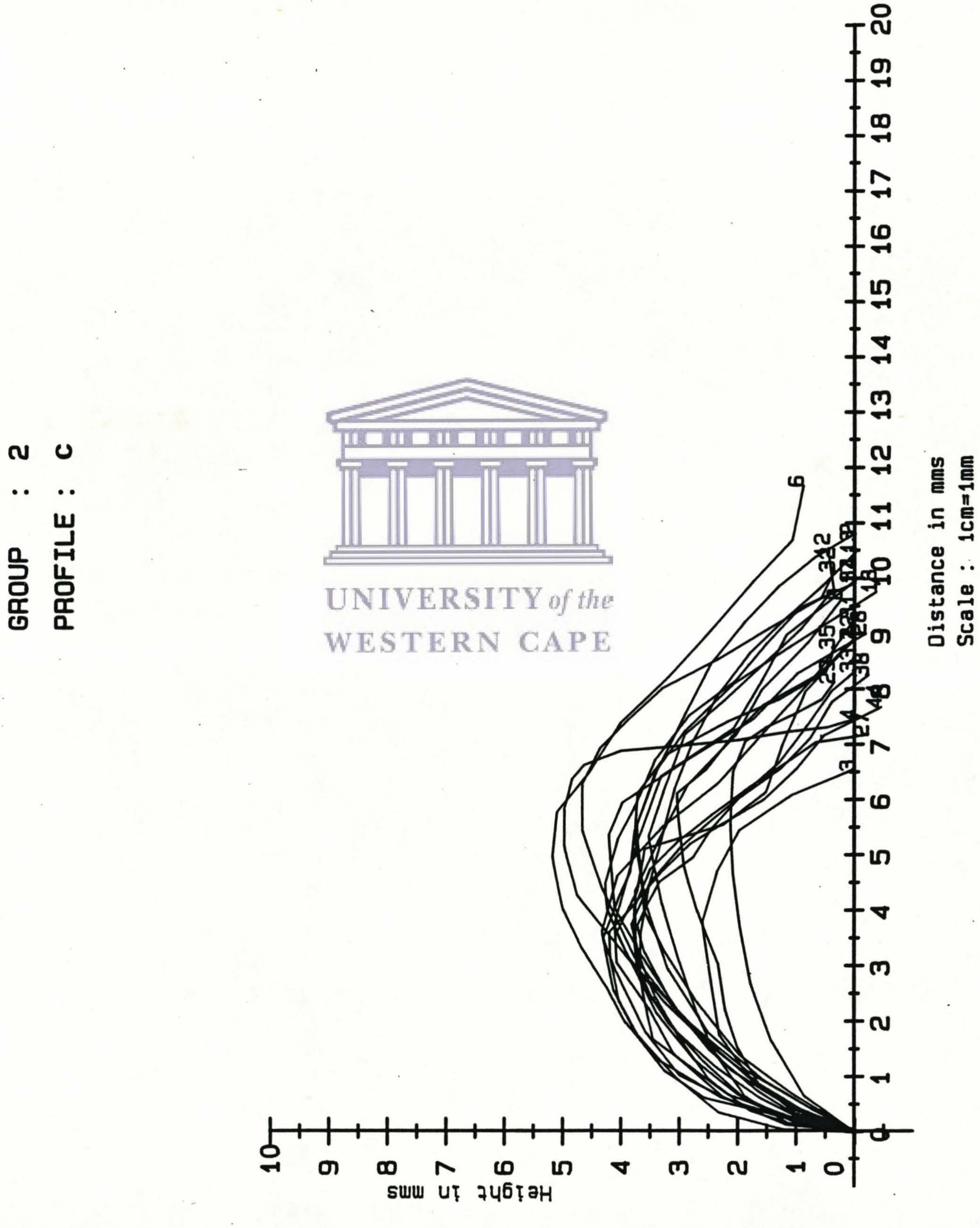

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FIGURE 33

GROUP : 2
PROFILE : E

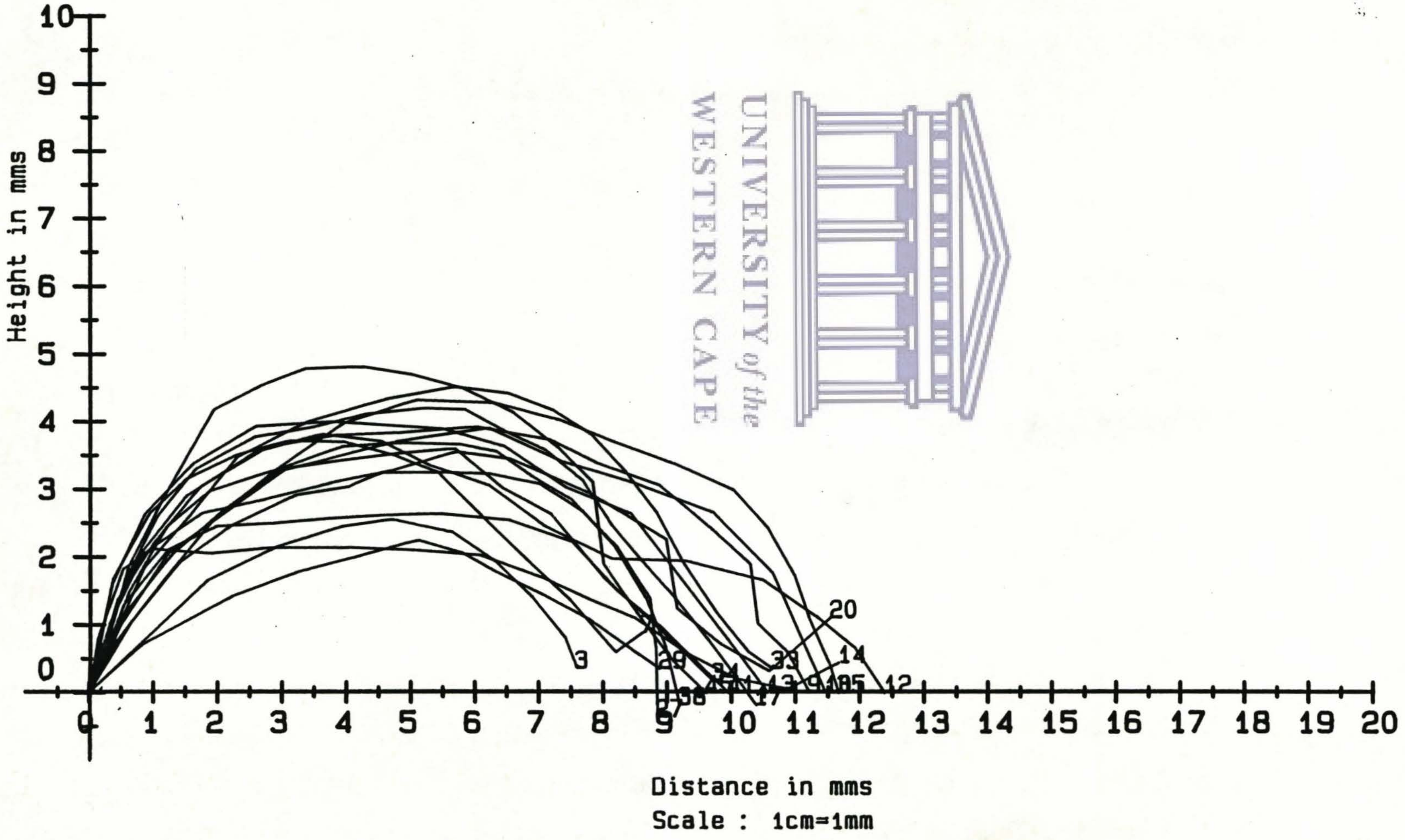

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FIGURE 34

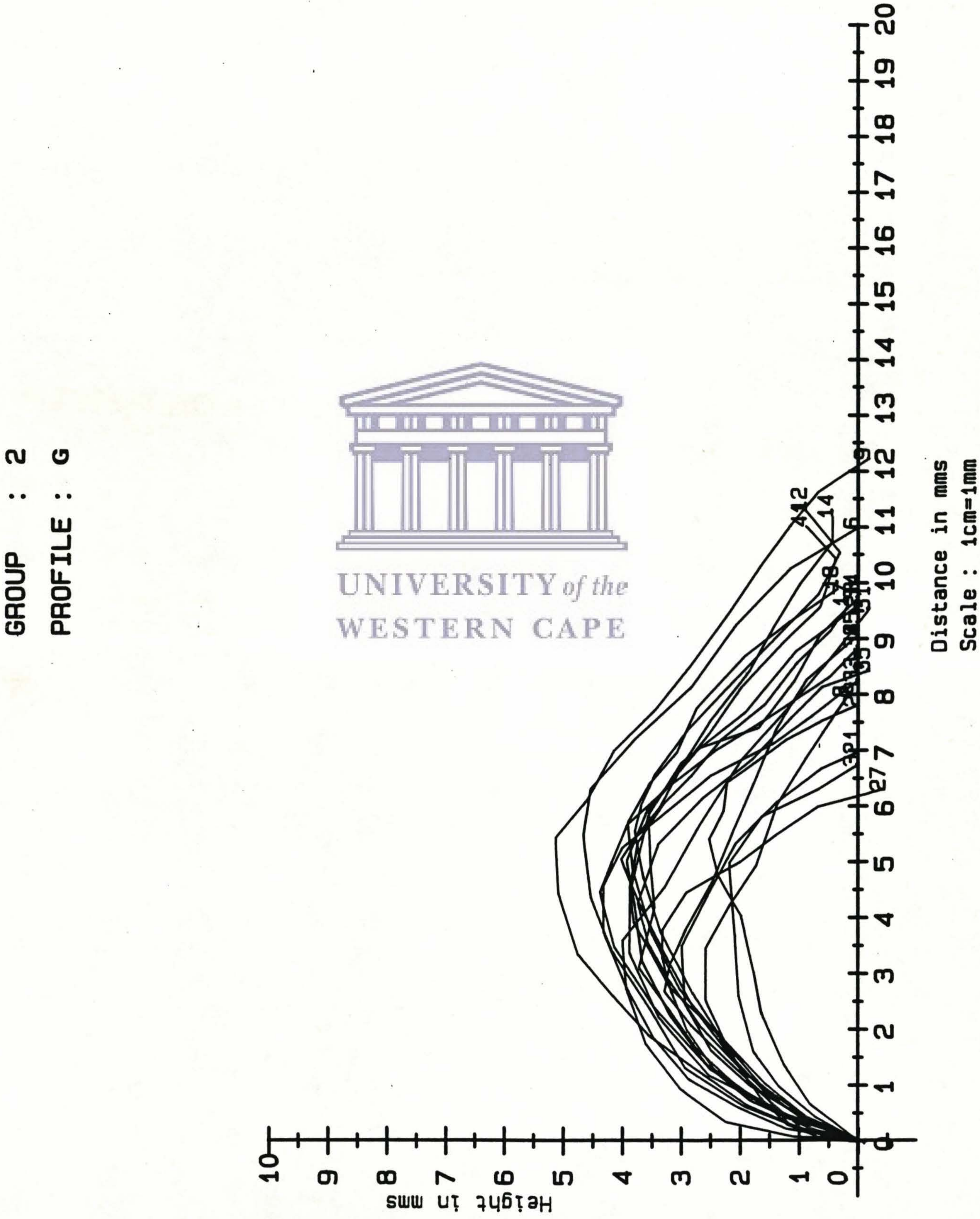

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FIGURE 35

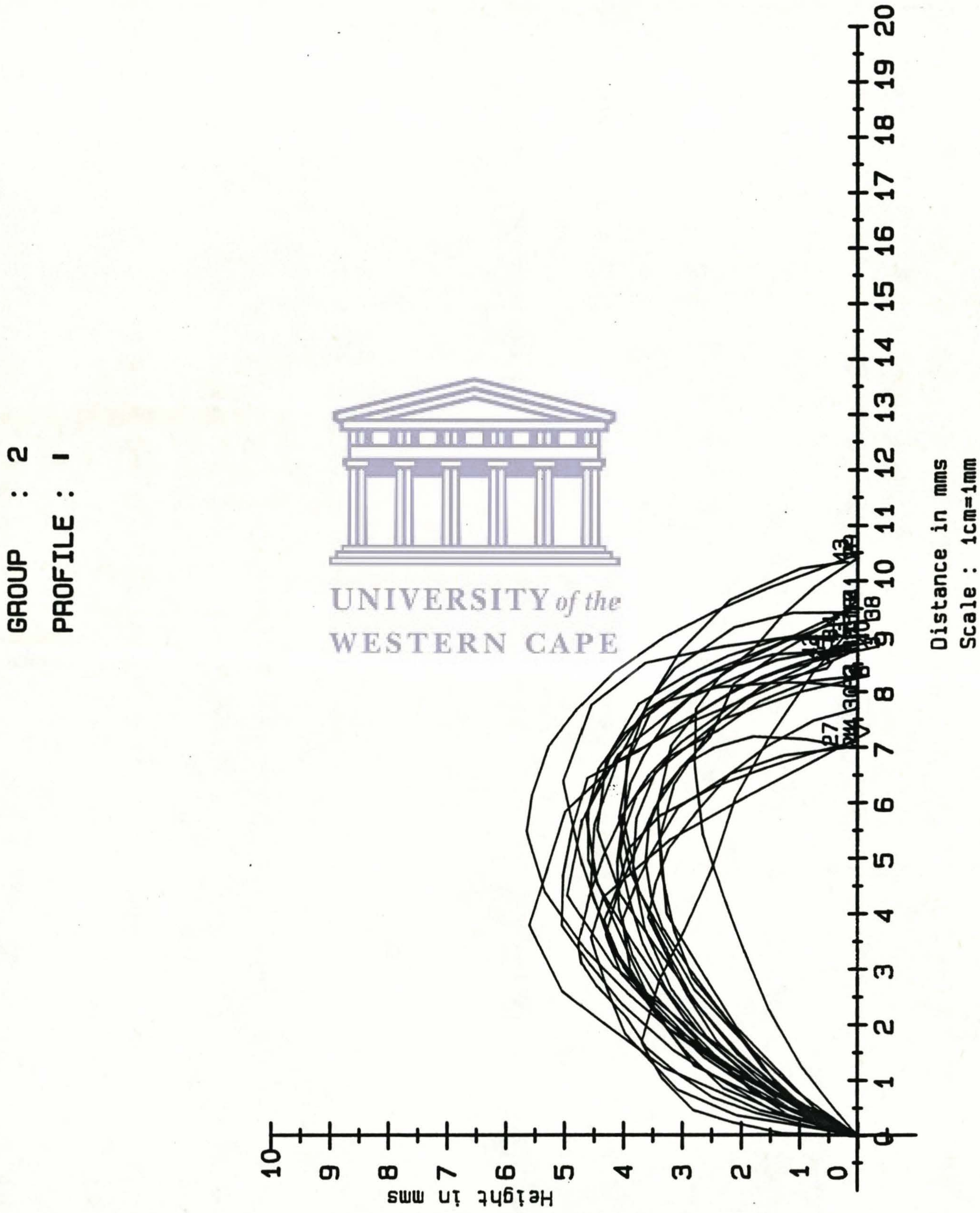

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FIGURE 36

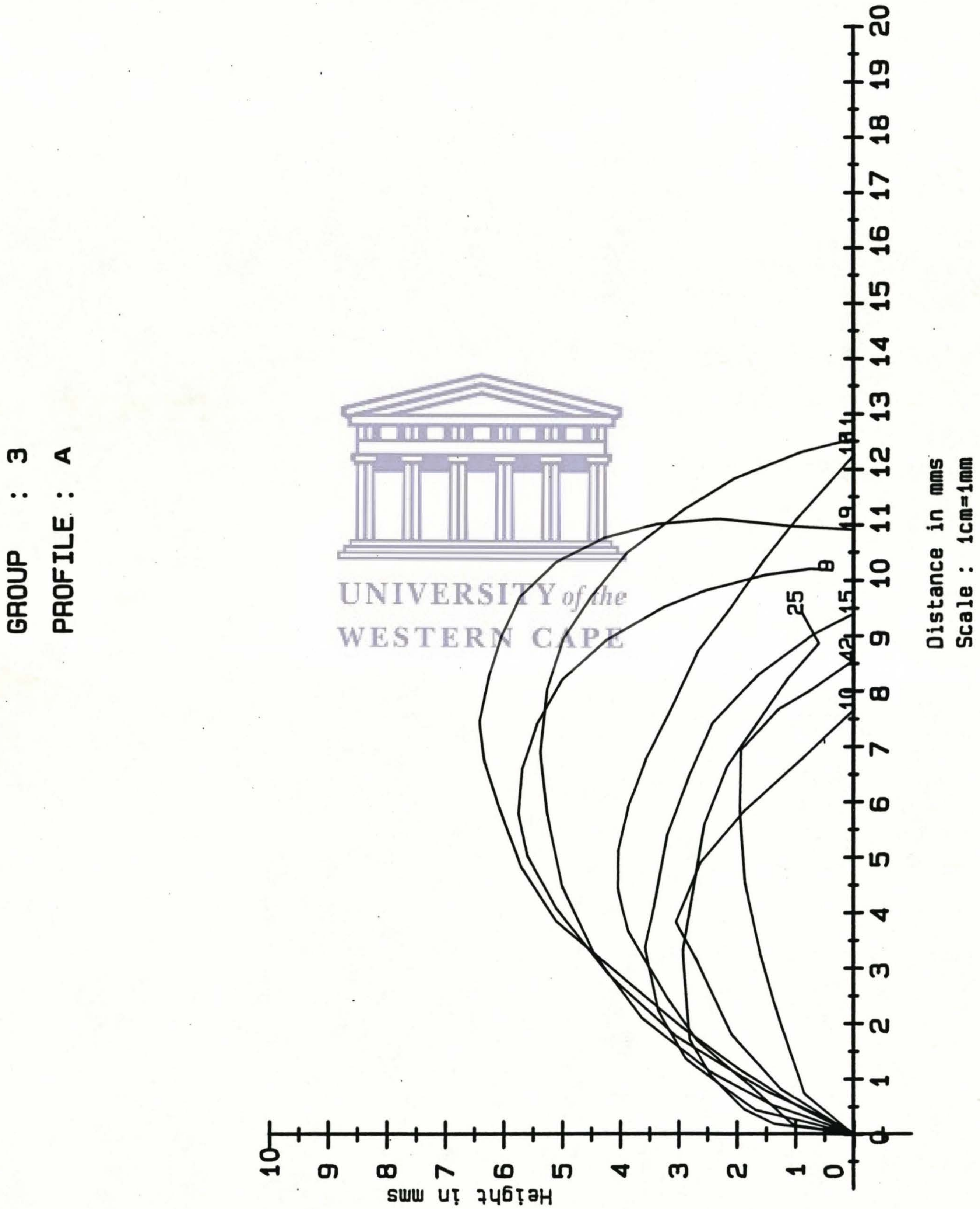

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FIGURE 37

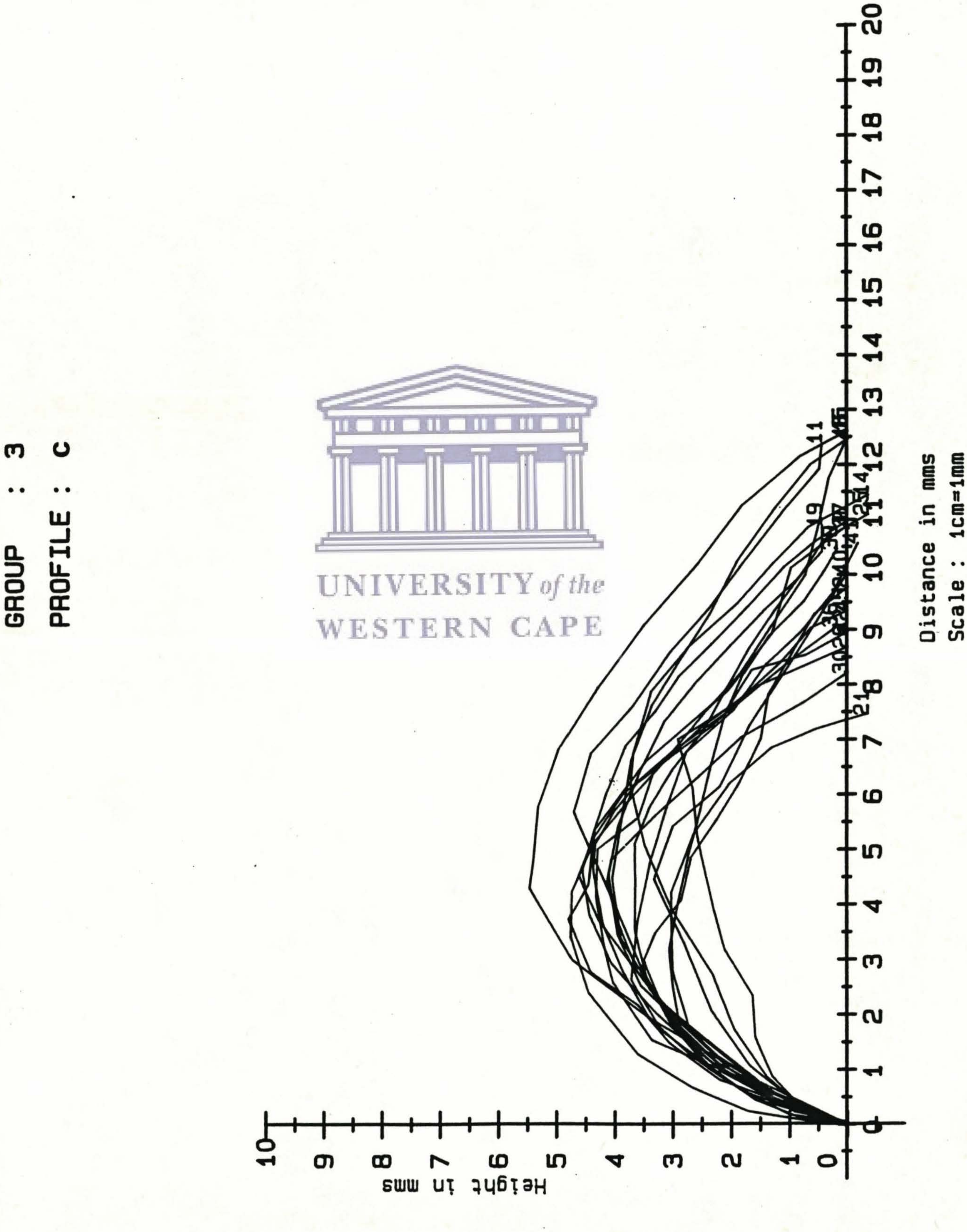

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FIGURE 38

GROUP : 3
PROFILE : E

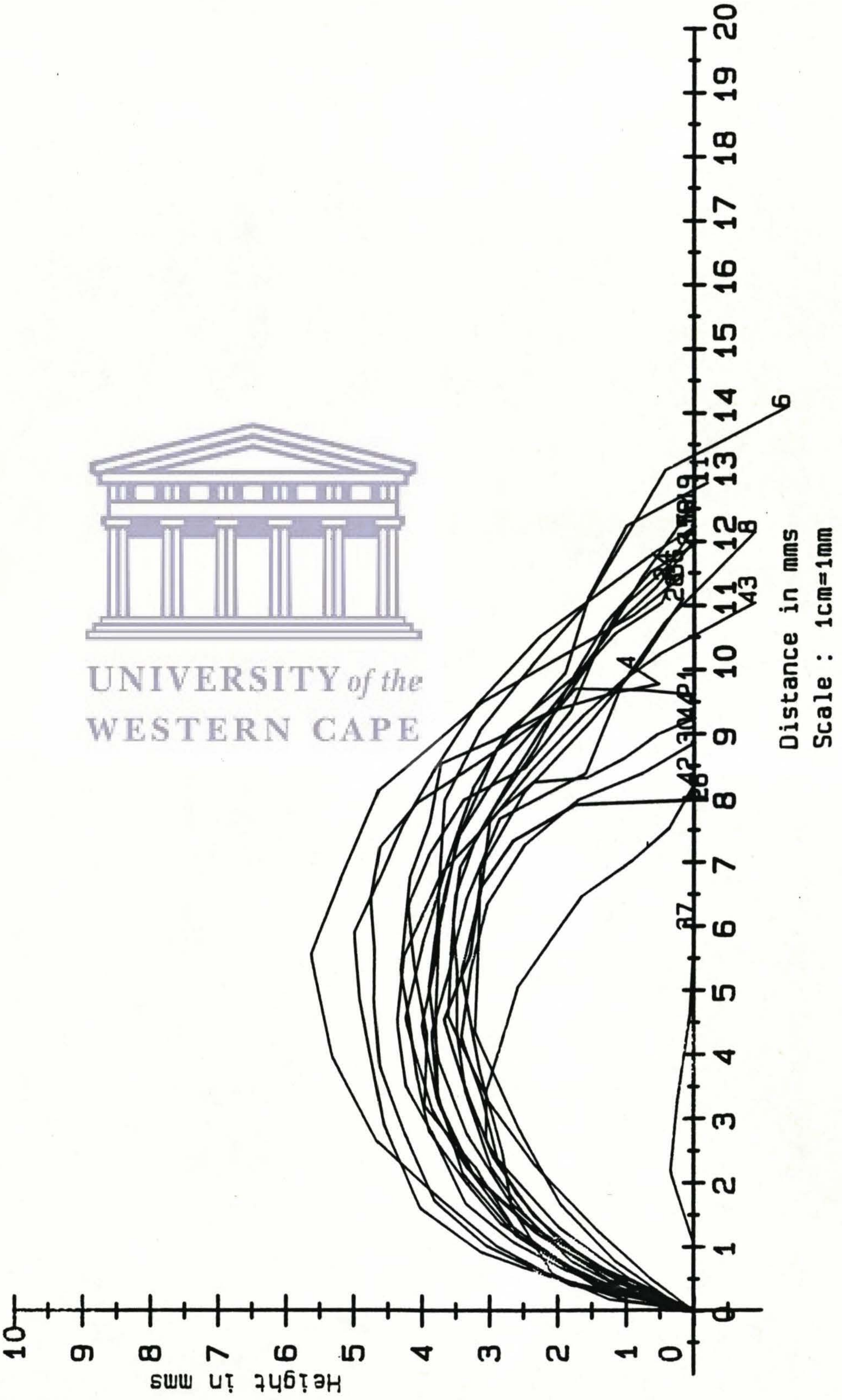

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FIGURE 39

GROUP : 3
PROFILE : G

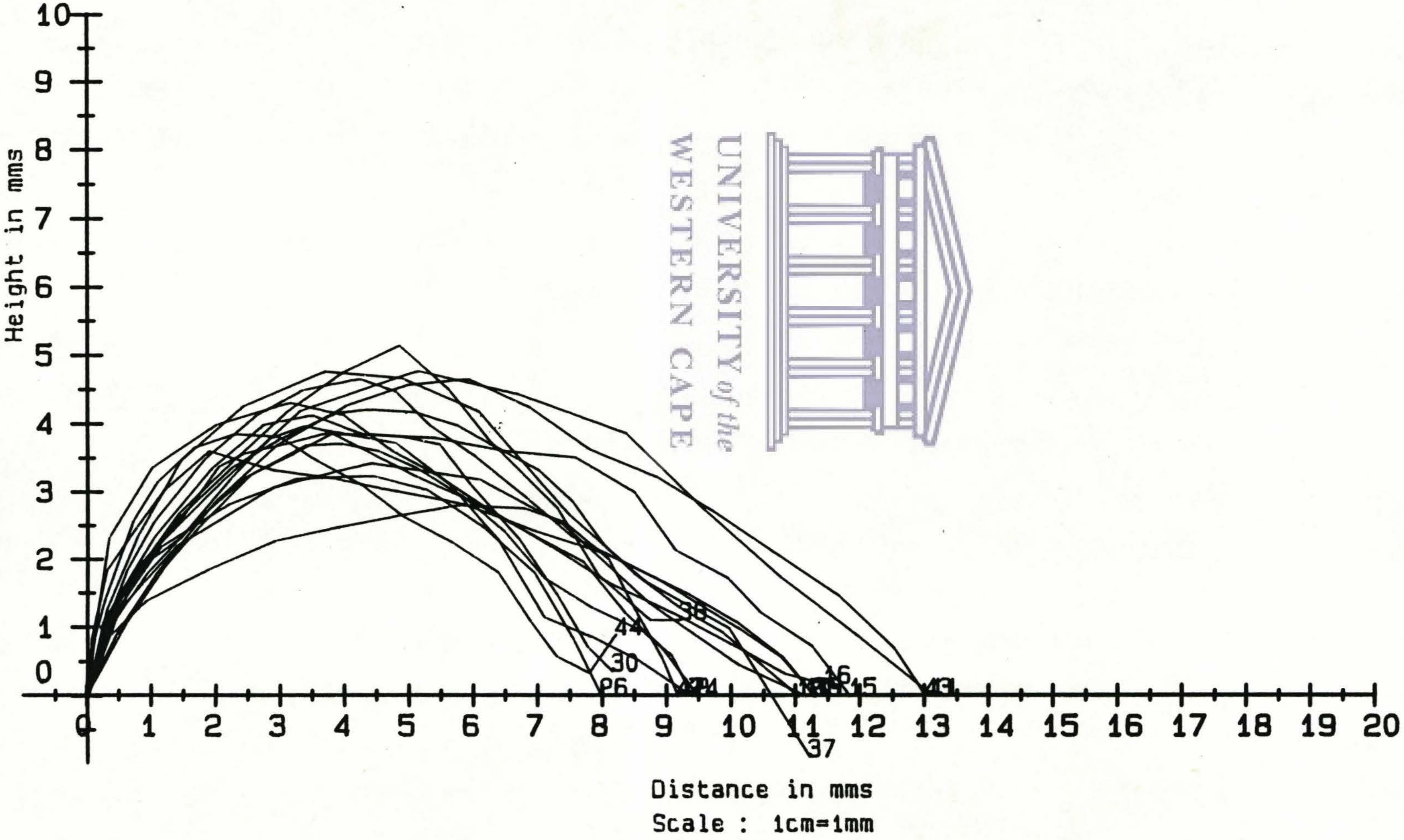

FIGURE 40

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GROUP : 3
PROFILE : 1

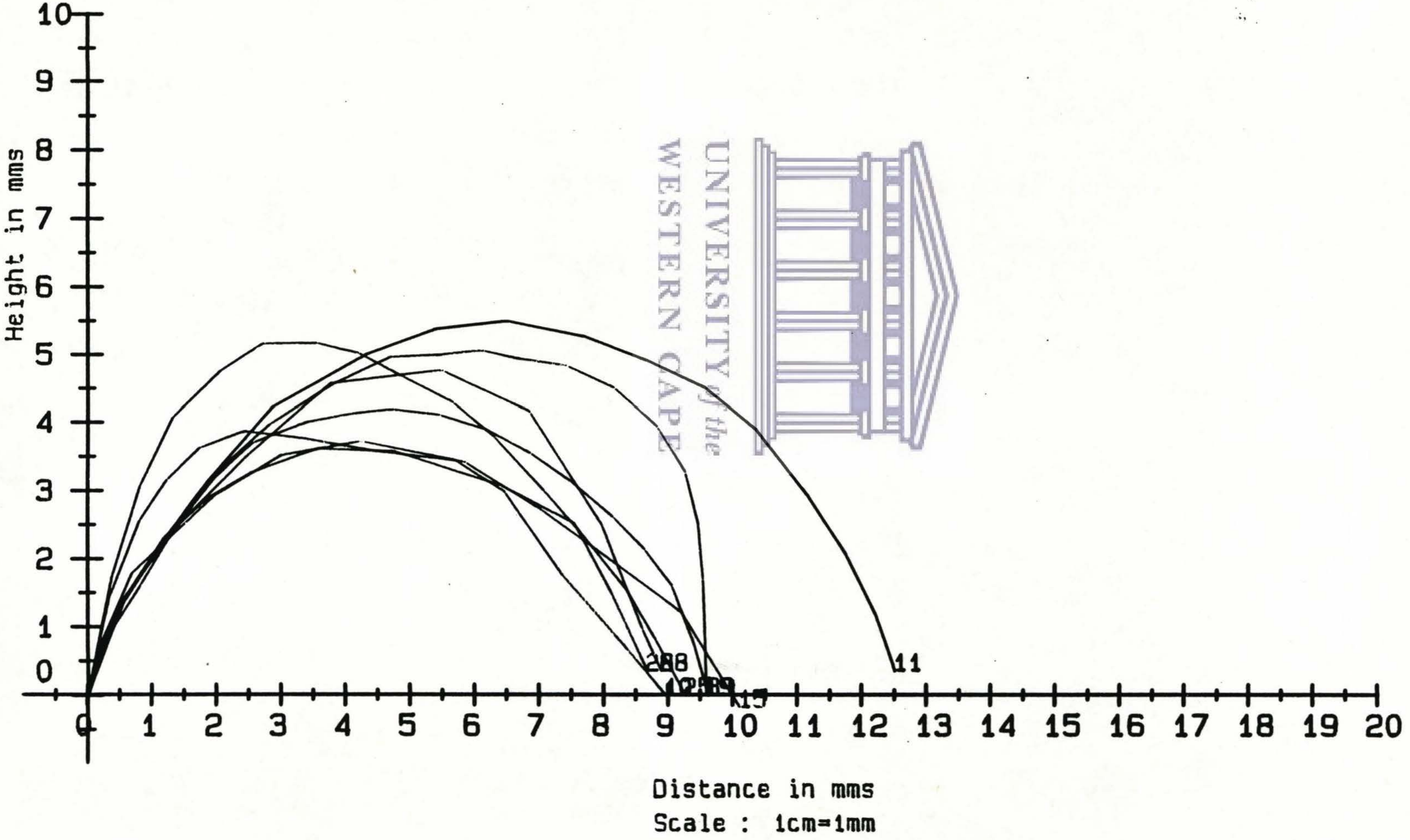

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FIGURE 41