The Research on Articulation Places of Mandarin Chinese Consonants from Perspective of EPG

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***Abstract*—This paper aims at drawing and analyzing the Articulation Places during production of Mandarin Chinese consonants by means of Electropalatography (EPG). Their tongue characteristics of onset are obtained: the articulation places of plosives are latter than the same manner of place of affricates, and the concentration degree of tongue-palate contact from both sides to the middle concentration degree is slightly higher; the tongue and hard palate contact of affricates is bigger than fricatives', tongue position is also slightly higher than fricatives'; aspiration will have an influence on target palate position, aspiration consonants' TC、AC is smaller than unaspiration's generally, tongue position of unaspiration is slightly higher than aspiration's.**

Keywords- Electropalatography; Mandarin Chinese; Articulation Places

I. INTRODUCTION

The development of technology and the improvement of physiological instrument brings the transition of linguistic research from the acoustics and physiology to biological mechanism in speech production. Artificial plate is a kind of device in EPG (Electropalatography), which is a kind of technique to access the contact between tongue and hard palate during production [1]. The research of EPG makes up for the shortage of the static research of consonants from traditional linguistics perspective, so according to the research of EPG we can check and make up for the research results of consonants. In process of pronunciation, velar needs raise your tongue and drop your soft palate, in order not to effect the person's pronunciation, electronic false palatine doesn't cover the soft palate area. [3]So, EPG can't collect velar completely.

II. PALATINE SIGNAL PROCESSING

A Palatine signal acquisition

This article uses 62 electrodes EPG which is designed by Articulate Instruments company in England. Collection and use of hardware mainly include electronic artificial palate, with chrome plated handle multiplexer(used to eliminate electrostatic of record person, in order to avoid the interruption of electrostatic)、EPG scanner、 Serial Port Code Converters 、adapter and so on.

B Parameters settings

If we want to design parameters for electronic false palatine, we must classify function of false palatine. The following draw is the functional partition of false palatine, the left divides electronic false palatine into three partitions: gum, soft and hard palate, the right divides into two partitions: anterior palate and post-palatal.

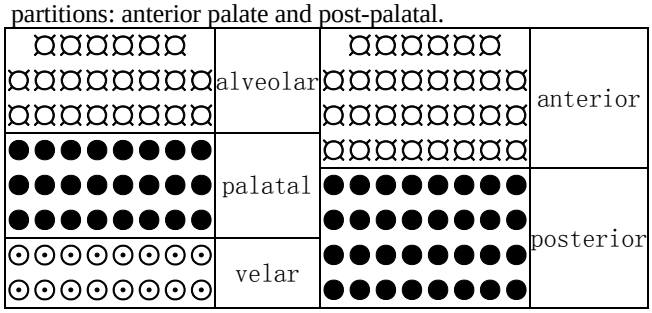

Figure 1. THE FUNCTIONAL PARTITION OF FALSE PALATINE

A） Contact proportion in function area of artificial plate

TC（Total Contact）= contact electrodes(n)/ the total number of electrodes；

AC （ Alveolar Contact ） = contact electrodes of alveolar(n)/ the total number of electrodes；

PC（Palatal Contact）= contact electrodes of palatal(n)/ the total number of electrodes；

VC（Velar Contact）= contact electrodes of velar(n)/ the total number of electrodes；

Contact electrode distribution index

There are three contact electrode distribution indexes: Contact Anteriority() （ CA ） 、 Contact Posteriority （CP）、Contact Centrality（CC）.

$$CA=(\log(1*(R(8)/8)+9*(R(7)/8)+81*(R(6)/8)+729*(R(5)/8)+6567*(R(4)/8)+59049*(R(3)/8)+531441*(R(2)/8)+3587227*(R(1)/6)+1))/(\log(4185105)).[4]. \quad (1)$$

$$CP=(\log(1*(R(1)/6)+1)+9*(R(2)/8)+81*(R(3)/8)+729*(R(4)/8)+6567*(R(5)/8)+59049*(R(6)/8)+531441*(R(7)/8)+3587227*(R(8)/8))/(\log(4185105)).[5] . \quad (2)$$

$$CC=(\log(1*((C(1)+C(8))/14)+17*((C(2)+C(7))/16)+289*((C(3)+C(6))/16)+4913*((C(4)+C(5))/16)+1))/(\log(5220+1)).[6]. \quad (3)$$

There are only thirteen signal consonants spell with vowel /a/, but /k/、/kh/、/h/ have latter place of articulation are beyond the scope of EPG collection, and doesn't in research. The rest ten consonants form blockage or obstruction by tongue-palate, so this article researches the rest.

III. PALATINE SIGNAL ANALYZING

A plosive and fricatives

There are only one group of the same manner of plosives and fricatives in labiodental、supradental、blade-alveolar、blade-palatal、velar and dorso-velar of Mandarin Chinese, if we research plosives and fricatives , just need research this group. There is exist one phenomenon that fricatives are a litter latter than the same manner plosives in Mandarin Chinese. The following figure is the parameters CC、CP of /k、kh/、/x/.

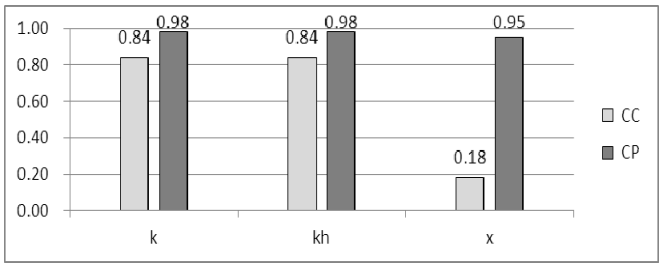

Figure 2. THE PARAMETERS CC、CP OF /K、KH/、/X/

From this picture we can know,the CC of /k、kh/ above 0.8 is higher than /x/which is 0.18, the concentration degree of tongue-palate contact from both sides to the middle concentration degree of /k、kh/ is slightly higher, but /x/ is lower. /k、kh/is plosive ,tongue-palate is completely block during pronunciation, but is not completely block. The CP of /k、kh/ is 0.98, it is slightly smaller than /x/ which is 0.95, plosives is slightly latter than the same manner fricatives.

B affricatives and fricatives

There are three groups the same groups of affricatives and fricatives in Mandarin Chinese, they are: supradental /ʦ、ʦh、s/、blade-palatal /tʂ、tʂh、ʂ、ʐ/ and velar /tɕ、tɕh、ɕ/, the velar don't spell with vowel/a/, so we research supradental and blade-palatal.

TABLE I. THE AFFRICATIVES AND FRICATIVES OF MANDARIN CHINESE

Articulation manner \ Articulation Places			supradental	Blade-palatal	velar
affricatives	unvoiced	Unaspiration	TS	Tʂ	tɕ
		Aspiration	TSH	TʂH	tɕH
fricatives	unvoiced		S	ʂ	ɕ
	voiced			ʐ	

Some domestic experts use EPG to research the physiological time to distinguish different pronunciation part of consonants. Cheng Jiayou and Bao Huaiqiao research the process of pronunciation of fricatives and affricatives in Mandarin Chinese， and distinguish plosives (aspirated、unaspiratied) and affricatives (aspirated、unaspirated) by average characteristics of VOT. This all based on the physiological time study, then further study affricatives and fricatives of Mandarin Chinese by TC、CC. In order to eliminate the influence of aspiration for pronunciation, we mainly research unaspirated affricatives and fricatives.

TABLE II. THE TC、CC OF UNASPIRATED AFFRICATIVES AND FRICATIVES OF MANDARIN CHINESE

place	supradental		Blade-palatal	
manner	unaspirated affricatives	fricatives	unaspirated affricatives	fricatives
consonants	ts	s	tʂ	ʂ
compare	affricatives>fricatives		affricatives>fricatives	
TC	0.56	0.42	0.40	0.35
CC	0.87	0.76	0.84	0.69

After comparison, For all the articulation places, there exist higher TC and higher CC in unspirated affricates than that in fricatives. Then, it can be concluded that tongue-palate area and concentration of the unspirated fricative part

in affricates are always higher than that in fricatives, showing that the plosive part in affricates put forward their fricative part's articulation places. The resistance stage of fricatives is not completely blocked, every parameters are smaller than affricatives'.But if the plenum affricatives have the trend to fricatives needs further research.

C Aspirated and unaspirated consonants

The unaspirated consonants and aspirated consonants are one-to-one relationship in Mandarin Chinese, there are six groups: /p/and/ph/, /t/and/th/,/k/and/kh/, /ʦ/and/ʦh/,/tʂ/and/tʂh/,/tɕ/and/tɕh/. Bilabials are beyond the acquisition domain of EPG, and velars don't joint with vowel/a/, so this article don't research /p/and/ph/,/tɕ/and/tɕh/, now we compare the remain four group consonants.

TABLE III. THE PARAMETERS COMPARE OF FOUR GROUP ASPIRATED AND UNASPIRATED CONSONANTS

phonetic system	place	AC	PC	VC	TC	AC、PC、VC compare
ʦa	supradental	0.86	0.38	0.44	0.56	AC>PC、VC
ʦha		0.77	0.38	0.25	0.48	AC>PC、VC
ta	Blade-alveolar	0.86	0.54	0.44	0.63	AC>PC、VC
tha		0.77	0.38	0.38	0.52	AC>PC、VC
tʂa	Blade-palatal	0.27	0.54	0.38	0.40	PC>AC、VC
tʂha		0.18	0.58	0.44	0.40	PC>AC、VC
k	Velar	0.00	0.21	0.88	0.31	VC>AC、PC
kh		0.00	0.17	0.88	0.29	VC>AC、PC

From table 3, we can know: the AC of supradentals and blade-alveolars are bigger than PC、VC, the tongue-palate contact is the biggest in post alveolar , tongue-palate contact mainly in hard palate area; the PC of blade-palatals is bigger than AC、VC, tongue-palate contact mainly in soft palate; AC、PC、VC、TC of aspirated are smaller than unaspirated, aspiration will have an influence on target palate position..

TABLE IV. THE PARAMETERS COMPARE OF ASPIRATION AND UNASPIRATION

place	supradental		Blade-alveolar		Blade-palatal		velar	
manner	affricatives		plosives		affricatives		plosives	
consonants	ʦa	ʦha	ta	tha	tʂa	tʂha	k	kh
TC	0.56	0.48	0.63	0.52	0.40	0.40	0.31	0.29
	>		>		=		>	
CA	0.99	0.99	0.99	0.99	0.71	0.69	0.33	0.32
	=		=		>		>	

This table showing that aspiration will have an influence on target palate position, the TC、AC of unaspirated consonants is smaller than unaspiration. The TC of aspirated supradental and blade-alveolar is smaller than unaspirated, the CA is equal. The CA of aspirated blade-palatal is smaller than unaspirated, the TC is equal. The velar express the most obvious, the TC、CA of aspirated consonants are both smaller than unaspirated.

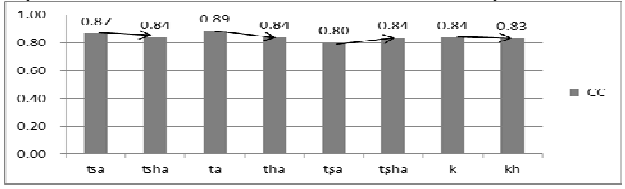

Figure 3. THE CC OF ASPIRATED AND UNASPIRATED CONSONANTS

The CC of aspirated consonants are similar to unaspirated consonants (the absolute value of difference within 0.05), and the CC of aspirated consonants is smaller than unaspirated consonants, showing that the tongue surface position of unaspirations are slightly higher than aspirations.

IV. SUMMARY

The articulation places of plosives are latter than the same manner of place of affricates, and the concentration degree of tongue-palate contact from both sides to the middle concentration degree is slightly higher; the tongue and hard palate contact of affricates is bigger than fricatives', tongue position is also slightly higher than fricatives'; aspiration will have an influence on target palate position, aspiration consonants' TC、AC is smaller than unaspiration's generally, tongue position of unaspiration is slightly higher than aspiration's.

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