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3 **Relationship of natural occlusal plane with different anatomical**
4 **landmarks**

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14
15 **Abstract**

16 **Objectives:** To evaluate the parallelism of natural maxillary occlusal plane with
17 inter-pupillary line and ala-tragus line, and to evaluate the anatomic relationship
18 of natural mandibular occlusal plane with retromolar pad among dentate subjects.

19 **Method:** The cross-sectional study was conducted from September 2017 to
20 February 2018 at Fatima Jinnah Dental College, Karachi, and comprised front
21 and profile photographs of subjects aged 20-28 years while holding the camper's
22 plane against the maxillary occlusal plane. The photographs were imported in a
23 software and an interpupillary line was drawn and the angle with Camper's plane
24 was measured. On both profile pictures, lines were drawn from base of the ala to
25 the superior, middle and inferior points on the tragus. The angle between ala-
26 tragus line and Camper's plane were measured. Intra-orally, height of the
27 mandibular occlusal plane in relation to the retromolar pad was evaluated using
28 a stainless steel scale. Data was analysed using SPSS 23.

29 **Results:** Of the 109 subjects with a mean age of 23.03 ± 1.36 years, 76(69.72%)
30 were females. Horizontal parallelism of occlusal plane with inter-pupillary line
31 was observed with a mean angle of 1.17 ± 1.27 degrees. The angle between the
32 occlusal plane and the inferior ala-tragus line was 4.25 degrees on the right side,
33 and 4.50 degrees on the left. Intraorally, mandibular occlusal plane coincided
34 with the inferior 48(44%) and the middle third 48(44%) of the retromolar pad.

35 **Conclusions:** Inter-pupillary line and retromolar pad area should be used as a
36 guide in the determination of plane of occlusion. The ala-tragus line was not
37 found to be a reliable guide.

38 **Key Words:** Occlusal plane, Anatomy, Dental occlusion.

39

40 **Introduction**

41 The current Glossary of Prosthodontic Terms (GPT) has defined occlusal plane
42 as “the average plane established by the incisal and occlusal surfaces of teeth;
43 generally it is not a plane but represents the planar mean of the curvature of these
44 surfaces.” In full-mouth rehabilitation, determination of occlusal plane is
45 considered an essential clinical procedure.(1) The occlusal plane (OP) in
46 edentulous patients must be oriented as close as possible to the one which existed
47 prior to teeth extraction.(2) In literature, numerous techniques and biometric
48 guidelines have been proposed for correctly locating the OP, which can broadly
49 be divided into intraoral and extraoral approaches. Intraoral landmarks include
50 upper lip,(3) commissure of the mouth,(4,5) height of the retromolar pad
51 (RMP),(3-6) hamular notch-incisive papilla plane,(7) and buccinator groove.(4)
52 Commonly described extraoral landmarks include inter-pupillary line (IPL)(3)
53 and Camper’s plane or the ala-tragus line (ATL).(8)

54 Conventionally, OP is made parallel anteriorly (horizontally) with the IPL and
55 posteriorly (sagittally) with ATL.(9) IPL is an imaginary horizontal line joining
56 the centre of pupils of both eyes. OP is recommended to be kept parallel with the
57 IPL when viewed from the front.

58 The OP analyser, commonly known as the Camper's plane, has been used for the
59 orientation of OP since 1924.(10) It was suggested that when maxillary occlusal
60 plane was kept parallel to ATL, the biting force was found to be the greatest
61 during clenching with the least muscle activity.(11)

62 In the earlier editions of GPT (5th-8th), the specific part of ATL was not
63 defined.(1) It was identified by a number of studies exploring the most
64 appropriate point of tragus to be used for ATL.(8,12-16) However, the present
65 edition of GPT has categorically defined ATL as "a line running from the inferior
66 border of the ala of the nose to the superior border on the tragus of the ear".(1)

67 Intraorally, the OP is commonly kept at the two-third height of RMP area.(3) The
68 RMP is a triangular soft tissue pad at the distal end of the residual alveolar ridge.
69 The anterior aspect of the triangle is keratinised, called pear-shaped pad, while
70 the posterior part is composed of non-keratinised epithelium, loose connective
71 tissue, glandular tissue, fibres of the buccinator and superior constrictor muscles,
72 temporalis tendon and the pterygomandibular raphe. RMP is resistant to
73 resorption because of underlying dense cortical bone and muscle attachments.
74 This makes this area a stable posterior landmark even in patients with excessive
75 alveolar ridge resorption.

76 In prosthodontics, the question whether the natural maxillary OP is parallel with
77 the ATL and IPL has fundamental importance, as this paradigm eventually
78 determines the position of the prosthetic teeth on the complete dentures. Till date,
79 to the best of our knowledge, there is no study available on the topic in Pakistani
80 population. The current study was planned to evaluate the parallelism of natural
81 maxillary OP with IPL and ATL, and to determine the anatomic relationship of
82 the natural mandibular OP coinciding with RMP in dentate subjects.

83

84 **Subjects and Methods**

85 The cross-sectional study was conducted from September 2017 to February 2018
86 at the Fatima Jinnah Dental College and Hospital, Karachi. After approval from

87 the institutional ethics review board, the sample size was calculated using World
88 Health Organisation (WHO) calculator(17) in the light of literature(5) with OP
89 coinciding with middle-third of RMP among 43.3% subjects. Using the
90 anticipated population proportion with 10% absolute precision at 95% confidence
91 level, the sample size was calculated, and inflated by 15%.

92 The sample was gathered using non-probability purposive sampling from among
93 healthy dental students on the campus aged 20-28 years, having intact secondary
94 dentition till second molar with normal occlusion, no previous orthodontic or
95 prosthetic treatment, and with no periodontal disease. Those with history of
96 maxillofacial trauma, surgery, missing or crowded teeth, or presence of crown
97 and bridge work or retained deciduous teeth, were excluded.

98 After taking informed consent, all the selected participants were photographed
99 using a Nikon D5300 camera with 105mm lens (ISO 500, f 1/5.6, exposure time
100 1/200), placed on an adjustable tripod stand. Photographs were taken in natural
101 head position with the subject's head unsupported while holding the Camper's
102 plane in contact with the natural maxillary OP. The camera was placed at the
103 height same as that of participant's head. One front and two profile (right and left)
104 photographs were taken. AutoCAD software 2017 was used to measure the angles
105 formed between OP, represented by Camper's plane, and IPL in horizontal
106 dimension and OP with ATL in sagittal dimension. A non-parallel relationship
107 was considered for the angle difference >2 degrees (Figure 1A).

108 In each of the lateral profile photograph, superior, middle and inferior points were
109 marked on the tragus of the ear. Three imaginary lines were drawn in AutoCAD
110 starting anteriorly from the base of the ala of nose and extending posteriorly
111 towards the tragus of the ear (Figure 1B). The OP angle with ATL passing from
112 ala of nose to the superior border of the tragus of the ear was labelled as the ATLs
113 angle. The OP angle with ATL taken from the middle point of the tragus of the
114 ear labelled as the ATLm angle. And the angle formed with ATL taken from the
115 lower border of the tragus of the ear was labelled as the ATLi angle.

116 The correlation of OP with RMP was evaluated with the help of a thin 6-inch
117 rigid stainless steel scale (Figure 1C). RMP was divided into three equal zones,
118 namely superior, middle and inferior with two imaginary lines. The
119 aforementioned scale was placed on the cusp tip of the mandibular canine passing
120 posteriorly to the disto-lingual cusp of the last molar tooth. The relationship of
121 mandibular OP with respect to the vertical height of RMP was recorded. The
122 measurements were recorded for both right and left sides.

123 Data was analysed using SPSS 23. Means and standard deviation (SD) of
124 continuous variables were computed. Shapiro-Wilco test was applied to check
125 data normality. The data of maxillary OP was normally distributed, while
126 mandibular data was non-normal. Thus, the choice of statistical test was made
127 accordingly. Paired sample T-test was applied to compare the two sides of the
128 face for each OP and ATL. Pearson's correlation test was employed to determine
129 correlation of the right and left pairs of the three ATLs. Wilcoxon's sign rank test
130 was applied to compare the two sides of the arch for the relationship of OP and
131 RMP. $P < 0.05$ was set as the level of significance.

132

133 **Results**

134 Of the 109 subjects with a mean age of 23.03 ± 1.36 years, 76(69.72%) were
135 females. Molar classification was Class I in 85(77.98%), Class II in 21(19.27%)
136 and Class III in 3(2.75%) subjects. Overall, 63(57.79%) subjects exhibited
137 acceptable parallelism of the maxillary OP with IPL. The OP-IPL angle did not
138 exceed 5 degrees with the mean angle being 1.17 ± 1.27 degrees.

139 Only inferior ATL was relatively parallel to the maxillary OP with a mean OP-
140 ATL_i angle of 4.25 ± 2.92 degrees on the right side. The superior ATL was the
141 least parallel with OP and the mean angle was 8.28 ± 4.63 degrees on the left side.
142 All readings on the left side were slightly greater than the right side, indicating
143 subjectivity in the recording of such facial landmarks (Table 1).

144 There were statistically significant differences in two sides of the face for superior
145 and middle ATL ($p < 0.05$), but inferior ATL was bilaterally comparable. (Table
146 2).

147 The mandibular OP was mostly coincident with both the inferior and middle-third
148 of RMP 48(44% in each zone). The difference in the two sides for mandibular
149 OP-RMP was not significant ($p = 0.52$) (Table 3).

150

151 **Discussion**

152 The correct orientation of OP is a complex but important clinical step in the
153 fabrication of complete dentures or full-mouth rehabilitation. Correct OP
154 contributes not only to desirable aesthetics but also to the comfort and stability of
155 the final prosthesis.(6) Different anatomical landmarks have been described for
156 the determination of the natural OP, (pre-extraction plane of occlusion) for the
157 edentulous patients needing complete dentures.(3-8) The present study
158 determined the parallelism of natural maxillary OP with ATL and IPL. Moreover,
159 the anatomic relationship of mandibular OP with RMP was also explored.

160 Various investigators have made recommendations regarding orientation of OP
161 with respect to related anatomical landmarks. Zarb et al.(3) recommended that
162 OP should be kept parallel to IPL. On the other hand, Zheng et al.(18) suggested
163 the use of orthodontics to achieve parallelism between OP and IPL, believing that
164 it will result in a symmetrical smile and superior aesthetics. Olivares et al.(19)
165 conducted a study on clinical pictures edited with 0, 2 and 4 degree angles
166 between OP and IPL. The participants included were orthodontists, general
167 dentists and lay people. The highest acceptance was for pictures exhibiting
168 parallelism in OP and IPL, but a difference of 2 degrees was within an acceptable
169 aesthetic range. In the present study, over 50% participants had OP parallel with
170 IPL. This is contrary to findings of Gupta et al. who observed such parallelism in
171 only 13% subjects.(12) Jain et al. found only 20% parallelism between OP and

172 IPL.(20) These differences are probably due to different methodology adopted by
173 the studies.

174 For the determination of natural OP in the sagittal dimension, various studies (8,
175 12-16) have recommended tragus of ear as the suitable anatomic landmark.
176 However, there was no clarity until the publication of the 9th edition of the GPT
177 (1), as to which part of the tragus is used for that. Now, it is certain that the
178 superior part of the tragus serves as the posterior determinant of the OP in the
179 sagittal dimension. Winkler (21), Al Quran et al.(8), and Gupta et al.(12) also
180 favoured using the superior border of the tragus as the reference point for OP.
181 The present study, in contrast, observed that inferior ATL, derived from using
182 inferior border of the tragus, served as the closest to the natural OP.

183 Subhas et al.(22) studied the relationship of OP with three different ATLs in 75
184 subjects with different head forms. They used lateral cephalometric radiographs
185 of dentate subjects aged 18-25 years, and stated that middle ATL was a reliable
186 landmark for individuals having mesiocephalic head form, and for those with
187 dolichocephalic and brachycephalic head forms, superior ATL could be used as
188 a reliable reference point in determining OP.

189 Abrahams et al.(23), Karkazis et al.(6) and Priest et al.(24) suggested that ATL is
190 not parallel to OP. One of the studies(23) found a 9.66° angle between natural OP
191 and ATLs, while another (6) observed a 2.88° angle between natural OP and
192 ATLM, and one study(24) found mean angle of 3.03 ± 4.49 between OP and ATLs,
193 and -4.09 ± 4.39 with ATLi. They didn't measure the angle with the mid-point of
194 the tragus. The current study found minimum angles for OP-ATLs and OP-ATLM
195 to be 7.61° and 5.72° , respectively.

196 Studies(13, 16, 25) have recommended the lower part of the tragus as the
197 reference point for the ATL for determining OP. It has also been suggested that
198 the position of OP be kept at right angle to the direction of occlusal forces to get
199 maximum occlusal stability.(15) It has been suggested that OP should be kept
200 parallel and closer to the mandibular ridge in patients with extreme resorption.

201 This reduces the potential leverage in the complete denture. Additionally, when
202 OP is established parallel to ATL at the inferior border of tragus, it is more
203 perpendicular to the occlusal forces and, thus, gets closer to the mandibular
204 ridge.(13) The present study proposes that the lower border of the tragus should
205 be used for locating OP in complete denture prosthetics. On the other hand, Jain
206 et al. found that OP was mostly parallel with the middle of the tragus of the
207 ear.(20)

208 There is a wide variability among studies for choosing and employing landmarks
209 for natural OP determination. Moreover, differences are there in sample size,
210 points of measurement and in methodology employed in these studies. Some have
211 used cephalometry,(6, 8, 23, 26) others have employed OP analyser,(5, 9, 12, 16)
212 while some have used photographs(13-15) as was the case in the present study.

213 The distal extension of mandibular complete denture rests over RMP.
214 Traditionally, the mandibular OP should coincide with RMP, but the specific part
215 of RMP was not clear. In the present study, almost half of the subjects had their
216 mandibular OP coinciding with the inferior third of RMP. This finding is in
217 agreement with Shigli et al.(5) They divided the RMP into three zones and found
218 that 56.7% participants had their mandibular OP coinciding with lower one-third
219 of the RMP, and 43.3% at the middle-third. More interestingly, there was not
220 even a single subject in which OP coincided with the superior RMP. Lundquist
221 et al.(4) divided RMP into two halves, and observed that in 75% individuals, the
222 OP was found at the lower half of RMP. Jain et al. discovered approximately half
223 of the time the OP was parallel with middle-third of RMP.(20)

224 One of the limitations of the current study is that it did not consider the changes
225 occurring in position of tragus and ala of nose with increasing age as the study
226 was carried out among young individuals. Moreover, cephalometric variables,
227 such as skeletal profile, jaw prognathism, skeletal malocclusion, posterior facial
228 height and curve of Spee, were not taken into account. These anthropometric
229 measurements could have affected the determination of the natural OP.

230 It is recommended that dentists should re-establish the OP in edentulous patients
231 by using IPL and inferior ATL for maxillary arch and middle and inferior-third
232 junction of RMP for mandibular arch.

233

234 **Conclusions**

235 Maxillary OP was found parallel to the inferior ATL sagittally and IPL was found
236 anteriorly. Mandibular OP coincided at the junction of inferior and middle-third
237 of RMP.

238

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240 **Conflict of Interest:** None.

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242

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314 **Table 1: Descriptive statistics of angles formed between occlusal plane and**
 315 **facial landmarks (n=109)**

Angle formed with occlusal plane	Minimum	Maximum	Mean	SD
Inter-pupillary line	0	5	1.17	1.27
Superior ala-tragus line right	0	17	7.61	4.43
Superior ala-tragus line left	0	23	8.28	4.63
Middle ala-tragus line right	0	15	5.42	3.78
Middle ala-tragus line left	0	19	6.03	4.17
Inferior ala-tragus line right	0	13	4.25	2.92
Inferior ala-tragus line left	0	16	4.50	3.30

316 SD: Standard deviation.

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320 **Table 2: Bilateral symmetry for angles formed between occlusal plane and**
 321 **ala-tragus line on both sides of the face (n=109)**

Right to left comparisons and correlations		Mean difference	SE	<i>p</i> -value*	Correlation	<i>p</i> -value**
Pair 1	superior ala-tragus line right	-0.67	0.28	0.019	0.79	<0.001
	superior ala-tragus line left					
Pair 2	middle ala-tragus line right	-0.60	0.27	0.027	0.75	<0.001
	middle ala-tragus line left					
Pair 3	inferior ala-tragus line right	-0.25	0.24	0.305	0.66	<0.001
	inferior ala-tragus line left					

322 SE: Standard error

323 *p*-value* is derived from Paired T-test

324 *p*-value ** is based on Pearson's correlation test

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330 **Table 3: Relationship of mandibular occlusal plane with retromolar pad**
 331 **position on both sides (n=109)**

Mandibular Occlusal plane-retromolar pad	Right side		Left side		test statistics *	p-value
	n	%	n	%		
Superior Third	13	11.9	18	16.5	-0.64	0.52
Middle Third	48	44.0	43	39.4		
Inferior Third	48	44.0	48	44.0		

332 *Wilcoxon's sign rank test was applied

333 ** Out of 109 pairs, there were 63 ties where left side RMP= right side RMP

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336



337 **Figure 1A: Frontal photograph: a=Inter-pupillary line and b = maxillary occlusal plane;**
 338 **1B: Profile photograph: blue= Superior ala-tragus line, yellow= Middle ala-tragus line,**
 339 **green= Inferior ala-tragus line and red =Maxillary occlusal plane; 1C: Intra-oral**
 340 **photograph; of relationship of mandibular occlusal plane with retromolar pad area; a=**
 341 **superior third, b= middle third, c= inferior third.**

343