

## Measurement of the Depth of Spee's Curve using Digital 3D Dental Models

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### Introduction

Ferdinand Graf von Spee is credited with characterizing human occlusal curvature viewed in the sagittal plane [4]. This curvature was named after him and is called curve of Spee.

This line lies on a cylinder that is tangent to the anterior border of the condyle, the occlusal surface of the second molar, and the incisal edges of the mandibular incisors. The curve of Spee located in the center of this cylinder in the midorbital plane so that it had a radius of 6.5 to 7.0 cm. However, clinically the distal marginal ridges of the posterior teeth in the arch and the incisal edges of the central incisors determine the curve of Spee [8]. This naturally occurring phenomenon has clinical importance in orthodontics and restorative dentistry [4].

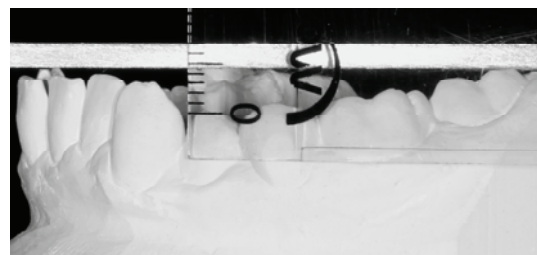
The curve of Spee allows define the normal functional protrusive movement of the mandible. Increased occlusal curves slipped contacts in vertical plane [5].

The characteristics of the curve of Spee in the mandibular arch have been investigated. Few studies have examined the characteristics of the Spee's curve in the maxillary arch. Xu H. with other authors examined the differences in the Spee's curve between the maxillary and mandibular arches [9]. There is little consensus in the literature concerning the measurement of the Spee's curve. Baldrige used the perpendicular distances on both sides, Bishara et al used the average of the sum of perpendicular distances to each cusp tip, Sondhi et al used the sum of the perpendiculars, Braun et al and Braun and Schmidt used the sum of the maximum depth on both sides [10]. However, there is disagreement about measurement methodology for curve of Spee. Some authors do not include incisors to depth measurements of Spee's curve. Frequently, the incisors are super-erupted, so a greater distance (depth of the curve) is obtained than when

excluding the incisors [7]. Leveling the occlusal plane involves restoring contact point relationships [2]. Andrews (1972) advocated levelling curve of Spee to a flat curve in order to facilitate construction of an optimal occlusion [6]. Calculation of Spee's curve is very important in diagnostics for orthodontics patient: the planning of treatment, retention, and prognosis as well as for evaluation of robustness of treatment results.

Conventionally, the depth of Spee's curve is measured manually on mandibular stone model. For measurement the occlusal plane or its projection is necessary. In certain relevant points the stick is pressed together with perpendicular ruler. Then, the assessment of deepest distance from buccal cusp tips is conducted. However, the method is impossible if one considers also the incisors.

For this, another method was created where the plate is used and central incisors are considered. The plate is set on stone model in the way that it touches the distobuccal cusp tips and central incisors. This is also technically problematic due to dental crowding and differences of dental heights. The ruler is set and the deepest point is evaluated approximately (Fig. 1.).



**Fig. 1.** Manual measurement using the plate and the ruler. Occlusal plane is formed using the plate. In this case, there are difficulties associated with plane going through central incisors

due to different dental heights. The deepest point is measured approximately by visual estimate.

Manual measurement is limited and results are imprecise. Some researchers measure the maximum depth of Spee's curve using Standardized photographs. New 3D technologies enable to measure these parameters precisely and easily.

Aim of this study:

To investigate a possibility of using 3D computer models for measurement of Spee's curve depth.

Objectives:

1. To measure Spee's curve depth manually using lower dental casts;
2. To measure Spee's curve depth using 3D model analogues;
3. To compare the manual and 3D measurements;
4. To evaluate the potential of 3D models for measurement of Spee's curve depth.

## Material and methods

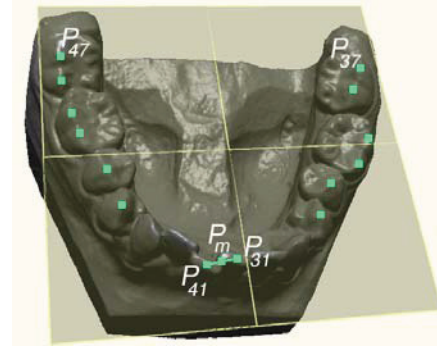
Two study groups were formed. The first group included the stone models (dental casts) of 15 subjects, the second – digital analogues of those dental casts. Dental casts had inclusion criteria: sufficient quality, permanent teeth, second molars grown. The stone model was made by laboratory worker using the methodology practiced at Clinic of Orthodontics (Academy of Medicine, Lithuanian University of Health Sciences).

Stone models underwent manual measurements. The plate was posed in a way that it touches the distobuccal cusp tips and central incisors. Perpendicular to plate, the ruler was posed and the maximum of the perpendicular distances between the buccal cusp tips of the mandibular teeth and a measurement plane were measured. All 15 models had measurements of Spee's curve depth on left and right side and the assessment was repeated 7 times.

The orthodontist scanned the stone model using the structured-light three-dimensional (3D) scanner HDI 3D [1]. A high-resolution digital camera acquires images of the light patterns projected on the cast surface. The software FlexScan3D automatically processes the images and creates the 3D model of one view. Later, the 3D models captured from different views were registered using modified Iterative Closest Point (ICP) algorithm [2]. Remeshed 3D computer model of dental cast can be used for evaluation of curve of Spee.

Data were transferred to 'Rapidform 2006' software. There were placed 14 relevant points on dental cast necessary for assessment of Spee's curve depth (Fig. 2). The 1st point was marked on the second molar distobuccal cusp tip, the 2nd point – on the second molar buccal cusp tip. Further points were marked as follows: the 3rd – on the first molar buccal cusp tip, the 4th – on the second molar buccal cusp tip, the 5th – on the second premolar buccal cusp tip, the 6th – on the first premolar buccal cusp tip, the 7th – on midpoint of central incisor. Such marking of the points was continued symmetrically on the other side of 3D model. The points were marked consecutively as described from tooth 37 to 47. This procedure was repeated 7 times for each dental cast – altogether 15 digital

analogues. For each 3D model of lower jaw, a numerical matrix of points was created and stored in a data file.



**Fig. 2.** Capturing of  $(x, y, z)$  location coordinates of points representing the curve of Spee

Fig. 3 shows the Spee's curve depth estimation algorithm, which can be divided into 4 stages: definition of spatial positions of cusp tips, definition of plane through the most occlusal anterior and posterior teeth, calculation of distances from plane to all cusp tips, finding maximum distance as depth of curve of Spee.

At first, when the data are loaded, the coordinates  $x_m$ ,  $y_m$  and  $z_m$  of the midpoint  $P_m$  of the segment from  $P_{31}(x_{31}, y_{31}, z_{31})$  to  $P_{41}(x_{41}, y_{41}, z_{41})$  in a 3D space were calculated using formula [3]:

$$\begin{cases} x_m = \frac{x_{31} + x_{41}}{2}, \\ y_m = \frac{y_{31} + y_{41}}{2}, \\ z_m = \frac{z_{31} + z_{41}}{2}. \end{cases} \quad (1)$$

For the evaluation of Spee's curve depth in a three-dimensional space, a occlusal plane passing through points  $P_m(x_m, y_m, z_m)$ ,  $P_{37}(x_{37}, y_{37}, z_{37})$  and  $P_{47}(x_{47}, y_{47}, z_{47})$  was defined as

$$A \cdot x + B \cdot y + C \cdot z + D = 0, \quad (2)$$

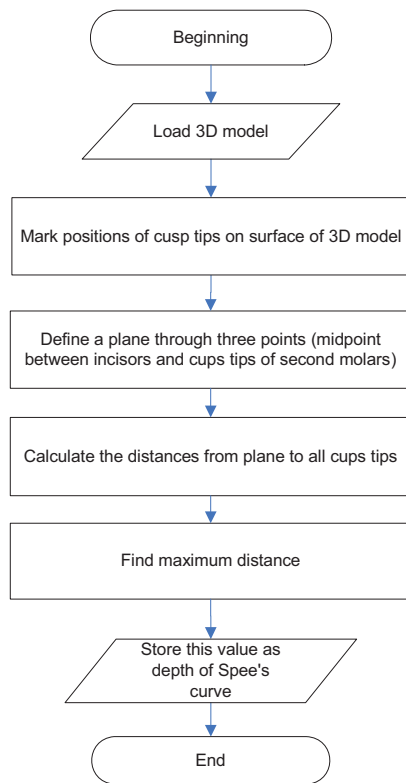
where

$$\begin{cases} A = \begin{vmatrix} y_{37} - y_m & z_{37} - z_m \\ y_{47} - y_m & z_{47} - z_m \end{vmatrix}, \\ B = \begin{vmatrix} x_{37} - x_m & z_{37} - z_m \\ x_{47} - x_m & z_{47} - z_m \end{vmatrix}, \\ C = \begin{vmatrix} x_{37} - x_m & y_{37} - y_m \\ x_{47} - x_m & y_{47} - y_m \end{vmatrix}, \\ D = - \begin{vmatrix} x_m & y_m & z_m \\ x_{37} & y_{37} & z_{37} \\ x_{47} & y_{47} & z_{47} \end{vmatrix}. \end{cases} \quad (3)$$

The perpendicular distances from this plane to the buccal cusp tip  $P_n(x_n, y_n, z_n)$  of tooth can be estimated as

$$d_n = \frac{A \cdot x_n + B \cdot y_n + C \cdot z_n + D}{\sqrt{A^2 + B^2 + C^2}}. \quad (4)$$

In norm, the sagittal Spee's curve depth is approximately 1–2 mm. Positive value is if the cusp tips are below occlusal plane, the negative – if above the occlusal plane.



**Fig. 3.** Algorithm of estimation of Spee's curve depth

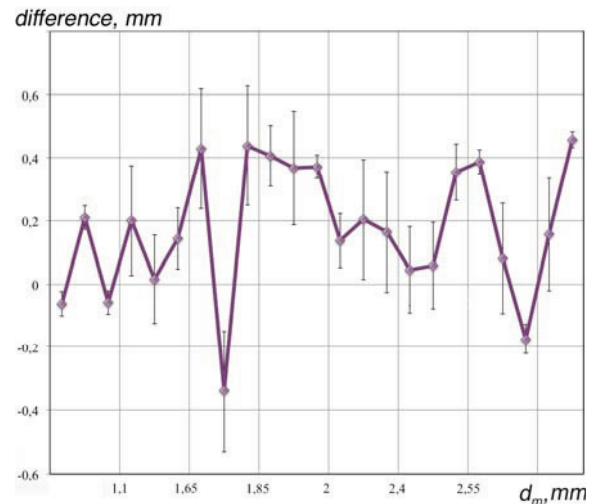
The Principal Components Analysis (PCA) [2, 11] can be used also for definition of plane orientation and position in 3D space.

Distances from plane to the cusp tips of all teeth were calculated. The maximum distance for left side tooth represented the depth of the curve of Spee for left side and maximum distance for right side tooth represented the depth of the curve of Spee for right side. All values were stored in data file for statistical analysis.

## Results

To test the reliability of method the lower dental casts of 15 persons were scanned and the process of landmark capturing and numerical manipulation was applied. The spatial positions of the distobuccal cusp tips of the incisors and the distobuccal cusp tips of second molars was used for definition of plane orientation and position in 3D space. The distances from this plane to all cusp tips were calculated and maximum distance separately for left side and right side were stored as Spee's curve depth by means of our computer software made in MATLAB. Those distances were measured using manual technique also. The study was performed 7 times on each stone cast model, 3D

dental model and average Spee's curve depth value and deviation of measurement results was calculated. The average values of Spee's curve depth obtained using different methods were compared. Within a confidence interval of 95%, we could say that measurement results of depth of Spee curve using conventional method and in this study presented algorithm don't differ more than 0.5 mm (Fig. 4) and are good correlated (the average correlation coefficient between to data sets is 0.97).



**Fig. 4.** The difference between average depth of Spee's curve values obtained using 3D digital model and results obtained using manual technique ( $d_m$ ). Vertical bars are 95% confidence intervals

Average deviation of results obtained using 3D computer models is  $\pm 0.04$  mm, while using conventional manual technique the deviation of measurement results is  $\pm 0.14$  mm. This means very strong improvement in repeatability of measurement using 3D models. For few casts the measurement results differ more than 0.5 mm. This is caused by low resolution of conventional equipment (0.5 mm).

## Conclusions

1. 3D digital models are acceptable alternative to dental casts for measurement of Spee's curve depth.
2. Scans of each patient's models and estimation of Spee's curve was accomplished for individualized treatment planning.
3. 3D models allow estimate Spee's curve depth more accurate, because location of plane is independent on size of canines.

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**R. Adaskevicius, V. Svalkauskiene. Measurement of the Depth of Spee's Curve using Digital 3D Dental Models // *Electronics and Electrical Engineering*. – Kaunas: Technologija, 2011. – No. 3(109). – P. 53–56.**

Aim of our study is to consider a possibility of using 3D computer models for measurement the depth of curve of Spee. Curve of Spee is very important in diagnostics of orthodontical patient. The structured-light three-dimensional (3D) scanner was used for scanning dental casts. The cusp tips of the molars, premolars, and incisors of the mandible were identified using digital 3D models and Rapidform 2006 software. The depth of the curve of Spee was evaluated by means of our computer software. Algorithm for depth of Spee's curve evaluation is presented. The dental casts of 15 subjects were scanned and measured to test the reliability of method contrasting with conventional manual measurement. The depth of Spee's curve was measured 7 times for every dental cast and repeatability of conventional and digital measurement methods was compared. Within a confidence interval of 95%, we could say that measurement results of depth of Spee's curve using two different methods don't differ more than 0.5 mm. Three-dimensional digital dental models is useful tool for analysis of depth of Spee's curve and treatment planning. Ill. 4, bibl. 11 (in English; abstracts in English and Lithuanian).

**R. Adaškevičius, V. Švalkauskienė. Spee kreivės gylio nustatymas panaudojant dantų erdvinius kompiuterinius modelius // *Elektronika ir elektrotechnika*. – Kaunas: Technologija, 2011. – Nr. 3(109). – P. 53–56.**

Darbo tikslas – ištirti, ar erdvinius kompiuterinius modelius galima panaudoti Spee kreivės gyliui nustatyti. Ši kreivė yra svarbi ortodontinėje diagnostikoje. Gipsiniams diagnostiniams modeliams skenuoti buvo panaudotas erdvinis skeneris, veikiantis struktūrinės šviesos projektavimo principu. Kandžių, kaplių ir krūminių dantų gauburų koordinatės buvo identifikuotos naudojant suformuotus kompiuterinius modelius ir programų paketą Rapidform 2006. Specialiai sukurta programa buvo apskaičiuoti Spee kreivės gyliai. Pateikiamas programos algoritmas. Metodo patikimumui įvertinti buvo nuskenuoti 15 pacientų diagnostiniai modeliai, apskaičiuotos Spee kreivių gylio vertės ir rezultatai palyginti su tradiciniais matavimo metodais gautomis vertėmis. Gylio verčių vidurkiams ir jų sklaidai nustatyti kiekvienas modelis buvo tirtas po 7 kartus. Su 95 % patikimumu galima teikti, kad pateiktu metodu nustatytos Spee kreivės gylio vertės skiriasi nuo tradiciniais matavimo metodais gautų rezultatų ne daugiau kaip 0,5 mm. Dantų kompiuteriniai modeliai yra tinkama Spee kreivės analizės priemonė. Il. 4, bibl. 11 (anglų kalba; santraukos anglų ir lietuvių k.).