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Closest Speaking Space During the Production of Sibilant Sounds and its Value in Establishing the Vertical Dimension of Occlusion

C.A. BURNETT and T.J. CLIFFORD

Department of Restorative Dentistry, School of Clinical Dentistry, The Queen’s University of Belfast, Grosvenor Road, Belfast BT12 6BP, Northern Ireland, United Kingdom

The purpose of this investigation was to determine whether the production of sibilant sounds involved adopting a jaw position that corresponded to the closest vertical speaking space (CSS), by analysis of the smallest vertical excursion of the mandible during the performance of different phonetic exercises. A further objective was to establish the variability in the CSS produced by individual sibilant phonemes. Thirty young adult subjects had their CSS determined during three separate phonetic tests, using a kinesiograph (Siromagnigraph, Siemens A.G., Bensheim, Germany) and a Bio-Pak (BioResearch Associates Inc., Milwaukee, WI) jaw-tracking software program. The first test was a general phonetic articulation test containing all the sounds of the English language and specifically including all six sibilant word sounds. The second phonetic test contained the six sibilant sounds making up a short sentence. The third test included six single words, each expressing a different sibilant sound. No statistically significant difference among the mean CSS determined in each of the three exercises was demonstrable. A phonetic test containing all sibilant sounds produced a CSS equivalent to that of a test containing all speech sounds. The vertical component of the CSS was also independent of the form or duration of the phonetic tests containing the sibilant word sounds used in this investigation. The CSS determined for 5 of the individual sibilant phonemes in the third exercise differed (p < 0.05) from that calculated for the three complete exercises. It was concluded that voicing sibilant phonemes, or word sounds, does cause the subject to adopt the CSS. When a phonetic test is used in the determination of the vertical dimension of occlusion, one of short duration containing all the sibilant sounds appears to give a reliable guide to the CSS. It was also concluded that subjects varied with respect to which of the group of sibilant sounds produced the CSS, and that a single sibilant word sound does not give a reliable indication of the smallest speaking vertical dimension.


Introduction.

The use of phonetics is one of many techniques available as guides to the vertical dimension of occlusion in dentulous and edentulous patients. The phonetic method, by assessment of mandibular position during production of certain speech sounds, identifies the smallest speaking vertical dimension or closest speaking space (CSS) and was originally suggested by Silverman (1951), who reported that it gave constant and reproducible results. The aim of the CSS method in determining occlusal vertical dimension for edentulous subjects is to provide an interocclusal space of about 2 mm between the incisor teeth during the pronunciation of sibilant word sounds. Special emphasis is placed on the format for the sibilants because they are among the most frequently used in articulate speech. The sibilants are high-frequency sounds produced by a stream of air directed through a minimal incisal separation. They occur in two forms, the “surd” form and the “sonant” form. The surd form is that produced without laryngeal vibration, voicing, or phonation, while the sonant form is the same sound produced with phonation (West et al., 1947). The /s/, /sh/, and /ch/ sounds are the surd forms of the sibilants. When these sounds are made in conjunction with laryngeal vibrations, the respective sonant forms /z/, /zh/, and /j/ are produced. All six sibilants have similar labial and incisal patterns in their formats, the major difference being a function of tongue position and phonation.

Despite a lack of objective measurement to show that sibilant sounds do indeed produce the closest speaking level of the mandible to the maxilla, and that different sibilants produce the same levels, the ‘closest speaking space technique’ (Silverman, 1952) has come to be widely accepted and has often been used in clinical research (Gillings, 1973; Murrell, 1974; Pound, 1977).

Morrison (1959) suggested the use of the words sixty-six and Mississippi and several short poems containing /s/ sounds for determination of an acceptable vertical dimension of occlusion in denture construction. Morrison preferred to use short poems, arguing that as the patient re-reads the passage and becomes familiar with its rhythm, involuntary muscle activity assumes greater influence and produces a more consistent closest speaking level. Mehringer (1963) adjusted occlusal registration rims to provide an incisal separation of 1 to 1.5 mm for sibilants, 2 to 4 mm for the nasal sonants, and 5 to 10 mm for the diphthongs. Pound (1977) proposed the /s/ sound as the critical guide to establishing the vertical dimension of occlusion for edentulous patients.

The purpose of this investigation was to determine whether the CSS occurs during the production of sibilant sounds. This was done by comparison of the smallest vertical components of speech—that is, the smallest vertical excursion of the mandible—produced during the performance of three different phonetic exercises. A further objective was to establish the variability in the CSS during the production of individual sibilant phonemes.

Materials and methods.

Thirty undergraduate dental students in the School of Clinical Dentistry, Queen’s University of Belfast, volun-
tarily took part in the investigation. There were 16 females and 14 males, and their ages ranged from 20 to 23 years. All had intact dentitions, except where extractions for orthodontic realignment had been performed or third molars were missing. No subjects suffered from any speech defect, and none reported any history or symptoms of temporomandibular joint or muscular dysfunction. There was no restriction on participants with respect to skeletal or incisal relationships, and the horizontal and vertical overlaps of the central incisor teeth were measured for each individual.

Mandibular movement was measured by an electromagnetic method of jaw tracking. The recording device used was a kinesiograph (Siernagnostograph, Siemens A.G., Bensheim, Germany), which did not interfere with jaw movement and allowed a measurement of spatial displacements of the mandible to be made. In this technique, mandibular movements are recorded as changes in the magnetic field produced during the movement of a lightweight magnet (3 g) rigidly retained on the lower central incisors by an adhesive. In this investigation, Simplex Rapid (Austenal Dental Products, Harrow, England), an auto-polymerizing acrylic resin, was used as the adhesive. All measurements recorded represented mandibular movement and were movements at the point of attachment of the magnet, in this case the lower central incisors. A headset which carried 8 magnetometers sensed the alterations in the magnetic field and transformed them into electrical potentials which were relayed directly to a computer (Nimbus VX/2, Research Machines Limited, Oxford, England), which utilized a software system (Bio-Pak, BioResearch Associates Inc., Milwaukee, WI) to record and display spatial co-ordinates in three planes, frontal, sagittal, and coronal, so permitting analysis of mandibular movement. This system has been shown (Balkhi and Tallents, 1991) to have linear output for up to about 40 mm of vertical displacement of the magnet when lateral movement is less than 10 mm, and these conditions were fulfilled in this study.

The CSS of each individual was determined during the reading of three exercises. The first phonetic test was as follows:

How are you Tom Dope? and no oranges were growing in Mexico and it is nice to see my grandfather swim about here and George depends on Ruth to bake a big lemon cake and roses are red and violets are blue and three lashings won't hurt poor Dick and Tim show Harry where to wash your clothes tub and Wednesday will be a laugh for all of us and the sixty-five trucks leave the zoo each year and perhaps you need to fire the man in England too and sweet Peggy Nun measured the fur hat and the children weren't catching anything.

This passage, containing 104 words, was specifically designed for use as a general phonetic articulation test and is closely modeled on that suggested by Kestenberg (1983) and formulated by the following criteria:

1. The frequency of occurrence of the various consonant phonemes are approximately the same as their relative frequency in spoken English.
2. All the phonemes which occur in the English language are used.
3. The words are kept as simple as possible and are all very common or easily recognized.
4. The test is brief so that it can be performed quickly (about 45-60 s).
5. A large number of each group of English consonants is included for elimination of random error.
6. Most phonemes are used at the beginning, middle, and end of at least one word.
7. Various blends (or co-articulations) of consonants are included.
8. Each of the sibilant sounds is included.

The second speech exercise contained the six sibilant sounds in the form of a short sentence:

"The fish in the river Yes are if I am any judge the more difficult" said Buzz, "but I remember a day after church when I got their measure."

The third exercise contained six single words, each containing a different sibilant phoneme in the same order as the previous exercise (the sibilant phoneme expressed in each word is set in bold type):

\[
\begin{align*}
\text{FISH} & /\text{sh}/ \\
\text{YES} & /\text{s}/ \\
\text{JUDGE} & /\text{j}/ \\
\text{BUZZ} & /\text{z}/ \\
\text{CHURCH} & /\text{ch}/ \\
\text{MEASURE} & /\text{zh}/
\end{align*}
\]

From this exercise, it was possible to obtain an overall mean value for the CSS as well as individual measure-

![Fig. 1—Incisal overlap in vertical and horizontal planes for the 30 subjects. The large ● denotes coincidence of two subjects’ incisal relationships.](image-url)
The CSS determined for each of the 30 subjects for each of the three exercises are shown in Fig. 2. The CSS determined in the three exercises for each individual was separated by less than 0.5 mm in 22 subjects. In a further four subjects, the range was 0.75 mm, and the remaining four subjects showed a range of 0.9-1.2 mm.

The CSS for the group of 30 subjects for the general phonetic articulation test was $2.0 \pm 1.1$ mm (mean $\pm$ S.D.; range $= 0.1-4.1$ mm). In the single-sentence sibilant phonetic test, CSS was $1.9 \pm 1.1$ mm (range $= 0.2-4.0$ mm), and that of the individual sibilant phonetic test was $2.0 \pm 1.2$ mm (range $= 0.1-3.9$ mm). No statistically significant difference among the mean CSS obtained for the three exercises was demonstrable.

The Table shows the CSS as elicited separately for each of the six sibilants in the third exercise. The individual sibilant CSS were found to be statistically significantly different from the CSS produced in each of the three complete exercises except with the phoneme /j/, which was found to be different from the second exercise only.

**Discussion.**

Several phonetic tests are recommended in prosthodontic texts as guides to the occlusal vertical dimension. These tests are frequently based on the /s/ sound produced in the pronunciation of the words “Mississippi” or “sixty-six”, in repeating the days of the week, or counting from 1 to 10. The aim of these tests is to permit detection of contact between teeth, or occlusal rims, which would indicate an excessive occlusal vertical dimension. The vertical component of the CSS determined for the general phonetic articulation test in this investigation had a mean value of 2.0 mm with a range from 0.1 mm to 4.1 mm. Silverman (1951) described a CSS range of 0-10 mm for 208 patients, and from his results a mean of 2.1 mm can be calculated, although Silverman himself did not derive this value. Benediktsson (1958) documented the /s/ position as having a range from 0 to 14 mm for 246 patients with a mean of 2.6 mm. Gillings (1973) determined the minimum jaw opening for 22 young adults as they counted from 1 to 10 as being 1.1 mm with a range from 0 to 3 mm. George (1983) recorded what he called a “near /s/” position, which equates with the CSS, of 1.8 mm for 31 subjects who had skeletal and occlusal Class I relationships. Howell (1986) published a value of 3.1 mm with a range of 0.0 mm to 8.0

<table>
<thead>
<tr>
<th>TABLE</th>
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<tbody>
<tr>
<td>SUBJECT GROUP MEAN CLOSEST SPEAKING SPACE (mm) FOR THE SIX SIBILANT PHONEMES</td>
</tr>
<tr>
<td>Mean</td>
</tr>
<tr>
<td>Fish /sh/</td>
</tr>
<tr>
<td>Yes /s/</td>
</tr>
<tr>
<td>Judge /j/</td>
</tr>
<tr>
<td>Buzz /z/</td>
</tr>
<tr>
<td>Church /ch/</td>
</tr>
<tr>
<td>Measure /zh/</td>
</tr>
</tbody>
</table>

Results.

The 30 subjects of the investigation showed a wide variation in their horizontal and vertical incisal relationships, as shown in Fig. 1. There was a range of 0 mm to 6 mm in the horizontal plane and from a 5-mm anterior open bite to an 8-mm overlap in the vertical plane.

The dimensions of the speech envelope, described as the mean ($\pm$ S.D.) of mandibular movement in three planes for the entire subject group as produced during the general phonetic articulation test, were: frontal plane, 8.6 $\pm 1.7$ mm (range $= 4.5-11.1$ mm); sagittal plane, 3.7 $\pm 1.3$ mm (range $= 1.8-8.3$ mm); and coronal plane, 2.1 $\pm 1.0$ mm (range $= 0.2-4.4$ mm).
mm for the mean CSS for his group of 95 subjects. The work of Howell (1986) is unique in basing results on a general speech test and as such was not solely reliant on the /s/ sound. The consensus from these studies would appear to support the clinical practice of providing a CSS of about 2 mm in complete denture construction. However, it must be borne in mind that this is an average value, and a range from zero to as high as 10 mm has been reported (Silverman, 1951; Geissler, 1975).

The speech pattern described by the lower incisor teeth for the 30 subjects during the reading of the general phonetic articulation test was remarkably similar to that produced by 95 subjects reading a standard passage of text as a general articulation test, the so-called “Rainbow Passage”, in the work of Howell (1986), the only previous documentation of a general speech envelope.

The values of the mean CSS for 30 subjects recorded in three separate phonetic exercises showed no significant statistical difference. This suggests that the CSS determined from a general phonetic articulation test containing all speech sounds is likely to be the same as that determined from a test containing only the sibilant sounds. It also indicates that the values for CSS determined from a long passage of prose, a short sentence, and individually articulated words each containing the sibilant sounds were uniform. The results imply that sibilant sounds do produce the CSS, although it cannot be inferred that other sounds would not also produce a comparable CSS, since the sibilants were the only word sounds tested on an individual basis.

Although the mean CSS determined for the 30 subjects in the three tests were similar, the CSS produced by a particular sibilant sound varied from individual to individual. This refutes previous suggestions that a single sound, that is, the /s/ sound, can be relied upon for determination of occlusal vertical dimension by the phonetic method. For reliable determination of a particular individual’s CSS, it is necessary to use a phonetic test which covers the range of sibilant sounds. This investigation showed that it was unnecessary to have a subject recite long passages of prose, since a phonetic test consisting of a short sentence or list containing all the sibilant word sounds could be satisfactorily used in determining the vertical dimension of occlusion by the phonetic method.

REFERENCES


