INTRODUCTION
Successful treatment outcome with complete denture is largely dependent on proper tooth selection and arrangement. Factors that may complicate the arrangement of posterior teeth are anatomic configuration of residual ridge, age of the patient, period of edentulism, physiologic and systemic status. In addition, forces from the perioral musculature impose challenges in determining the tooth positions.1 These forces are directed against the denture. They either help in stabilizing it or will dislodge it.

The objectives of any prosthodontic service are to restore the patient to normal function, contour, esthetics, speech and health.2 Various tooth arrangement schemes aim to provide functional stable prosthesis. Dislodging forces, discrepancies in residual ridge, maxillo-mandibular relationships, residual ridge relationships, functional and para-functional mandibular movements, esthetic requirements and preferences of patients are factors governing appropriate tooth arrangements.3

Fish drew the profession's attention to the concept of neutral zone in complete denture construction. 4 He argued that natural teeth occupy a zone of equilibrium. In this zone the outward forces exerted by tongue counterbalance the inward forces of lips and cheeks. Other researchers supported him.5,6 Neutral zone may be defined as the space where during function the forces of the lips and cheeks pressing inwards neutralize the forces of the tongue pressing outwards.7 The neutral zone concept implies acquired muscle control especially by tongue, lips, and cheeks towards denture stability.

Some professionals suggest that long period of edentulism modifies the position of neutral zone.8,9 The duration of edentulism influences residual ridge resorption.10-15 Mean RRR was 2.75 mm in the first 2 years, 1.36 mm/year in the first 5 years and 0.5 mm throughout the 5th year.16 Multiple tooth extraction followed by restoration with removable dentures may result in vertical and horizontal ridge resorption.17 Lammie claimed that the direction of mandibular ridge resorption allows mentalis muscular attachments to fold over the alveolar ridge.18 This results in posterior positioning of neutral zone. Subsequently mandibular anterior teeth may be positioned more lingually. However, Fahmy proposed that Lammie's findings are true for patients, edentulous for less than 2 years.1,18 Neutral zone is labially located by a mean of 2 mm in patients edentulous for more than 2 years.1

This study was done to estimate the amount of shift in position of the neutral zone and the centre of alveolar ridge crest in different edentulous periods.
METHODOLOGY

This observational study was carried out from August 2004 to December 2006 (4 months) at the Lahore Medical and Dental College. Edentulous patients were allocated into two groups of 64 each, by non-probability sampling. Group A had an edentulous period of 6 months to 2 years. Group B had an edentulous period of more than 2 years.

Patients with edentulous period for at least 6 months exhibiting normal range of maximal mouth opening (40-50 mm) and normal temporomandibular joint movements were included. Patients with any intra oral soft tissue or bony pathology and reduced intermaxillary space were excluded from the study.

Impression compound was used to record the mandibular neutral zone for each patient during function. Individual standardized casts were made form mandibular base plates. Casts were made parallel to the horizontal by means of a base former. Bucco-lingual widths of mandibular occlusal rim and crest of mandibular ridge on cast were measured by a Vernier calliper with graduations up to 0.05 mm. Widths of the composition rims were recorded by the Vernier calliper at 3 mm cervical from the occlusal level. Residual ridge crest was equally scrapped off to allow proper seating of denture base on the cast.

0.4 mm and 0.8 mm stainless steel wires were glued onto the centres of ridge crests and occlusal rims respectively (Figures 2 and 3). Standardized occlusal radiographs at 52 KV, 20 mA and 4-4 ms were used to analyze the non-articulated casts with denture bases and neutral zone rims (Figure 4). Distance of the radiographic film from the beam source was kept constant at 100 cms. A stainless steel ball of 6.25 mm diameter was attached on occlusal rims to standardize the magnification of images (Figure 3). Following formula was applied to evaluate the image magnification.19

\[
\frac{d \text{ (source to object distance)} \times I \text{ (image length)}}{D \text{ (source to film distance)}}
\]

The thickness of the cast was modified for every case to adjust to a total (height of occlusal rim and the thickness of the casts) of 48 mm; D (source to film distance) was 1000 mm; d (source to object distance) was 1000-48 = 952 mm; I (image length) was image of steel ball on radiograph = 6.45 mm. Magnification of the stainless steel ball was calculated as 952 x 6.45/1000. Actual image length was taken as 6.14 mm. Difference between actual and magnified image was taken as 6.45-6.14 = 0.31 mm. Percentage of magnification was taken as 0.31/6.14 x 100 i.e. 5.04%.

The inter-wire distances were measured on occlusal radiographs at midline, right and left premolar and molar regions. Each film was placed on illuminator and the images of the 2 wires in bucco-lingual direction were studied. Zero score was assigned when the two wires coincided. Buccal and labial locations of thicker wires (neutral zone) were assigned a positive value. Lingual locations of neutral zone with respect to ridge crest were assigned a negative value. Measurements were made with a Vernier calliper.

To eliminate magnification error 5.04% of each reading was calculated. It was subtracted from the radiographic reading. The resultant figure was considered as the actual reading.

The data was entered into SPSS program version 10.0 and analyzed accordingly. Numerical variables like age, edentulous period, buccolingual widths of occlusal rim and ridge crest and radiographic distance between centres of neutral zone and ridge crest were analyzed by calculating mean and standard deviation; t-test was applied to compare the positions of neutral zone and alveolar ridge between groups A and B. Probability p-value of ≤ 0.05 was considered significant.

RESULTS

A total of 128 edentulous patients were selected according to the specified criteria. Mean length of edentulous period was 1.1 years for group A and 4.3 years for group B. To minimize the disparity of length of edentulous periods between the two groups A and B, this confounding variable was controlled.

Out of the total 128 patients, 69 were previously wearing dentures. Mean widths of alveolar ridge in group A was...
Relationship of neutral zone and alveolar ridge with edentulous period

Table I: Bucco-lingual widths of crests of residual ridge and mandibular occlusal rim.

<table>
<thead>
<tr>
<th>Groups</th>
<th>Bucco-lingual width of alveolar ridge 3 mm</th>
<th>Bucco-lingual width of mandibular occlusal rims</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Right retromolar</td>
<td>Left retromolar</td>
</tr>
<tr>
<td>A</td>
<td>Mean ± S.D</td>
<td>Mean ± S.D</td>
</tr>
<tr>
<td>Mean ± S.D</td>
<td>5.85 ±1.03</td>
<td>5.83 ±0.98</td>
</tr>
<tr>
<td>B</td>
<td>Mean ± S.D</td>
<td>Mean ± S.D</td>
</tr>
<tr>
<td>Mean ± S.D</td>
<td>5.53 ±1.22</td>
<td>5.65 ±1.42</td>
</tr>
</tbody>
</table>

A Edentulous period of 6 months to 2 years; B Edentulous period of more than 2 years.

Table II: Comparison of the distance between centres of neutral zone and alveolar ridge crest (group A and B).

<table>
<thead>
<tr>
<th>Area</th>
<th>Group</th>
<th>N</th>
<th>Mean ± SD</th>
<th>T</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right molar</td>
<td>A</td>
<td>64</td>
<td>0.414 ±1.1</td>
<td>6.61</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Right premolar</td>
<td>B</td>
<td>64</td>
<td>-1.187 ±1.5</td>
<td>6.75</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Anterior midline</td>
<td>A</td>
<td>64</td>
<td>0.604 ±0.7</td>
<td>4.67</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Left molar</td>
<td>B</td>
<td>64</td>
<td>-0.366 ±1.4</td>
<td>7.94</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Left premolar</td>
<td>A</td>
<td>64</td>
<td>0.538 ±1.1</td>
<td>5.75</td>
<td>&lt; 0.01</td>
</tr>
<tr>
<td>Left molar</td>
<td>B</td>
<td>64</td>
<td>-1.171 ±1.3</td>
<td>5.75</td>
<td>&lt; 0.01</td>
</tr>
</tbody>
</table>

5.85 mm, 5.83 mm and 5.66 mm at right, left retromolar papillae and midline respectively. Mean widths of mandibular occlusal rim in group A was 16.06 mm, 16.07 mm and 15.81 mm at right, left retromolar papillae and midline respectively.

Mean alveolar ridge width of group B was 5.53 mm at right retromolar papilla, 5.65 mm at left retromolar papilla and 5.35 mm at midline. Mean width of occlusal rim of group B was 15.63 mm, 15.70 mm and 15.65 mm at right, left retromolar papillae and midline respectively (Table I).

Comparison of the distance between centres of neutral zone and alveolar ridge crest (groups A and B) (Table II).

At midline, the mean distance was +0.60 for group A and -0.36 for group B. (p < 0.01). On an average, in longer edentulous period (> 2 years), neutral zone is lingually shifted by 1.06 mm in anterior, premolar and molar areas.

DISCUSSION

The objectives of the study were to estimate the amount of shift in position of the neutral zone and the centre of alveolar ridge crest in different edentulous periods. This was achieved by measuring the distance between the centres of neutral zone and crests of alveolar ridges.

The location of neutral zone in relation to centre of alveolar ridge crest showed few deviations that may help in correct tooth positioning. In the mandibular right and left premolar regions and molar region, neutral zone was buccally located in group A. In group B, neutral zone was lingually shifted in these areas which statistically significant. This result is in accordance to a study by Damriel who suggested lingual placement of mandibular premolars and molars. Lingual positioning of neutral zone may result because of aging facial changes. Prolonged periods of edentulism may result in sagging of the facial musculature. In mandibular molar area, adjacent buccinator fibres run horizontally downwards and forwards. Edentulism eliminates the tooth and alveolar bone support of the buccinator fibres. McGregor suggested shortening of buccinators fibres in absence of dental bulge. This may result in distortion of facial curtain. On contraction buccinators direct the forces further lingually. Consequently neutral zone may be placed more lingually in posterior segment.

At mandibular premolar regions, neutral zone was buccally located in patients edentulous for less than 2 years. Edentulous period for more than 2 years had lingually shifted neutral zone at premolar region. In normal dentitions, premolars are present slightly buccal to the centre of alveolar ridge. The buccal surface of the bicuspids forms a point of fixation for the medial roll of buccinator and other muscles of the modiolus to keep the saliva and food inside the mouth during chewing and swallowing. It provides the buccinator with sufficient leverage with the help of tongue to create a peristaltic movement necessary for mastication. In group A, reduced bone resorption due to the short period of edentulism might be responsible for buccal location of neutral zone. With longer edentulous periods the loss occurs equally on both buccal and lingual sides of the ridge in mandibular premolar region. Teeth may be placed on the ridge or slightly lingual to the ridge in this area. Denture may be narrowed in width in mandibular premolar region to prevent denture dislodgement against the modiolus muscular knot.

In group B, neutral zone was lingually located in right and left molar region. On comparison of groups A and B, p-value was less than 0.01 in mandibular molar area.
The p-value is statistically significant. Heartwell suggested that continuous bone resorption leads to narrower maxillary arch and broader mandibular arch. In prolonged period of edentulism, bone loss is from lingual side in mandibular molar region. This may lead to buccal positioning of molar residual ridge. Demirel focuses on lingual placement of mandibular molars. He explains that when the occlusal contact occurs in working side, the occlusal force approaches to fulcrum. This happens when the mandibular buccal cusps are placed directly over the crest of the residual ridge. Occlusal forces will be vertically centred over the mandibular buccal cusps, intercusping with central fossae of maxillary teeth. Consequently torque is reduced. Fahmy also concluded that neutral zone might be buccally located in mandibular molar area, in patients with prolonged period of edentulism.1

Fahmy concluded that posteriorly in mandible, neutral zone was located more buccally by 1.05 mm to 2.388 mm in prolonged edentulous periods.1 Cramped tongue can act as a dislodging force affecting the stability of a mandibular denture. Fahmy's study found different results from this study.1 This may be due to the differences in methods. Sample size for longer edentulous periods was relatively small (n=9) in Fahmy's study.1 Present study had the larger sample size (n=64) for group B. Fahmy had not measured the buccolingual widths of occlusal rims and the crest of ridge to mark the centres.1 So centres were marked arbitrarily in Fahmy's study.1 In the present study, buccolingual widths of occlusal rims and ridge crests were measured with a vernier calliper to an accuracy of 0.05 mm. Fahmy did not reduce the crest of the ridges on casts for proper seating of the denture bases.1 In the present study, crest of ridges were reduced on the models to create space for the wire. This assured proper seating of the denture bases on the model. Fahmy did not use any formula to eliminate the error of magnification of images on radiographic films.1 A specific formula was utilized in the present study to eliminate any error of magnification of images on radiographic films.19 Fahmy recorded the final measurements with a millimetre scale to an accuracy of 0.5 mm.1 In the present study final measurements on the radiographic films were done with a vernier calliper to an accuracy of 0.05 mm.

In this study, group A had labially located neutral zone at midline. In group B, centre of the neutral zone was located lingually than the centre of alveolar ridge crest by a mean of 0.36 mm. On comparison of groups A and B, the p-value was statistically significant. In natural dentition, mandibular incisors have labial angulations. Consequently, the alveolar bone will be located labially. In group A, the period of edentulism was comparatively short. Due to reduced bone resorption in this period neutral zone was located in a labial location by a mean of 0.60 mm.

Group B had a longer period of edentulism. Bone resorption accentuated with prolonged period of edentulism. Bone loss occurs on labial aspect of anterior mandibular residual ridge.25 Results of the present study are in accordance with Lammie’s study.18 Demiral advocates that lower anterior teeth may be arranged in a way that their labial surfaces may not exceed the midline of the labial vestibule. If phonetics and esthetics are taken into consideration, then mandibular anterior teeth may slightly overlap the ridge in patients with longer period of edentulism.

However, Fahmy supported Lammie’s theory in patients who were edentulous for a period less than 2 years.1,18 In Fahmy’s study neutral zone was labially located by a mean of 2 mm in patients with edentulous period longer than 2 years.1 Results of the present study reveal that lower anterior teeth may not be placed excessively lingually. Labial extent of position of lower anterior teeth may be affected by period of edentulism and extent of bone resorption.

For future research, comparison of neutral zone record made by different materials (silicone, tissue conditioner, denture lining materials, soft wax, and polymer of dimethyl siloxane with calcium silicate) may also help in correct judgement of the potential denture space. This can eliminate the effect of properties of one specific material on neutral zone record.

CONCLUSION

With longer period of edentulism, centre of neutral zone may be lingually shifted as compared to the centre of alveolar ridge crest at midline, premolar and molar areas. With shorter edentulous periods, teeth may be placed over the ridge or within neutral zone. The tone and contour of the surrounding musculature may be considered in tooth arrangement. The well-formed residual ridge may adequately support and retain the dentures. Multi-factorial residual ridge resorption may alter the relation of teeth to alveolar ridge. However, the neutral zone record may aid in determining the correct tooth position.

REFERENCES


