A comparison of the accuracy of two methods used by pre-doctoral students to measure vertical dimension

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Statement of problem. Measuring vertical dimension is a soft-tissue measurement. Therefore, inaccuracy may occur.

Purpose. The purpose of this study is to compare the accuracy of the Willis gauge method with the caliper method.

Material and methods. The Willis gauge measures the distance between the septum of the nose and the chin. The caliper method measures the distance between reference points on the tip of the nose and the chin. Twenty predoctoral students applied both methods 10 times in measuring the rest vertical dimension (RVD) and the occlusal vertical dimension (OVD) of a single edentulous patient. The measurements obtained from one experienced clinician were selected as controls for the interocclusal distances (IOD) for the Willis and the caliper methods, respectively. One-sided *t* tests and a 1-sided nonparametric test were used to determine significant differences between the 2 methods (α=.05).

Results. The variances in the RVD values for the Willis gauge method were higher than for the caliper method for most students. A Wilcoxon signed rank test showed that the accuracy of the OVD measurements for the caliper method was significantly better than for the Willis gauge method (*P*=.001). This was not the case for the RVD measurements (*P*=.073).The average IOD for the Willis method was significantly higher than the control IOD (*P*=.026). The average IOD for the caliper method was not significantly larger than the control (*P*=.1303).

Conclusion. This study showed that the use of the caliper method by predoctoral students was a significantly more reliable method of measuring the OVD for the patient evaluated. (J Prosthet Dent 2004;91:59-66.)

Clinical implications

The variation of the OVD measurements was significantly smaller for the caliper method than for the Willis method as measured by predoctoral students. The difference between the IOD for the Willis gauge and for the caliper methods was not significant.

The determination of the occlusal vertical dimension (OVD) is an important procedure in the treatment of the edentulous patient.[1-4] Adequate interocclusal distance (IOD) is associated with daily use of complete or removable partial dentures.[5] Incorrect determination of the OVD and centric relation may result in failure of complete denture treatment.[6] Many methods to determine a vertical dimension for the rehabilitation of edentulous patients are described in the literature.[7-12] These methods include the use of physiologic rest position,[2,13,14] phonetics,[2,15-18] esthetics,[19] swallowing,[19-22] craniometrics,[23-27] cephalometrics,[28-32] and electromyography.[33-36] However, there is no single precise scientific method for determining the correct OVD for the edentulous patient.[3,7,20,24,26,31,37] Some authors prefer the concept of a "zone of comfort," a "vertical comfort range," or a "preferred vertical dimension of occlusion."[38-42] Many dentists use the physiologic rest position as a starting point.[23] In order to establish the physiologic rest position, several authors recommend a combination of techniques.[4,7,17,43-46]

Different methods exist for measuring vertical dimension in physiologic rest position and maximum intercuspation. When selecting a method, the following criteria have been recommended: accuracy and reliability of the measurement, adaptability of the technique, type and complexity of equipment needed, cost, and the length of time required to make the measurement.[2,3] Studies using extraoral reference points report that skin markers are not reliable as a means of determining intermaxillary bone relationships.[37,46,47] There is a discrepancy between values obtained from the rest positions as measured on the skin and as measured intraorally.[13] Mean facial measurements may account for only half the skeletal movement.[48] In contrast, another study showed the IOD to be greater with a chin reference method than

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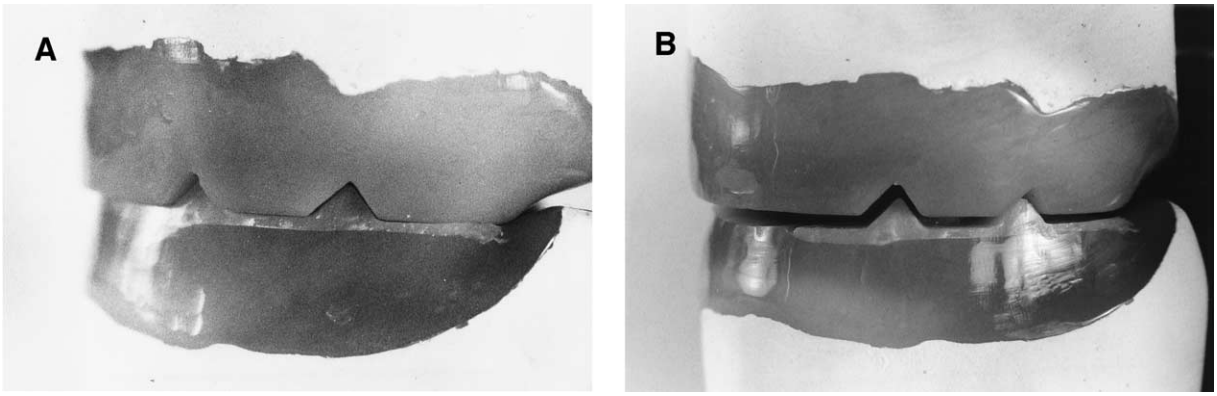

Fig. 1. A, Record bases and rims at occlusal vertical dimension. **B,** Record bases and rims at rest vertical dimension.

with a tooth-attached reference point.[45] The use of skin markers produces greater variations than the use of bone references on cephalometric radiographs.[7] On the other hand, several authors report that facial measurements and cephalometric data were found to be accurate for measuring vertical dimension of occlusion.[2,9] Despite conflicting evidence in the literature regarding the measuring of the vertical dimension in edentulous patients, the use of facial reference points is still a popular method in clinical practice, and both the caliper and the Willis gauge techniques are used in research studies.[4-6,9,16,19]

The Willis gauge method is described by Basker and Davenport.[49] The Willis gauge measures the distance between the septum of the nose and the chin. Inaccuracies resulting from the use of the Willis gauge method are caused by the following: inconsistent angulation of the instrument (especially for convex profiles, patients with moustaches and beards, short necks, full lips, round chins) and compression of the soft tissue under the chin and septum of the nose by pressure exerted by the gauge.[49]The caliper method measures the distance between reference points on the tip of the nose and the chin. The caliper method is influenced by compression of soft tissue in the region of the skin markers.

The purpose of this study was to compare the accuracy of the Willis gauge method with the caliper method based on the hypothesis that the caliper method is more accurate than the Willis gauge method in measuring vertical dimension in an edentulous patient. Measurements were made by predoctoral students.

MATERIAL AND METHODS

A patient who met the following requirements was selected: Class III edentulous alveolar ridges,[50] a normal straight profile, no history of temporomandibular joint pathology or dysfunction, no denture-wearing experience, and no extraoral or intraoral pathology. After the patient's consent had been obtained, the following procedures were performed by a prosthodontist. Preliminary impressions of both edentulous jaws were made using irreversible hydrocolloid (Blue Print; De Trey, Weybridge, UK) in stock trays (Eezytray; Wright Cottrell, Dundee, Scotland). Custom trays were fabricated in light-polymerized acrylic resin (Megatray; Megadenta, Radeberg, Germany) on the diagnostic casts without relief. The fit of the custom trays was evaluated intraorally and overextended borders were reduced. The custom trays were border molded with modelling plastic impression compound (Greenstick; SDS Kerr, Salerno, Italy). Excess of modelling plastic impression compound was removed and definitive impressions were made with zinc oxide–eugenol impression material (SS White; SS White Group, Gloucester, UK). The impressions were examined for accuracy and correct anatomic extension. Mandibular and maxillary record bases and occlusal rims of base-plate wax (Associated Dental Products, Swindon, UK) were fabricated on the definitive casts (Dentstone KD; Abertay, Aberdeen, Scotland). The maxillary record base and rim were placed intraorally and trimmed to restore proper lip support. The height and the orientation of the maxillary record rim were adjusted according to the techniques described by McCord and Grant.[4] The physiological rest position was determined using a combination of relaxation, phonetic speech, and facial appearance, resulting in a position of comfort with lips lightly touching.[2,3,49,51]

An arbitrary 2 mm for IOD was reduced from the mandibular record rim.[9] An anterior stop was maintained and the posterior portions of the mandibular record rim were removed to provide a clearance of at least 2 mm between the maxillary and mandibular rims, with only the mandibular anterior stop touching the maxillary record rim. A cone of soft wax (Toughened 4.0; Associated Dental Products) was added onto each side of the reduced mandibular record rim. The mandibular record rim was positioned intraorally and the mandible was manipulated into centric relation by a direct interocclusal recording technique (physiologic po-

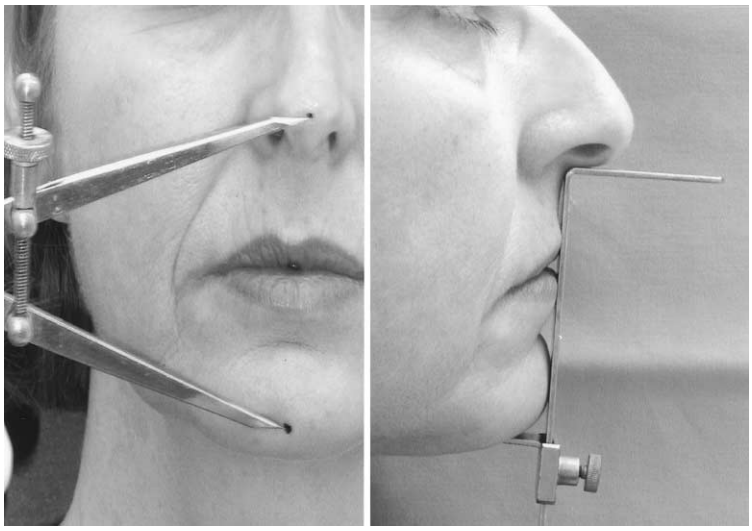

Fig. 2. Caliper method (*left*) and Willis method (*right*).

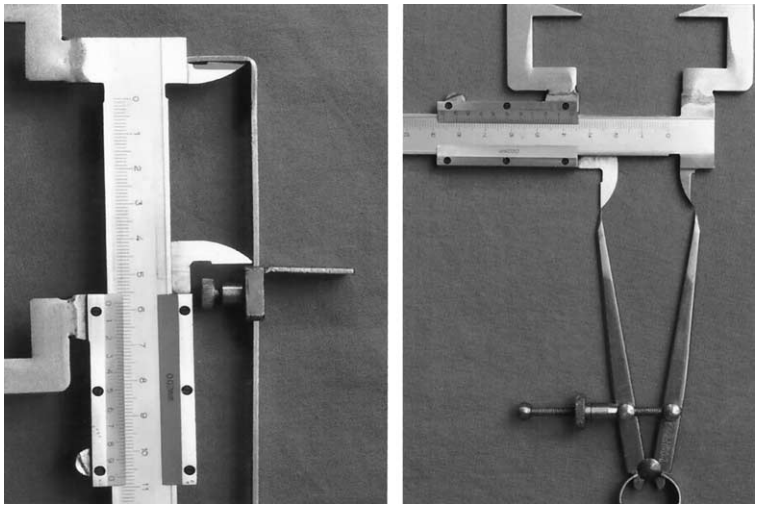

Fig. 3. Boley gauge used to measure distance recorded by Willis gauge (*left*) and caliper (*right*).

sition) using reproducibility of the record as a means of judging the accuracy of the position.[52] When the wax had solidified, the mandibular record base was removed from the mouth. Another cone of soft wax was placed between the anterior stop and the 2 posterior cones, and the horizontal dimension of the centric relation position was determined. These last 2 soft cones occluded with notches carved in the maxillary record rim. The rims were evaluated for stable articulation. The casts were mounted in an articulator (ASA Instruments; Bozzano, Italy). Solid wax segments locking in the maxillary notches replaced the mandibular cones. The position of the solid segments represented the position of the future mandibular posterior teeth. For the purpose of the study, the wax record bases and rims were finished, invested, and processed in heat-polymerized acrylic resin (Mr Dental; Meadway). The record bases were evaluated intraorally for comfort and retention. The acrylic ridges on the mandibular record rim articulating with the maxillary notches were relieved and relined with auto-polymerized acrylic resin (Total; Stratford-Cookson Co, Surrey, UK) in the centric relation position to ensure accurate stability and occlusal contact (Fig. 1).

A group of 20 predoctoral students consisting of 10 fourth-year and 10 fifth-year students participated in the study. The fourth-year students were completing their first clinical module in complete denture prosthetics. The fifth-year students had already completed the complete denture prosthodontics module. The students had been taught the Willis gauge method. The clinical appli-

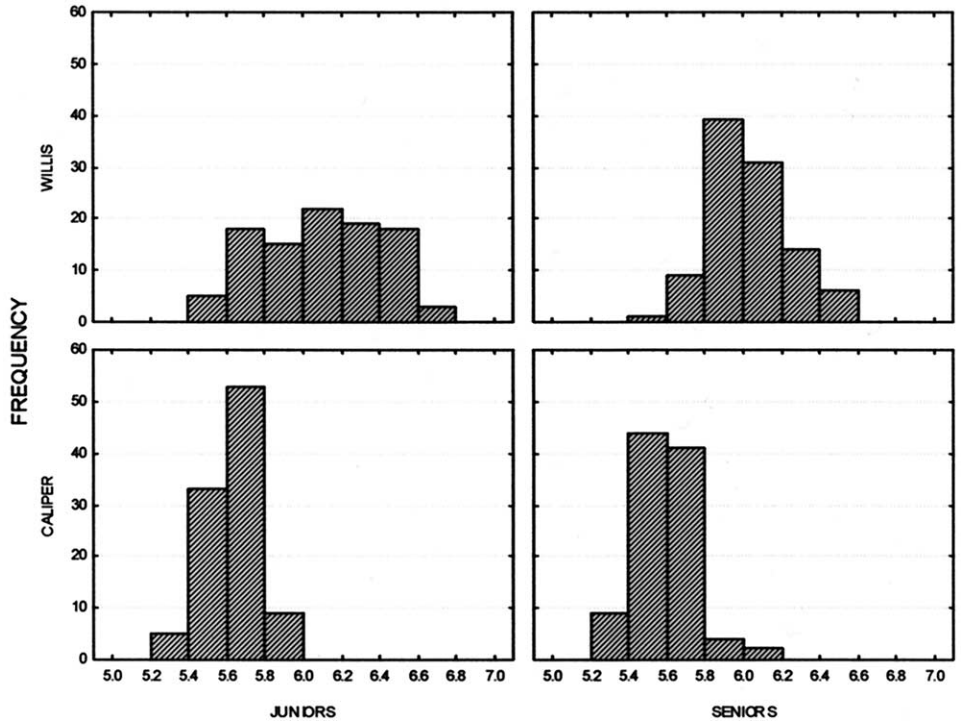

Fig. 4. Histograms of occlusal vertical dimension measurements (cm) for fourth- and fifth-year students.

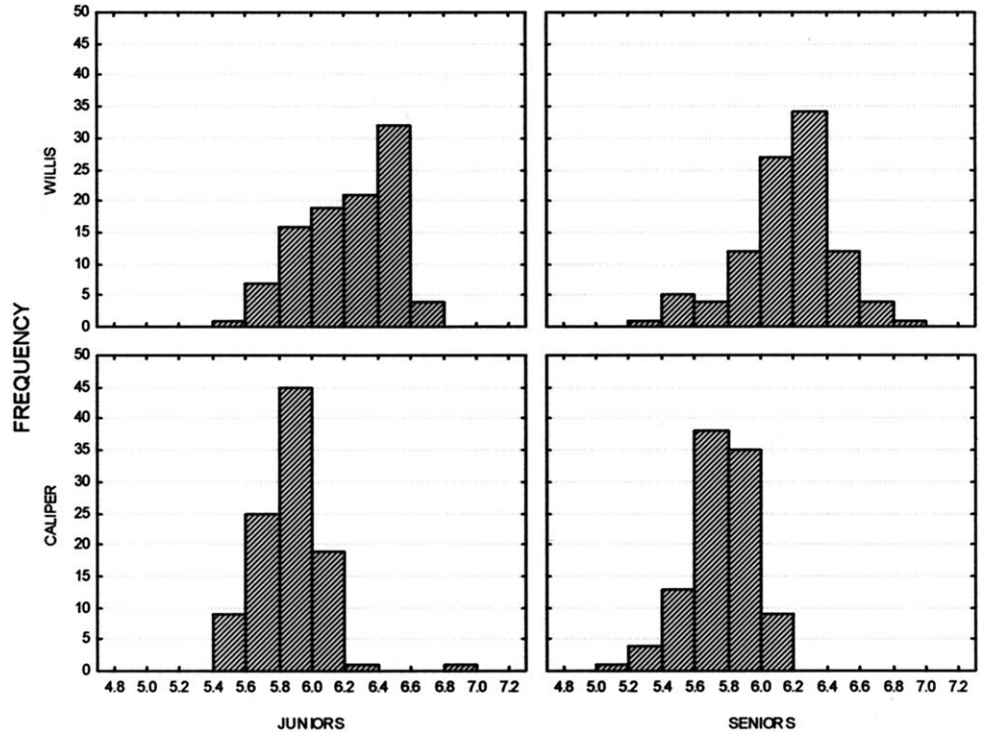

Fig. 5. Histograms of rest vertical dimension measurements (cm) for fourth- and fifth-year students.

Table I. Standard deviations for occlusal vertical dimension values

	Standard deviations		
	Willis	**Caliper**	**Difference**
Fourth-year students	0.125	0.106	0.019
	0.120	0.107	0.013
	0.181	0.080	0.102
	0.077	0.089	−0.012
	0.142	0.127	0.015
	0.117	0.098	0.019
	0.090	0.088	0.002
	0.095	0.127	−0.032
	0.169	0.084	0.085
	0.180	0.137	0.043
Fifth-year students	0.263	0.149	0.113
	0.220	0.168	0.052
	0.122	0.110	0.012
	0.131	0.119	0.012
	0.107	0.100	0.007
	0.310	0.138	0.173
	0.114	0.107	0.007
	0.135	0.082	0.053
	0.181	0.047	0.133
	0.105	0.082	0.024
Control	0.023	0.057	−0.034

Table II. Standard deviations for rest vertical dimension values

	Standard deviations		
	Willis	**Caliper**	**Difference**
Fourth-year students	0.204	0.105	0.099
	0.157	0.114	0.042
	0.232	0.294	−0.063
	0.123	0.092	0.031
	0.196	0.148	0.048
	0.135	0.215	−0.080
	0.156	0.155	0.001
	0.104	0.138	−0.034
	0.121	0.107	0.015
	0.119	0.081	0.038
Fifth-year students	0.216	0.090	0.126
	0.128	0.154	−0.026
	0.315	0.108	0.207
	0.224	0.165	0.058
	0.216	0.120	0.096
	0.149	0.131	0.018
	0.135	0.208	−0.073
	0.190	0.142	0.048
	0.143	0.110	0.033
	0.182	0.156	0.026
Control	0.109	0.121	−0.012

cation of the caliper method was new to all students. Every student received a leaflet with instructions for a standard method of establishing a patient's physiologic rest position and the correct use of the Willis gauge (SS White Group, Gloucester, UK) and the caliper (Moore & Wright, Sheffield, UK). The instructions for the establishing of the physiologic rest position included a combination of relaxation, phonetics, and facial appearance methods as recommended in the literature.[4,7,17,43-46] Figure 2 illustrates the 2 methods of measurement. Every student recorded the following in this sequence: the RVD with the maxillary record base in place using a Willis gauge without visible measurement markings; the RVD with the maxillary record base in place using the caliper; the OVD with both record bases in place using the same Willis gauge; the OVD with both record bases in place using the caliper. This sequence was repeated 10 times by each student.

The measurement markings on the Willis gauge were masked with opaque tape. The records were made by the students and were consequently measured by a prosthodontist using a Boley gauge (National Keystone, Cherry Hill, NJ) with up to 0.1-mm accuracy (Fig. 3).

The patient was positioned in the dental chair in a fully upright position, with the back of the patient in maximal contact with the back of the chair. A headrest supported the head with the ala-tragus line in a horizontal position. This position was maintained throughout the recording procedures. The patient was allowed a break of 5 minutes every 20 minutes. One experienced clinician repeated the same measurements and these values were used as a control.

To determine if the caliper method was more accurate than the Willis method, the differences between the standard deviations for each student were calculated and a 1-sided Wilcoxon signed rank test was used to determine if the variation due to the caliper method was less than the variation due to the Willis method ($\alpha = .05$).

To determine if the average interocclusal distance of the students' measurements was more than the control as recorded by the experienced clinician, 1-sided t tests were used ($\alpha = .05$). No sample size or power analysis was done before the experiment.

RESULTS

Figures 4 and 5 illustrate the different distributions of the OVD and RVD measurements for the fourth-year and fifth-year students. Standard deviations for both methods were calculated for every student (Tables I and II). For most of the students, the SDs of RVD values for the Willis gauge method were higher than for the caliper method.

Since the differences in SDs of RVD were not normally distributed, the Wilcoxon signed rank test was used to test if the variation over all students using the Willis gauge method was higher than the variation due

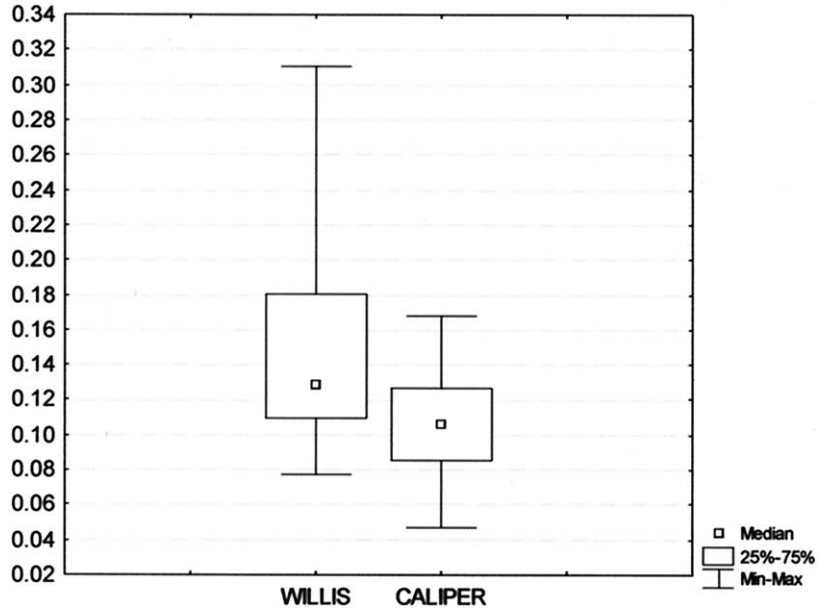

Fig. 6. Box-and-whisker plot for occlusal vertical dimension SDs as in Table I.

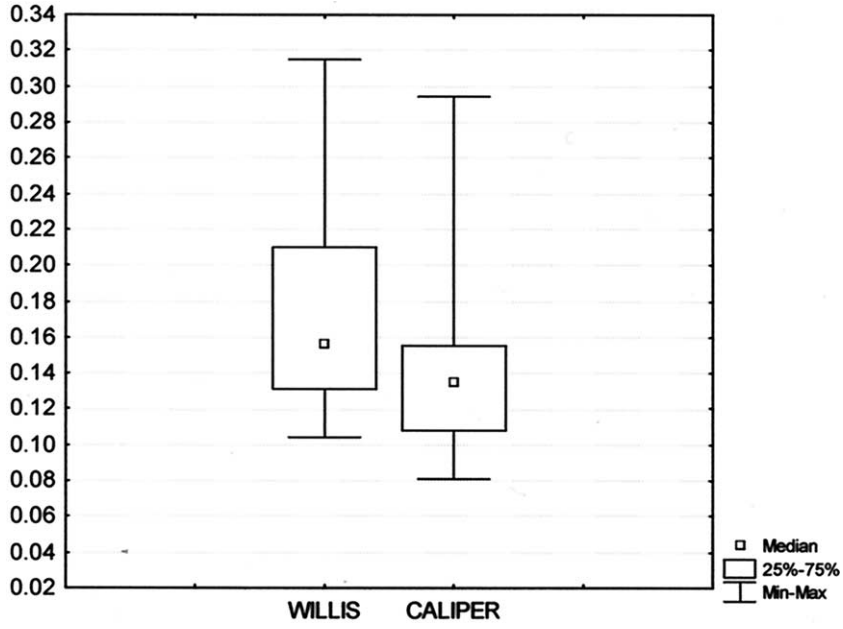

Fig. 7. Box-and-whisker plot for rest vertical dimension SDs as in Table II.

to the caliper method. The 1-sided test yielded a *P*-value of .0366. Repeating this procedure for the OVD data yielded significant differences between the SDs of the 2 methods with the Wilcoxon signed rank, at $P=.00051$. The box-and-whisker plots of the SDs for the 2 groups clearly indicate a significant difference between the 2 methods (Figs. 6 and 7).

The average value of the IOD was 0.152 cm for the Willis gauge method and 0.194 cm for the caliper method (Table III). The average IOD for the Willis gauge method was significantly higher than the control as measured by the experienced clinician for the Willis gauge ($P=.026$) but not for the caliper method ($P=.130$).

Table III. Resultant interocclusal distance values in cm calculated from rest vertical dimension and occlusal vertical dimension averages for Willis and caliper methods.

	Willis (average values)			Caliper (average values)		
	RVD	OVD	IOD	RVD	OVD	IOD
All students (n = 20)	6.206	6.054	0.152	5.814	5.620	0.194
Fourth-year students (n = 10)	6.234	6.098	0.137	5.875	5.628	0.247
Fifth-year students (n = 10)	6.178	6.010	0.168	5.754	5.612	0.142
Control	5.922	5.827	0.095	5.810	5.645	0.165

RVD, rest vertical dimension; *OVD,* occlusal vertical dimension; *IOD,* interocclusal distance.

DISCUSSION

This study was based on the hypothesis that the measurements obtained by the caliper method are more accurate than the Willis gauge method. The result of this study supported the hypothesis at a significance level of 5%. The SDs for the 2 methods were significantly different for OVD measurements. The RVD SDs for the methods were significantly different at less than a 10% significance level. The reason why the SDs differed significantly for OVD and not as much for RVD requires further investigation. Postural changes in the mandible, although kept to a minimum by standardizing the position of the patient, could possibly have influenced the measurements of the RVD in both the Willis and caliper methods. For OVD measurements postural changes do not play a role.

The control IOD was calculated as the difference between the RVD and OVD values obtained with the Willis method made by an experienced clinician. The control IOD was 0.095 cm with the Willis method and 0.165 cm with the caliper method. Table III shows the IOD values for the groups of fifth-year students, fourth-year students, and the control IOD from the experienced clinician. The average of the students with the Willis method was significantly higher than the standard IOD for the Willis method, but not with the caliper method.

The average value of the IOD for the Willis method was 0.1524 cm and for the caliper method 0.1945 cm. The difference between the value of the IOD of both methods was only 0.042 cm. This difference could be considered small and potentially clinically negligible.

No power analysis to determine sample size was done. The SDs illustrated in Figures 6 and 7 are rather large. These factors can be considered study limitations.

In this study, the variation of measurements between 2 extraoral reference points using 2 different techniques was measured. Changes in distances between extraoral reference points do not necessarily reflect a similar change in distance measured between intraoral reference points.

All measurements by a particular student were made during the same visit. Intervisit variation was not measured in this study. The effect of intervisit variations may be a topic for future research.

Both the caliper and the Willis gauge method are convenient and quick. The caliper is less expensive. It is interesting to note that students, without prior experience, mastered the caliper method easily and made more accurate OVD measurements than they did with the more familiar Willis gauge method.

CONCLUSIONS

The caliper method for measuring the OVD was shown to be significantly more accurate than the Willis method when used by predoctoral students. Clinically, however, the differences between the 2 methods may be small.

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