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Faculty of Dentistry

DETERMINATION OF THE CURVE OF SPEE IN THE MANDIBLE OF HUMAN PERMANENT HEALTHY DENTITION AMONG DENTAL STUDENTS IN THE UNIVERSITY OF KHARTOUM

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بسم الله الرحمن الرحيم

قال تعالى:

(والرآسخون في العلم يقولون ءآمنا به كلّ من عند ربنا وما يذكر إلا أولوا الألباب )

صدق الله العظم
سورة آل عمران (7)
To My father .. Malik, who always supported me by his living soul.

To my dear mother (Amna Fareh)...for her kind care and love

To my dear wife “Rasha Saliheen”.. for her patience, encouragement and support.

To my kids . . Mohammed & Ahmed A. Gabbar.. the roses of our little family
Words can hardly express the feeling. Abstract entities like gratitude demand a limitless canvass for their display, which is difficult if not impossible to obtain? Nevertheless, it is customary to use the customary ways to show one's appreciation.

I am deeply indebted to all my students, through whom I have learned. True enough; the best way to learn is to teach.

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I am grateful to my family members who were neglected due to my preoccupation with this grossly demanding job.

If the reader finds the work useful, I would consider myself privileged if not, I can only ask forgiveness for any shortcomings.
Abstract

The aim of this study was to assess and analyze the sphere of the Curve of Spee, and to investigate the effects of gender on the Curve of Spee. Analysis of the Curve of Spee may assist dentists in developing occlusion in the sagittal plane. The mandibular Curve of Spee may be used as a reference for prosthetic construction. The purpose of this study was to assess and analyze the sphere of curve of the Spee in a sample of Sudanese population.

The effects of gender on Curve of Spee were also investigated. A total of 60 Sudanese adults (30 men and 30 women) with permanent healthy dentitions participated, standard digital pictures of the right side of mandibular dental casts were made with a digital camera. The cusp tips of the molars, premolars and canines of mandible were identified. The radius and the depth of Curve of Spee were measured on the dental cast by means of computer software (Image Tool). Descriptive analysis was performed, statistical values (means, standard deviation) T test were used to assess the statistical significance ($\alpha = 0.05$). The Curve of Spee showed a mean radius of approximately 119.6 mm in males, and 112.1 mm in females. Radii of the Curve of Spee in males were slightly
larger than females. The depth of the Curve of Spee in the mandibular arch was 1.89 mm for men and 1.87 for women.

There was no significant difference in the depth of the arch between men and women, and no difference in the steepness.
Curve of Spee

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الجنس

التاريخ

العلاج

وذلك

السودانيين، الوريدين بين السنين، الفك في دراسات لا توجد القوس المعني لإسقاط

السهمية المشوية على الأسنان، يساعد

الافق (يمكن)

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التبديل

الصورة

الدور

النوع

الإثمان

الأشعة時代، 30 وذكر

الأشهر، 30 أنثى

الصحة

المحلي

التركيز

العمق

المسالك، وإطعامهما

الперв

البكامل

السليم

الثامنة

الصغرى

المتزايد

التمديد

العامة، السودانية مستمرة

الدراسة

هذة

الشريك 30 وذكر

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السير

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الصور، وتنبؤ

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1. INTRODUCTION AND LITERATURE REVIEW

1.1 Introduction and justification:

The orientation of the occlusual plane is an important clinical procedure in prosthodontic treatment,\(^1\) thus the determination of the occlusual plane is one of the most important clinical procedures in prosthodontic rehabilitation of edentulous patients. The position of the occlusual plane of orientation, forms the basis for ideal tooth arrangement.\(^2\)

Proper management of the occlusual plane is an essential consideration when multiple long-span posterior restoration are designed, or when restorations are added to an existing tooth arrangement characterized by rotated, tipped, or extruded teeth, as excursive interferences may be incorporated.\(^3\) The Curve of Spee, which exists in the ideal natural dentition, allows harmony to exist between the anterior tooth and condylar guidance.\(^3\)

The glossary of prosthodontic terms (2004),\(^4\) defines the occlusual plane as “the average plane established by the incisal and occlusual surfaces of the teeth” generally, it is not a plane but represents the planner mean of the curvature of these surfaces. In the normal natural dentition, there exist an anterior posterior curve that passes through the
cusp tip of the mandibular canine and the buccal cusp tips of the mandibular premolars and molars, and that extends in a posterior direction to pass through the most anterior point of the mandibular condyle. This curve was originally described by Ferdinand Graft Spee in 1890. The curve exists in the sagittal plane and is best viewed from the lateral aspect; it permits the total posterior disclusion on mandibular protrusion, giving proper anterior tooth guidance.

Curve of Spee (anterior posterior curve) has been defined as the anatomic curve established by the occlusual alignment of the teeth, as projected onto the median plane, beginning with the cusp tip of the mandibular canine and following the buccal cusp tips of the premolar and molar teeth, continuing through the anterior border of the mandibular condyle. The Curve of Spee may be pathologically altered in situations resulting from rotation, tipping, and extrusion of teeth. Restoration of the dentition to such an altered occlusual plane can introduce posterior protrusive interference. Such interferences have been shown to cause abnormal activity in mandibular elevator muscles, especially masseter and temporal muscle. This can be avoided by reconstructing the Curve of Spee to pass through the mandibular condyle, which has been demonstrated to allow posterior disclusion on mandibular protrusion. As the angle of condylar guidance is greater than the Curve of Spee, posterior disclusion is achieved.
Clinically, the Curve of Spee is determined by distal marginal ridges of the most posterior teeth in the arch and the incisal edges of the central incisors.\(^{(9)}\) Moh et al.\(^{(15)}\) describe the curves as a line from the tip of the canine touching the tips of the buccal cups of the posterior teeth.\(^{(11)}\) The same definition is given by Ramfjord Ash.\(^{(11)}\) Okeson\(^{(12)}\) and Klineberg,\(^{(13)}\) the latter add that such curve is necessary to allow protrusive contact of incisor teeth without posterior tooth interferences.

Several researchers have investigated the functional significance of the curve. Spee himself suggested that this curve was the most efficient model enabling the teeth to remain in contact during the forward and backward gliding of the mandible during chewing. He was the first to suggest that this should be considered in the construction of dentures, to enable better mastication and to avoid lever effects during chewing.\(^{(14)}\) Baragar and Obsorn\(^{(15)}\) relate the anatomy of the Curve of Spee to mandibular morphology and biting force, concluding that in the sagittal plane, the long axes of mandibular molars are each tilted in direction that most efficiently converts muscle force into work.

The morphologic arrangement of teeth in the sagittal plane has been related to the slope of the articular eminence, incisal vertical overlap, molar cusp height, and the amount of posterior contact.\(^{(16)}\) Matched interactions between these features and the Curve of Spee ensure balanced occlusual function.\(^{(17)}\) Recent studies have suggested that
the Curve of Spee has biomechanical function during food processing by increasing the crush-shear ratio between the posterior teeth and the efficiency of the occlusual forces during mastication.\(^{(17)}\)

Analysis of the Curve of Spee; may assist dentist in developing occlusion in the sagittal plane, the maxillary as well as the mandibular Curves of Spee could be used as a reference for prosthetic reconstruction.\(^{(16)}\)
1.2. Literature review

1.2.1 The Maxillo-Mandibular Relations:

There are three relationships of the mandible to the maxilla; with the teeth in centric occlusion and, with the mandible in its rest position when the teeth are out of contact, that is relaxed position, and the dynamic relationship of the jaws during function.\textsuperscript{(18)}

The maxilla is firmly united to the skull and only moves with this structure. The mandible on the other hand is attached to the skull by the two tempromandibular joints and is capable of opening, closing, protrusive and lateral movements and also combination of any of these.

The mandible is prevented from over closing by the occlusion of the natural teeth, and it is also necessary to retrude the mandible at the conclusion of all functional movements, in order that the cusp may be interdigitate. These two facts result in the mandible returning, at the conclusion of every masticatory stroke, to a position in which the cusps of the opposing teeth are in contact, and the heads of the condyles are placed as far back in the glenoid fossa as they can go without sacrificing their ability to make lateral movements. This maxillo-mandibular relation is termed centric occlusion.

When the mandible is not functioning and provided the subject is not in a state of tension and is breathing normally through the nose, the muscles and ligaments which are attached to the mandible support it in a
relationship to the maxilla which is remarkably constant for any given individual. In this relation, the heads of condyles are fully retruded in glenoid fossa to the extent that will allow freedom for lateral movements and the occlusual surfaces of the teeth are separated by 2-4 mm. The term relaxed relation is also commonly used for any relationship of the mandible to the maxilla from this physiological rest position up to, but not including contact of the teeth.

When the mandibular condyles are drawn forwards by the contraction of the lateral pterygoid muscles, they are forced to move downwards because their superior articular surfaces, the eminentia articulates, are sloped downwards and forwards. When the occlusal surfaces of the teeth make eccentric contact during function, the cusps and incisive edges of the mandibular teeth slide up the cuspal inclines of the maxillary teeth. Thus the mandible follows definite paths dictated by the guidance it receives from the condylar path posteriorly and the cuspal slopes and incisive edges anteriorly.

In edentulous individuals all tooth guidance is lost and thus the mandible may close until mucous membrane of the lower ridge meets that of the upper. It is no longer necessary for the individual to retrude the mandible at the conclusion of each functional movement, because no cusps require to be interdigitated. Finally, the functional paths of the
mandible are lost because, although the condylar guidances still exist, the
cuspal and incisal guides do not.(20)

The relaxed relation is stated to remain unchanged because it is
dependent on the muscle not the teeth. The problem, therefore, which
faces the prosthodontist to discover the relations which the mandible bore
to the maxilla when the natural teeth were present and relate the models
to each other in similar manner.

The teeth may then be set up on the model with knowledge that
they will articulate correctly when placed in the mouth.

The orientation and setup of the teeth should follow the anterior-
posterior curve (Curve of Spee). The compensating curves are the
artificial curves introduced into dentures in order to facilitate the
production of balanced articulation. They are the artificial counterpart of
the curves of Spee and Monson which are found in the natural dentition.
This curve follows an imaginary line touching the buccal cusps of all the
lower teeth from the lower canine backwards, and approximates to the arc
of a circle. A continuation of this curve backwards in the natural dentition
(curve Spee), will nearly always pass through the head of the condyles.

This curved arrangement of the posterior teeth in this anterior-
posterior curved manner may best appreciated by reference to diagram
illustrated in the following page. If be the path followed by the condyles
is horizontal, then the teeth can be set to conform to horizontal plane. When the mandible moves forward, the teeth will remain in contact.

If the path traveled by the condyles is sloped away from the horizontal plane (as it always is to some degree) then as soon as the mandible moves forwards the condyles commence to descend, and the posterior teeth will lose contact if they have been set to conform horizontal plane. If the posterior teeth, instead of being set in a horizontal plane, are set to an anterio-posterior curve, then as the mandible moves forwards and the condyles travel downwards all the teeth can remain in contact.

Spee located the centre of the curves along “a horizontal line through the middle of the orbit behind the crista lachryma posterior\(^{(19)}\) a structure identified in the Textbooks of era\(^{(20)}\) as a vertical ridge on the lacrimal bone giving partial origin to the orbicularis oculi muscle. Spee’s idea was advanced in 1920 by George Monson.\(^{(21)}\) Based on anthropological observation, Monson described a 3-dimensional sphere that passed through the incisal edges and occlusual surfaces of the mandibular teeth. It is not usually noted that, while Spee described a curve of a proximately 2.5 inch radius \((6.5 \text{ – 7.0 cm})^{(5)}\) Monson\(^{(19)}\) proposed the now widely accepted curve of 4 inch radius. Spee noted that it would be possible to locate the centre of the curvature “by reconstruction and measurement with the compass”.

The Curve of Spee may be pathologically altered in situations resulting from rotation, tipping, and extrusion of teeth. Restoration of the dentition to such an altered occlusual plane can introduce posterior protrusive interferences, such interference have been shown to cause abnormal activity in mandibular elevator muscles, especially the masseter and temporalis muscle. This can be avoided by reconstructing the Curve of Spee to pass through the mandibular condyle, which has been demonstrated to allow posterior disclusion on mandibular protrusion. As the angle of condylar guidance is greater than the Curve of Spee, posterior disclusion is achieved.

The Broadrick flag (Broadrick occlusual plane Analyser; Teledyne Water Pik, Fort Collins, cob), permits reconstruction of the Curve of Spee in harmony with the anterior and condylar guidance, allowing total posterior tooth disclusion on mandibular protrusion. Its use assumes proper functional and esthetic positioning of the mandibular incisors, should the anterior guidance be inappropriate, it must be redesigned prior to use of the Broadrick flag. The position of the designed restorations should not interfere with lateral excursive mandibular movements.

The tooth arrangement in the bucco-lingual plane referred, to as the curve of Wilson. The curve of Monson is, in effect, a combination of the curves of Spee and Wilson in a 3-dimensional plane.
The Broadrick flag is a useful tool in prosthodontic and restorative dentistry, as it identifies the most likely position of the center of the Curve of Spee. However, this position should not be regarded as fixed or immutable. Esthetics and function place considerable demand on the design of the occlusal plane.\(^{(3)}\) Compromise can be achieved by altering the length of the radius of the curve. In patients with retrognathic mandible, a standard 4 inch curve would result in flat posterior curve, causing posterior protrusive interferences. Such “low” mandibular posteriors would also lead to extrusion of the opposing maxillary teeth.\(^{(3)}\)

If the maxillary posterior teeth were to be restored to this low occlusal plane, the crown to root ratio would be less than ideal. Hence, a \(3\frac{3}{4}\) inch curve is more appropriate when class II skeletal relationship exists. Conversely, a 4 inch curve would create a steep posterior curve in patients with a class III skeletal relationship, leading to further posterior interferences. A 5-inch radius would be more suitable in this situation.\(^{(3)}\)

The centre of the curve also may be varied to achieve the same effect. The center should always lie along the long arc drawn from the anterior survey point. This alteration will not affect the position of the posterior survey point (PSP), an important fact when the position of the mandibular anterior teeth is esthetically and clinically suitable. When the center of the curve or it radius is altered for esthetic reasons, care must be taken not to create new interferences. Needles\(^{(22)}\) noted that to ensure
posterior disclusion on mandibular protrusion, the curve should extend through the condyle. When the PSP is located, the level and orientation of the distal molar tooth may always be suitable. Should this be the scenario, it follows that the PSP may be taken as the anterior border of the condyle, represented by the most anterior point on the condylar element on the articulation. Care should be taken to ensure that the angle of the condylar guidance is not less than the Curve of Spee, as this would introduce posterior protrusive interferences.\(^{(8)}\)

It should be further considered that the arrangement of the maxillary and mandibular teeth influences lateral excursive movement when viewed from a frontal aspect, the mandibular molars have a slight lingual inclination and the buccal cusps of these teeth are higher than the lingual. This arrangement is referred as the curve of Wilson,\(^{(24)}\) and it facilitates lateral excursion free from posterior interferences. Attention should be paid to this principle when the diagnostic wax-up is designed. Monson proposed that the mandibular teeth should be arranged to close a sphere of 4-inch radius, with the mandibular incisal edges and cusp tip touching the sphere, thus permitting protrusive and lateral excursions free from posterior interferences. It bears repeating that the now widely accepted 4-inch radius was proposed by Monson rather the Spee.\(^{(21)}\)

Hyperactivity in the temporalis and masseter muscle, has been demonstrated during mandibular protrusive movement when in
appropriate posterior tooth contacts are present. Careful restoration design to ensure proper anterior guidance will prevent the introduction of such interferences and the establishment of such abnormal activity. Excursive interferences may result in wear, fracture restorations, and temporomandibular joint dysfunction.

The use of an acrylic template can facilitate controlled conservative reduction. In the clinical report presented Lynch, the template was a vital tool for transferring the designed blueprint from the diagnostic wax-up on the articulator to the mouth. The template allowed accurate reduction of the extruded mandibular first molar to the level of the redesigned occlusal plane, followed by appropriate reduction for the cast restoration. This ensured that the fabricated onlay was in harmony with the occlusal plane and that minimal tooth structure was removed. Acrylic templates also were used for conservative preparation of the other teeth.

Neije M, et al introduced the definition of articulation equilibrium of some morphological factors (I was the Curve of Spee) in a formula:

\[ \frac{A_{cg} \times A_{ig}}{A_{po} \times \text{Curve of Spee} \times \text{cusp Angle}} \]

(Acg. Angulation of the condylar guidance; Apo, Angulation of the plane occlusion, Aig: Anterior Incisor Guidance).
According to this formula, changing the Curve of Spee (leveling) influences other factors such as angulation of the condylar guidance, angulation of the incisal guidance and angulation of the plane of occlusion.\textsuperscript{(20)} Leveling the Curve of Spee is an everyday practice in orthodontic as well in prosthodontic offices, several authors have suggested that leveling requires additional arch length. Baldrige\textsuperscript{(27)} and Braun et al\textsuperscript{(28)} found a linear relationship between arch circumference and the amount of leveling. They predicted a ratio some what less than 1:1 between the depth of the Curve of Spee and the amount of arch circumference needed to level the curve. In contrast, Germane et al\textsuperscript{(10)} accepted a nonlinear relationship between both variables, Woods considered the lower incisors a separate segment that can be intruded or extruded independently of the buccal segments. Therefore, arch length is not necessary increased during leveling of the Curve of Spee as long as the leveling is achieved through anterior teeth intrusion. Braun et al\textsuperscript{(28)} confirmed this in a study with computer-supported technology.

Kuitert et al\textsuperscript{(29)} investigated the changes of form and depth during and after set-up of the teeth.

Braun and Schmidt\textsuperscript{(30)} studied the differences in the Curve of Spee between man and women and between the different Angle classifications.
The shape of the curve for males and females seemed to be identical, and no significant differences could be found among class I, class II division I, or class II division 2. The same conclusion can be drawn from this study, and, therefore, the entire group was not split according to these variables.

Numerous studies have been conducted to assess the amount of relapse of mandibular anterior crowding,\(^{(31,32)}\) over time, decreasing mandibular dental arch dimension in both treated and untreated malocclusions seem to be a normal physiological phenomenon.

Occlusual studies underwent a similar pattern of development, passing through phases of fiction, hypothesis, and finally, fact.\(^{(33)}\)

What we call ideal occlusion today was described as early as the 18\(^{th}\) century by John Honter.\(^{(34)}\) Carabelli, in the mid-19\(^{th}\) century, was probably the first to describe in a systematic way abnormal relationships of the dental arches.

The previous occlusual studies focused on either changes in occlusion over a period of time\(^{(35,36)}\) or the axial relationship of teeth from a static viewpoint.\(^{(8-11)}\) Similarly certain researchers studied the functional aspect of occlusion\(^{(37,38)}\) and others investigated the shape of dental arch. Work has also been done to quantify occlusion and to compare the masticatory efficiency of patients with normal occlusions with those
having class II malocclusion. The Genetic aspects of occlusion have also been examined, the genetic factors which can be considered such as:

- Teeth can vary in size e.g. microdontia and macrodontia.
- The shape of the individual teeth can vary (such as 3rd molars and upper lateral incisors).
- They can vary when and where they erupt, or they may not erupt at all (impacted)
- Teeth can be congenitally missing (partial or complete anodontia), or can be extra (supernumerary) teeth.
- The skeletal support (maxilla-mandible) and how they are related to each other can vary considerably from the norm.

In 1964, Andrews studied white North Americans to understand the relationship of teeth in people who were considered to possess normal occlusion. The result of his assessment of 120 non orthodontic normal casts was his “six keys" to normal occlusion. The six keys are:

- Vertical crown contour.
- Horizontal crown contour.
- Crown angulation.
- Crown inclination
- Facial prominence of each crown.
• Depth of Curve of Spee.

These keys helped the prothodontist and orthodontist to appreciate the significance of occlusion and served as a yardstick for clinically analyzing treatment results. It proved that despite the voluminous information from studies on occlusion, occlusion could still be simply examined.

During facial development the growth process that involves diverse soft and hard tissue structures (muscle, nerves, vessels, viscera, bones and teeth) are continuously creating more or less important imbalances between different dental organs. Several compensations generally occur, and the adult arrangement should be near as possible to harmonious, balanced, and well-functioning whole.

The development of human adult occlusion traverses several stages and does not take less than 6 or 20 years to be complete. During this long process, compensation involves dentoalveolar remodeling as well as modification in the related structures, first of all in the mandible, maxilla, and temporomandibular joint. The three dimensional arrangement of dental cusps and incisal edges in human dentition (the curve of Monson) and in particular its two-dimensional projection in a quasi-sagittal plane parallel to the alveolar process (the Curve of Spee) has been reported to develop as an adjustment that could provide intrinsic compensation for anterioposterior dental discrepancies. This
hypothesis is just one of the several that have proposed to explain the functional significance of this morphologic arrangement. Others include a better resistance against the forces developing during occlusion and chewing, thus leading to more stable dental arches,\(^{40-49}\) an increase of the crush/shear ratio during chewing in the molar region;\(^{45}\) dynamic implications in protrusive movements correlating the Curve of Spee, the angle of the eminentia, molar cusp height, incisor overbite, and the posterior contact.\(^{44}\) Apart from Enlow’s hypothesis, which all the biomechanical and dynamic consideration pertain to adult dental arches, where growth and development are thought to be completed.

Indeed, all the previous quantitative investigations on occlusual curvature have concerned adult dental arches, only, and even recent mathematical model relating the Curve of Spee to arch length\(^{42,43}\) did not take adolescent arches into account. Osborn\(^ {45}\) also investigated child and adolescent arches but they used a single mean Curve of Spee obtained from adult skulls. Ferraio-etal have recently investigated\(^ {50}\) the three-dimensional characteristic of the curvature of the occlusual surfaces in a group of a healthy adults. The three-dimensional coordinates of mandibular cusps of all but the third molars were obtained with a computerized image analyzer, interpolated with a spherical model, and a mean radius very similar to Monson’s 4-inch value.\(^ {51}\)
1.2.2 The effects of dental wear on the curve of Spee:

In most mammals, dental wear is a physiological and regular occurrence. Indeed the teeth of many herbivorous species are not well adapted to mastication until attrition has removed the smooth, enamel-covered cusps\textsuperscript{52}. Physiological attrition (wear) is defined as the gradual and regular loss of tooth substance as a result of natural mastication\textsuperscript{53}. More extensive attrition than would normally be expected is called intensified attrition and pathological attrition may result from abnormal occlusion. The abrasive property of food is paramount in determining the rate of physiological attrition\textsuperscript{54-55-56-57-58-59}. In the past, the role of attrition of teeth was much more marked than it is today. However, with increased food processing, use of hands and of tools\textsuperscript{52} and the general rejection of the teeth as weapons\textsuperscript{60} the whole of the masticatory apparatus in humans has somewhat atrophied.

Many workers are of the opinion that a certain degree of attrition is beneficial for dental health\textsuperscript{55}. Studies\textsuperscript{61-62-63-64-65} have demonstrated the advantages of dental wear in eliminating cuspal interferences to excursive movements; Studies\textsuperscript{66-67} have also shown the benefits of removal of stagnation areas in reducing caries and periodontal disease.

Lack of occlusal and proximal attrition may lead to crowding, rotation and overlapping of anterior teeth, with the second pre-molars and
third molars being excluded from the dental arcade and consequently remaining impacted. Studies\textsuperscript{68-65-69} demonstrated that failure of third molars to erupt completely was due to lack of space in the alveolar arch between the second molar and the ascending ramus. They attributed this, in contemporary human mandibles, to the growth rate and orientation of the mandible and condyle and to the direction of the eruption of the other teeth. However, with some occlusal and interstitial dental wear, the pre-eruptive dimensions of teeth would be reduced, thus increasing the available space. All of this evidence led Murphy\textsuperscript{64} to suggest that prophylactic cuspal grinding should be as commonplace as routine caries inspection in the dental surgery.

Wear on the occlusal surface of teeth will have an effect on the orientation of the occlusal planes. In human dentitions they do not lie in a perfectly horizontal plane. In lateral view the occlusal plane of the maxillary arch runs in a downwardly convex curve from canine to last molar, whilst the occlusal plane of the mandible has a matching downwardly concave curve from canine to last molar. This is known as the curve of Spee\textsuperscript{16}. It is not clear as to whether the curve of Spee is a description of the occlusal surface of each arch separately, or in maximal intercuspspation. On occasion it has been defined as the curvature of the occlusal surfaces described by an imaginary line joining the lower buccal
and canine cusps in the sagittal plane\textsuperscript{70}. At other times it has been described as the curved movement of the mandible when incisal guidance is less than condylar guidance\textsuperscript{71}. An study\textsuperscript{50} measured the curve of Spee as a single entity related to an imaginary plane touching the incisal edges of the lower incisors and the distobuccal cusps of the lower second molars – called it the plane of orientation. Tobias\textsuperscript{72}, on the other hand, accounted for the Curve of Spee as a succession of changing mesiodistal slopes from anterior to posterior.

In frontal view the occlusal surfaces of upper posterior teeth of each side lie in a downward-curved transverse plane, whilst those of the mandible in an upwardly curved transverse plane. These curves are the curves of Wilson or Monson\textsuperscript{73}. Following the pioneering measurements of occlusion carried out by Count von Spee, Monson (1932) proposed the spherical theory of occlusion, postulating that the ``centre of a sphere with a radius approximately 4 inch is equidistant from the occlusal surfaces of the posterior teeth and from the centers of the condyles''. He further claimed that the long axes of the posterior teeth form extensions of radii from the centre of this sphere. These theories have largely been rejected\textsuperscript{74} and the continuous curvatures are now thought simply to reflect the long axes of individual teeth. It is unclear as to whether the curvatures apply to the worn or unworn dentition, but dentures have been set up along the curve of Monson in the transverse plane and the curve of Spee.
in the antero-posterior plane ever since the publication of this theory, to allow for movement along the sphere.

Many workers have studied the change in the curve of Monson with wear. They found that the brunt of the wear occurred on the buccal cusp of the lower teeth and the palatal cusp of the upper teeth. This would reverse the curve of Monson into the so-called Avery curve. An intermediate condition exists called the helicoidal occlusal plane, in which the transverse occlusal plane between the first molars is reversed, that between the second molars is flat, and finally that between the third molars fits the classic Monson pattern. The helicoid is described by many workers whose findings are reviewed by Tobias.

The changes in inclination of the occlusal surface of the tooth as a result of wear have been described by Molnar as natural form, oblique (buccolingual), oblique (lingual-buccal), oblique (mesiodistal), oblique (disto-mesial), horizontal, rounded (buccolingual) or rounded (mesiodistal). No indication was given as to whether these were consistent with the curve of Spee or the Curve of Monson. Doubt was cast on the curve of Monson by Brown et al. when they measured the worn and unworn dentition and found no conclusive evidence to demonstrate the existence of that curve. The presence of the helicoid caused by dental wear in the buccolingual direction has been demonstrated by many workers and can be explained by the force and
direction of occlusal loads. The downwardly concave, anteroposterior occlusal plane of the mandible, or the curve of Spee\textsuperscript{52}, had not been extensively studied. It can be perceived on a daily basis in the modern dental surgery in orthopantomograms and bitewing radiographs and is used to orientate these views\textsuperscript{88}. The relation between masticatory movements and the curve of Spee is not clear. Protrusive and retrusive forces are restricted to the incising phase of mastication, which in early man and the non-human primates was also used for tearing meat from bones, reflected in the specialized spade shape of their incisors\textsuperscript{45}. It is not known whether this movement leads to wear of the molar cusps.

If there is an increased overjet, the molar teeth may be in contact during the forward movement of the mandible. However, if there is an increased overbite, the anterior guidance from the palatal surface of the maxillary incisors will take the posterior teeth out of occlusion. On the other hand, if there was an edge-to-edge or incomplete overbite, then forward movement could take place without posterior disclusion\textsuperscript{89}. This may have an effect on the curve of Spee and if the protrusive force were enough to maintain the ratio of wear described by Murphy\textsuperscript{68}, then the curve of Spee would become steeper. This, however, would result in a more containted area for the upper teeth making occlusion more restrictive\textsuperscript{40}. In the current studies the wear scores revealed that the mandibular first molars were worn to a greater extent than the second
molars, which are worn to a greater degree than the third. This concurs with the findings in study stated by Murphy\textsuperscript{64}, and is used in the charts of wear patterns used in age determination generated in study\textsuperscript{56}. These findings also revealed that the steepness of the mesiodistal gradients also followed this sequence and so any curves that existed before wear would be either accentuated or reversed. The increased wear of the first molars may be due to their earlier eruption (and therefore earlier exposure of soft dentine), or their playing a disproportionately large role in the occlusal table, imparting the bulk of the accumulation of the food. It has been assumed thus far that, following incision, food is passed back on to the occlusal table of molars and pre-molars for grinding, and that all surfaces are equally employed. It, however, seems unlikely that a large enough amount of food is taken in to cover the entire occlusal table, and that the most anterior parts of the occlusal table are probably reached and employed first.

When teeth erupt into occlusion, each tooth lies up in a direction that ensures maximal resistance to the direction of forces applied to the occlusal surface in chewing\textsuperscript{52}. In physiological wear this damage-limitation system should be maintained and this will be reflected in the pattern of wear and the orientation of the occlusal wear planes.

As elderly people are retaining their teeth for longer, the worn dentition becomes increasingly relevant to dentists. If the Curve of Spee
is not maintained in the worn dentition, then prosthetic teeth should not be aligned along it. It is essential in all aspects of restorative dentistry to maintain occlusal harmony and comfort, and it is therefore imperative to accrue as much data as possible on occlusal wear planes.

1.2.3 Dental arch changes in adults:

The human craniofacial skeleton and its associated dental arches undergo visible alterations as they grow, adapt, and age. Relatively rapid changes occur during the transitional dentition, and once a functional permanent dentition is established, smaller changes continue to be observed. An understanding of the mechanisms underlying these slowly occurring changes in supposedly “nongrowing” adults, however, remains elusive.

There is substantial literature describing the development of the dentition. Given that there is relatively rapid growth during the first two decades of life, the study of the growth changes occurring during the juvenile and adolescent periods has consumed the vast majority of previous research efforts.\textsuperscript{78-79}

These naturally occurring changes in untreated dentitions often are used as comparative “gold standards,” against which the dental changes produced by orthodontic treatment are evaluated. It has been only recently that adult growth and development has been studied in detail.
Although there was some information in the literature indicated that the adult craniofacial skeleton continues to increase in size, the findings from the cephalometric recall study of Behrents that involved subjects from the Bolton-Brush Growth.

Study Case at Western Reserve University provided indisputable evidence that craniofacial growth continues into adulthood. Given these findings, which have been replicated recently by West on another sample of untreated persons, it is reasonable to assume that changes also occur in the associated dental arches. These changes presumably influence the duration and success of orthodontic retention procedures, especially if the arch changes continue to occur into the fifth and sixth decades of life. In addition, the increasing interest in adult orthodontics and the broadened scope of treatment possibilities, including the increasing popularity of dental implants, makes an understanding of the dentoalveolar changes in the adult of even greater importance. Because of the time interval involved in gathering such longitudinal data on human beings, however, there have been relatively few descriptions of the longitudinal dental arch changes that occur in persons beyond the age of 20 years. To date only one investigation has been conducted specifically to examine certain dental arch changes into midadulthood. Furthermore, longitudinal changes in arch depth have been examined in subjects only to 26 years of age, and gender changes in arch perimeter
and incisor irregularity have not been analyzed in subjects beyond the age of 20 years.

The University of Michigan Elementary and Secondary School Growth Study\textsuperscript{90-91} carried out a study which was designed to describe the dental arch changes from adolescence to the fifth decade of life. The Curve of Spee in this study decreased significantly only in the untreated male sample. In addition, this decrease occurred in the same age range that the overjet changed significantly, i.e., 13.8 years to 17.2 years of age. This study revealed that, the Curve of Spee, similar to overbite and overjet, is stable in adulthood.
1.3 Objectives

1. General:

Determination of the Curve of Spee in the mandible of human permanent healthy dentition among a sample of Sudanese population (dental students in the U of K, 2005 - 07).

2. Specific:

a. To assess the sphere of the Curve of Spee among Sudanese population. in a sample of Sudanese population.

b. To study the characteristics of the Curve of Spee in the mandibular arch.

c. To compare the data obtained with those from previous studies.

d. To measure the radius and the depth of the Curve of Spee on the dental casts by means of computer software.
2. MATERIAL AND METHODS

2.1. Study design:

Cross-sectional descriptive study.

2.2. Study area:

Khartoum State, University of Khartoum (Faculty of Dentistry).

2.3. Study population:

Mandibular impressions were taken from 60 students 30 males and 30 females with age range of 19 – 27 years.

2.4 Inclusion criteria: All subjects had to meet the following criteria:

1. Complete permanent dentition, including the second molars (at least 28 teeth).

2. Normal occlusion with the following criteria:
   - Angle class I relationship.
   - Normal overjet.
   - Normal overbite.
   - Maximum intercuspation.

3. No temperomandibular or craniocervical disorders.

4. No extensive restoration, cast restoration or cuspal coverage.

5. No previous or current orthodontic treatment.

6. No pathologic periodontal condition.

7. Clinically normal arch shapes with minimum dental crowding.
2.5 Exclusion criteria:

1. Deciduous or mixed dentition.
2. Malocclusion.
3. Class II, III occlusion.
4. Temperomandibular disorders.
5. Extensive restoration, cast restoration or cuspal coverage.
6. Previous or current orthodontic treatment.
7. Periodontal disease.
8. Dental crowding or abnormal arch shape.

2.5. Study variable:

The variables in this research were defined as following:

a. **Universal variable:**

b. age, gender, index of study cast.

c. **Dependent variable:** the radius (R) and the depth (D) are measured on the dental casts.

d. **Independent variable:** determination of occlusal plane.

2.6 Sampling:

**Sample frame:** Dental Students, Faculty of Dentistry, University of Khartoum.

Filtered using inclusive criteria and based on a detailed questionnaire and clinical examination.
Given the advice of the statistician and according to limited availability of similar studies, the sample size has been chosen according to previous international researches published highly reputable journals (J of Prosthetic Dent 2004).

**Sample size:** Since the total numbers of students enrolled at the faculty are 684 students, 9% were studied, the number of students were 60 (30 male-30 female).

2.7 **Casts preparation:** Dental casts were made in type III stone (stone; whip mix, locusville, ky) from Alginate impression (Tropicalgin, Thixotropic Zhermack 45021 Badia police (RO) Italy). The impression material was manipulated according to the manufacturer’s instructions and all the casts were based by using stock rubber base.

2.8 **Imaging and measurement:**

    Standardized digital images of the right hand side of mandibular dental casts were made with the digital camera. (Yashica EZ Digital 5011, Japan) fixed on tripod.

2.9 **Photo standardization:**

    1. The camera to teeth distance is 15 cm for all pictures to eliminate image distortion.
    2. The cast fixed on surveyor table which fixed to rigid plastic plate by screws to ensure stability.
3. The casts were photographed beside a scalar, to ensure control of magnification.
4. These casts are oriented so that the lens of the camera is parallel to the buccal surface of the posterior teeth.
5. The line between the distal cusp of the 2nd molar and the cusp of the canine was oriented parallel to the horizontal axis of the camera display.

- Each digital image of the dental cast was transferred to a personal computer for analysis.
- The cusp tips of the molars, premolars, and canines of the maxilla and mandible were marked using the cursor.
- The radius (R) and the depth (D) of the Curve of Spee were measured on the dental casts by means of computer software (UTHSCSA Image Tool (IT)\(^1\)).
- All dental landmarks were confirmed and measurement performed by the same operator.
- A reference plane was drawn from the buccal cusp of the canine to the disto-buccal cusp tip of the second molar.
- The deepest of these distances represented the depth of the Curve of Spee and was used in this study.

\(^1\) UTHSCSA Image Tool (IT): Is an image processing and analysis program. Image analysis functions include dimensional (distance, angle, perimeter, area) and gray scale measurements (point, line and area histogram with statistics).
• Mean and standard deviation were calculated for each measured parameter.

• For all analysis, the level of statistical significances was defined as \( \alpha = 0.05 \).

• Statistical differences between replicate measurements were tested with paired student T test, with \( \alpha = 0.05 \).

2.10 Data collection:

Data are collected by:

1. Data collection form.
2. Diagnostic casts.

2.11 Data processing and analysis:

Data processing involved:

1. Categorizing the data.
2. Coding.
3. Summarizing the data in master sheet.

2.12 Data analysis:

Descriptive analysis was performed, statistical values (mean, standard deviation) for several readings and the frequency distribution by
cross tabulation for each variable compared. T. test was used to assess the statistical significance.

All this was achieved by the statistical package for the social science (SPSS).
3. RESULTS

The data in table 1 shows

Frequency table: Age distribution for males was presented by 30 samples which was equals to 50% of the whole sample. The same percentage was applied to female samples. The age range for both genders was 19-27yrs, the most frequent age was 23 yrs., and the least frequent age was 20, and 25 yrs.

**Table 1:** Distribution of the sample according to the age and gender

<table>
<thead>
<tr>
<th>Gender</th>
<th>Year</th>
<th>Frequency</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td>19-27 yrs.</td>
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<td>3.3</td>
<td>3.3</td>
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<tr>
<td></td>
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<td>20</td>
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<td>1.7</td>
<td>5.0</td>
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<tr>
<td></td>
<td></td>
<td>21</td>
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<td>5.0</td>
<td>10.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>22</td>
<td>6</td>
<td>10.0</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>23</td>
<td>8</td>
<td>28.3</td>
<td>48.3</td>
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<td></td>
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<td>24</td>
<td>6</td>
<td>25.0</td>
<td>73.3</td>
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<td></td>
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<td>1</td>
<td>11.7</td>
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<tr>
<td></td>
<td></td>
<td>26</td>
<td>2</td>
<td>13.3</td>
<td>98.3</td>
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<tr>
<td></td>
<td></td>
<td>27</td>
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<tr>
<td></td>
<td>Total</td>
<td>30</td>
<td>100.0</td>
<td></td>
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</table>

<table>
<thead>
<tr>
<th>Gender</th>
<th>Year</th>
<th>Frequency</th>
<th>Valid Percent</th>
<th>Cumulative Percent</th>
<th>Cumulative Percent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Male</td>
<td>23-26 yrs.</td>
<td>23</td>
<td>9</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>24</td>
<td>9</td>
<td>30.0</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>25</td>
<td>6</td>
<td>20.0</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td></td>
<td>26</td>
<td>6</td>
<td>20.0</td>
<td>20.0</td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td>30</td>
<td>100.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
The data in Table I show that:

The mean radius of the curve of Spee was approximately 115.85 mm (male, 119.6 mm; female, 112.1 mm) and the mean depth was 1.88 mm (male, 1.89 mm; female, 1.87 mm), while the mean of orientation axis was 39.31 mm (male, 40.11 mm; female, 38.51 mm) in the mandibular arch.

Table 2: Descriptive Statistics of the study sample

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Mean</th>
<th>Std</th>
<th>Variance</th>
<th>max</th>
<th>Min</th>
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<tbody>
<tr>
<td>Age</td>
<td>23.57</td>
<td>1.70</td>
<td>3.52</td>
<td>27</td>
<td>27</td>
<td>19</td>
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<tr>
<td>Radius</td>
<td>115.89</td>
<td>11.41</td>
<td>76.13</td>
<td>140</td>
<td>90.04</td>
<td></td>
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<tr>
<td>Depth</td>
<td>1.88</td>
<td>0.45</td>
<td>0.23</td>
<td>2.93</td>
<td>1.04</td>
<td></td>
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<tr>
<td>Ox</td>
<td>39.31</td>
<td>9.83</td>
<td>192.16</td>
<td>33.18</td>
<td>40.06</td>
<td></td>
</tr>
</tbody>
</table>
The data in Table 3 shows the highest radius’ value in the female sample was 136.35 mm while the lowest value was 97.23 mm, for male samples the highest radius’ value was 140 mm and the lowest value was 90.04 mm. The highest depth value concerning the male samples was 2.81 mm, and the lowest value was 1.04 mm, while for females the highest depth value was 2.93 mm, and the lowest value was 1.04 mm the same that of males.

**Table 3: Descriptive Statistics of the study sample by Gender**

<table>
<thead>
<tr>
<th></th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
<th>Male</th>
<th>Female</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>22.83</td>
<td>24.30</td>
<td>1.88</td>
<td>1.119</td>
<td>1.252</td>
<td>3.5</td>
<td>26</td>
<td>27</td>
<td>23</td>
<td>19</td>
</tr>
<tr>
<td>Age</td>
<td>119.64</td>
<td>112.14</td>
<td>8.73</td>
<td>12.63</td>
<td>159.57</td>
<td>76.15</td>
<td>140</td>
<td>136.35</td>
<td>90.04</td>
<td>97.23</td>
</tr>
<tr>
<td>Radius</td>
<td>1.89</td>
<td>1.876</td>
<td>0.48</td>
<td>0.42</td>
<td>0.173</td>
<td>0.231</td>
<td>2.81</td>
<td>2.93</td>
<td>1.04</td>
<td>1.04</td>
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<tr>
<td>Depth</td>
<td>40.11</td>
<td>38.51</td>
<td>1.87</td>
<td>1.76</td>
<td>3.11</td>
<td>3.46</td>
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<td></td>
</tr>
</tbody>
</table>
The data in Table 4 show that:

The radii of the curve of Spee in the mandibular arch were significantly larger in male than in female (p = 0.01). The mean depth of the curve of Spee was approximately 1.895 mm (male, 1.9 mm; female, 1.89 mm). There was no gender difference in the depth of the curve of Spee (p = 0.916)

- The deepest cusp tip was the mesio-buccal cusp of the first molar in the mandibular arch.

**Table 4:** Comparison of mean, SD and P. value of radius, depth and OX of both samples (Group statistics).

<table>
<thead>
<tr>
<th></th>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>P-value</th>
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</thead>
<tbody>
<tr>
<td>Radius</td>
<td>Female</td>
<td>30</td>
<td>112.1</td>
<td>12.63</td>
<td>1.59</td>
<td>0.01</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>30</td>
<td>119.6</td>
<td>8.73</td>
<td>2.31</td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>Female</td>
<td>30</td>
<td>1.876</td>
<td>0.48</td>
<td>0.09</td>
<td>0.916</td>
</tr>
<tr>
<td></td>
<td>Male</td>
<td>30</td>
<td>1.89</td>
<td>0.42</td>
<td>0.08</td>
<td></td>
</tr>
<tr>
<td>Ox</td>
<td>Female</td>
<td>30</td>
<td>38.51</td>
<td>1.76</td>
<td>0.33</td>
<td>0.533</td>
</tr>
</tbody>
</table>

37
Table 5: The mean and SD of radius, depth and OX of the curve (one-sample statistic)

<table>
<thead>
<tr>
<th>Gender</th>
<th>N</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>Std. Error Mean</th>
<th>P-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radius</td>
<td>30</td>
<td>112.1</td>
<td>12.63</td>
<td>1.6</td>
<td>0.000</td>
</tr>
<tr>
<td>Depth</td>
<td>30</td>
<td>1.88</td>
<td>0.42</td>
<td>0.1</td>
<td></td>
</tr>
<tr>
<td>Ox</td>
<td>30</td>
<td>38.5</td>
<td>1.76</td>
<td>2.5</td>
<td>0.000</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radius</td>
<td>30</td>
<td>119.6</td>
<td>8.73</td>
<td>2.3</td>
<td></td>
</tr>
<tr>
<td>Depth</td>
<td>30</td>
<td>1.89</td>
<td>0.48</td>
<td>0.1</td>
<td>0.000</td>
</tr>
<tr>
<td>Ox</td>
<td>30</td>
<td>40.1</td>
<td>1.87</td>
<td>0.3</td>
<td></td>
</tr>
</tbody>
</table>
The data in Table 6 show:

Indirect proportional relation between the radius and the depth in the group samples:

**Table 6: Correlations between radius and depth in the group sample**

<table>
<thead>
<tr>
<th></th>
<th>Radius</th>
<th>Depth</th>
<th>Ox</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Radius</strong></td>
<td>1.0</td>
<td>-0.2</td>
<td>-0.16</td>
</tr>
<tr>
<td><strong>Depth</strong></td>
<td>-0.2</td>
<td>1.0</td>
<td>-0.05</td>
</tr>
<tr>
<td><strong>Ox</strong></td>
<td>-0.16</td>
<td>-0.1</td>
<td>1.0</td>
</tr>
</tbody>
</table>
The data in Table 7 show:

The negative relation between the radii and the depths which indicate indirect proportional relation between the radius and the depth within the same gender.

**Table 7: Correlations between radius, depth and OX within a Gender (one-sample statistic)**

<table>
<thead>
<tr>
<th>Gender</th>
<th>Radius</th>
<th>Depth</th>
<th>Ox</th>
</tr>
</thead>
<tbody>
<tr>
<td>Female</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radius</td>
<td>1.0</td>
<td>-0.01</td>
<td>-0.29</td>
</tr>
<tr>
<td>Depth</td>
<td>-0.01</td>
<td>1</td>
<td>-0.09</td>
</tr>
<tr>
<td>Ox</td>
<td>-0.29</td>
<td>-0.09</td>
<td>1.0</td>
</tr>
<tr>
<td>Male</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radius</td>
<td>1.0</td>
<td>-0.31</td>
<td>-0.30</td>
</tr>
<tr>
<td>Depth</td>
<td>-0.31</td>
<td>1.0</td>
<td>0.14</td>
</tr>
<tr>
<td>Ox</td>
<td>-0.30</td>
<td>0.14</td>
<td>1.0</td>
</tr>
</tbody>
</table>
Figure (1): Mean value of Radius, Dept, Orientation axis in males and females

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Male Mean</th>
<th>Female Mean</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radius</td>
<td>119.64</td>
<td>112.14</td>
</tr>
<tr>
<td>Depth</td>
<td>40.11</td>
<td>38.51</td>
</tr>
<tr>
<td>Ox</td>
<td>1.89</td>
<td>1.88</td>
</tr>
</tbody>
</table>
Figure (2): Standard Deviation of Radius, Depth and Orientation Axis for males and females.
Figure (3): Scatters of Radius, Depth and Orientation acis means for males and females
Figure (4): Scatters of Radius, Depth and Orientation acis means for males and females.
Figure (5): Age distribution by gender for females
Figure (6): Age distribution by gender for males

- Age: 23 yrs. Valid Percent: 30.0%
- Age: 24 yrs. Valid Percent: 30.0%
- Age: 25 yrs. Valid Percent: 20.0%
- Age: 26 yrs. Valid Percent: 20.0%
Figure (7): Gender distribution

Male 50%

Female 50%
4. DISCUSSION, CONCLUSION AND RECOMMENDATIONS

4.1 Discussion:

It has been postulated for almost a century that the occlusal plane is curved because of sagittal inclination of the teeth. From the lateral view, this morphological arrangement, called the curve of Spee is convex for maxillary arch and concave for mandibular arch.

Measurement of the curve of Spee remains controversial. Clinically; the curve of Spee is determined by the distal marginal ridges of the most posterior teeth in the arch and the incisal edges of the central incisors. Inclusion of the incisors in the interpolation generates a larger and flatter curve and increases variability.

The lengths and positions of the radii exhibit such large deviations that the mean cannot be used as standard. In the present study, the curve was described as a line of best fit from the tip of the canine that touched the tips of the buccal cusps of the posterior teeth. The curve of Spee permits total posterior disclusion on mandibular protrusion, given proper anterior tooth guidance. The curve of Spee may be pathologically altered in situations resulting from rotation, tipping, or extrusion of the teeth. Restorations of the dentition to such an altered occlusal plane can
introduce posterior protrusive interference. Such interference has been shown to cause abnormal activity in mandibular elevator muscles, especially the masseter and temporalis muscles. Furthermore, it has been suggested that excursive interference may result in wear, fracture of restorations, and temporomandibular joint dysfunction. Whenever extensive prosthetic reconstruction is planned, the dental cusps may show a flat curve of Spee. This lessens the risk of relapse, and simplifies the problem of canine guidance for disclusion of posterior teeth, but it reflects neither the characteristics nor the functional significance of the curve of Spee. Such simplification of a natural arrangement may alter the complex neuromuscular system, and subsequently affect dentoalveolar relations. The depth of the Curve of Spee may be a critical point for treatment protocols.

In this study, the concavity of the Curve of Spee did not differ in mean from that of women. In the subjects investigated, the shape of the Curve of Spee was not influenced by gender (table 4). The lack of sexual dimorphism is in agreement with previous findings. The orientation axis (Ox) which represents an imaginary line joining the tip of the canine cusp to the tip of the distobuccal cusp of the second molar, shows a mean length of 40.1mm in males, and 38.5mm in females, with no significant difference (P. value 0.533), (table 4). Though males had an (Ox) of 40.1mm, with a high standard deviation of 13.86,
the females had a standard deviation of 1.67 which indicated variation in the arch length (OX). These variations are probably attributed to gender or genetic factor.

When the teeth are in occlusion the disto-buccal cusps of the lower teeth are in contact with their antagonists, while the mesio-buccal cusps enter between the two cusps of the upper teeth. Therefore the measurements in this study were taken only on the disto-buccal cusps.

In the preceding section it was shown that in some samples the projection of the buccal cusps of the bicuspid and molars upon a plane forms the arc of a circle. These points lie in the same cylindrical surface, as pointed out by Spee; and the line connecting them, when projected, has been designated "the curve of Spee" by subsequent writers\textsuperscript{92}. Since the precise form of the curve of Spee is not always the same, it has been the purpose of this study my purpose to find some convenient standard by the use of which the differences can be expressed quantitatively. For this purpose Spee himself (1890) selected the length of the radius of his curve and the results of his observation were given by him in a chapter entitled: "Specielle Befunde an verschiedenen Gebissen." This method of comparison is valuable when the degrees of the curvature of the various curves of Spee are compared with each other. I have therefore followed the principle of Spee and determined the radius of the circle in order to determine the degree of curvature.
Since the curve of Spee is obtained by connecting the summits of the cusps of the bicuspids and molars, the length of the arc cannot be represented by the radius alone. The full form of the curve of Spee in any instance is determined by both its radius and the length of the arc. It is thus clear that in order to make a comparison of the curves of Spee as given by various mammals; we need, besides the radius, which represents the curvature at any point, also the length of the arc is needed. It has been stated that in the cylinder surface lies the part of the circle which passes through each cusp of the bicuspids and molars and the middle point of the anterior face of the articular surface of the condyle. It is possible to determine the length of the radius of any given circle or arc from the three points taken on the circumference by means of digital caliper. The data obtained in this study using the above described method are given in table (3).

As to the physiological and anatomical significance of the curve of Spee and as to the relation of the curve of Spee to the other parts of the skull, Spee (1890) has put forward the opinions which were briefly summarized at the beginning of this paper, and the purpose of this study it was to reconsider these statements of Spee in the light of obtained data.

It is evident, from the data in tables (4,6), that there is no direct relation between the values of "radius" of the Curves of Spee and the values of depth, between genders. The mean values of radii was 119.6mm for male
and 112.1mm for female, the depth of the curve of Spee remained approximately the same for both (1.8 mm). The same result was obtained by Toshiko Suasuki, et al.\textsuperscript{16}

Spee stated in his study (1890) that, in general, the greater the radius of the cylinder-surface on which the occlusal line of the teeth lies, the bigger will be that animal, and the more prognathic the skull. In this study it was clear that the males had a bigger radius than females, this fact supports Spee's hypothesis\textsuperscript{92}.

It may be pointed out that, although the curve of Spee is often called "the compensating curve", since it compensates the movement of the jaw during mastication, and it is important to emphasize that such compensation, should precisely be applied when prosthodontic reconstruction is to be undertaken.
4.1 Conclusion and Recommendations

4.1 Conclusion:

1. This study has revealed that the depth of curve of Spee was not influenced by gender (p =0.916).

2. Although, the steepness (concavity) of the curve of Spee (compensating curve) was the same for both genders, the radius was larger in males than females (p =0.01).

3. Determination of Curve of Spee in Angle class I occlusal relation assist dentists in developing occlusion in the sagittal plane as a reference whenever prosthodontic reconstruction are undertaken.

4.3 Recommendations:

Further studies in Curve of Spee in subjects having Angle class II and class III occlusal relationship are advised including comparison between the curve on both sides of mandibular arch. Determination of the curve of Spee can be studied for subjects having class II and class III occlusion, and further analysis of the curve on the left side of mandibular arch should be carried out to investigate if there is comparison between the two sides of the mandibular arches.
REFERENCES


21- Monson GS. Occlusion a applied to crown and bridgework. J Nat Dent Aso 1920: 7; 399 - 413.


Appendices

Appendix-1:

Data Collection Form (1)

1. Serial Code No.: ........................
2. Age: ......................................
3. Gender:  
   a- Male  
   b- female  
4. Clinical Examination:  
   a. No. of the teeth  
      
     | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 |
   
   b. Previous orthodontic treatment  
      a) yes  
      b) No  
   c. Current orthodontic treatment  
      a) yes  
      b) No  
   d. Angle classification:  
      i- Class I  
      ii- Class II:  
         a) Div. I  
         b) Div II  
      iii- Cass III  
   
   e. Overjet: ..........................................................(Normal Overjet 2-4mm) 
   f. Overbite: .......................................................  
   g. Cross bite: ....................................................  
5. Restoration:  
   a) filling  
   b) Onlay  
   c) Inlay  
   d) Others  
6. TMJ:  
   a. Myofacial Pain Dysfunction Syndrome (MPDS):  
      i- Localized muscle pain:  
         a) dull  
         b) intermittent  
         c) continuous  
      ii- Habits:  
         a) clinching  
         b) grinding  
      iii- Anterior displacement (Clicking):  
         a) Yes  
         b) No  
   iv- Mouth opening:
a) < 35mm   b) > 35 mm   c) = 35 mm

v- Osteoarthrosis:
   a) Crepitus   b) Pre-auricular pain
   c) Movement Limitation

vi- Rheumatoid arthritis:   a) Yes   b) No
Appendix-2

Data collection form (2)

Serial code number: -----------------------------------------------

Age: -----------------------------------------------

Gender:  Male ☐     Female ☐

Measurements:

Mandible:

Radius (R): ----------------------------------------------- m.m

Depth (D): ----------------------------------------------- m.m
Appendix-3:

Photo standardization

1-

2-
Measurement of the Curve of Spee:
cusp tips Used for measurements of Curve of Spee indicated with black dots; most anterior and Posterior dots dissected by orientation axis. Deepest distance from orientation axis to tooth represents depth of Curve of Spee.