COMPARISION OF ARTICULATION AMONG CHILDREN USING DIGITAL AND NON DIGITAL HEARING AIDS

By

*Shaista Majid**

*Sadia Idrees***

*Sadaf Noveen****

ABSTRACT

Hearing aids have been used successfully and efficiently for many decades for rehabilitation of hearing impaired children. In present era, advancement in technologies has brought varieties hearing aids that enable hearing impaired children to utilize their residual hearing efficiently for speech and language learning. Recently two types of hearing aids are available according to amplification circuitry, i.e. analog and digital. The present study was aimed at comparing articulation of children using digital hearing aids (DHA) with analog, the non-digital hearing aids (AHA) users. A sample of thirty Children with Hearing Impairment, fifteen DHA users and fifteen AHA users, with age range from 8 to 13 years was selected by purposive sampling technique to participate in the study. Picture Articulation Test with the subjective assessment technique was used to assess the articulation of children from speech sample taken in response to picture stimuli. The results showed that both groups of children with DHA and AHA demonstrated the presence of articulation errors. In children using DHA the intelligibility was significantly better than that of AHA users. Significantly children using AHA presented phonetic and phonological errors, but no significant difference found in articulation among male and female children, children with mono aural and binaural hearing aid fittings, and children with different amplification periods. A detailed analysis of articulation with a larger sample of children using both types of hearing aids with more considerations of external and internal variables is recommended in future to further clarify the issue.

Key Words: hearing impaired children, speech and language learning, Hearing aids, articulation, analog hearing aids, digital hearing aids.

* Assistant Professor, Department of Special Education, AIOU, Islamabad, Pakistan.
** Research Scholar, Department of Special Education, AIOU, Islamabad, Pakistan.
***Senior Speech Therapist, National Institute of Rehabilitation Medicines, G-8/2, Islamabad.

Introduction

Speech is the main vehicle for expressing our thoughts and feelings to others. Human beings use speech to communicate. This unique ability of human beings depends on brain that transforms experiences into symbols. Hearing plays its significant role in organizing auditory experiences efficiently in the brain. It is through hearing that children learn to speak and use speech as children learn their speech sounds by listening to their environment.

Berg (2008) claimed that speech is learnable system for children who are deaf. Hearing impairment effects the normal development of speech sounds because of lack of or less auditory feed back. Speech development in children with hearing impairment is also influenced by the extent and type of amplification. Many types of amplification and listening devices are available including hearing aids, cochlear implants and other listening devices. The hearing aid is an electronic device which amplifies the incoming sound signal to make it audible for the child. Several studies have emphasized the effectiveness and importance of hearing aid usage in optimal speech and learning development of children with hearing impairment. According to amplification circuitry two types of hearing aids are used, i.e. analog hearing aid (AHA), and digital hearing aid (DHA). In analog hearing aids the audiologist **can make the required** electronic adjustments, while digital hearing aids use digitized sound processing to convert sound waves into digital signals. These aids modify the voltages to amplify, filter, and limit the sounds by a computer chip that analyzes environmental signals to determine if the sound is noise or speech and provide clear amplified distortion free signals. Lamore, et al. (1998) reported that the residual auditory ability for speech recognition leads to better performance in hearing environments.

Speech is basically a fluent flow of segmental and prosodic elements including voice, resonance, prosody, articulation and so on, and dysfunction to any of these results in poor intelligibility. According to DeBodt, Hernan Dez-Diaz, & Van De Heying (2002) the intelligibility of speech depends on articulation dominantly and some other factors such as nasality, voice and prosody make the intelligibility more balanced. Speech training of a child with hearing impairment relies on combination of auditory and tactile clues and speech reading. The learning speech skills by children using hearing aid may be classified into three overlapping tasks; 1) Articulation, 2) voice content and 3) prosody. Articulation of children with hearing impairment is considered to play a major role in speech intelligibility.

In Pakistan, many children with hearing impairment have been fitted with analog hearing aids **as it is cheap and affordable** as compared to the electronic hearing aids. The emphasis in selecting a hearing aid must be on the benefits, as many researchers have reported the significant differences in the audition, speech recognition, and speech perception in analog and digital hearing aid users. **The** present study was designed to compare the articulation of children using digital and analog hearing aids to determine the effects of hearing aid on articulation of children with hearing impairment.

Phonological Development

The gradual process of acquiring adult speech patterns is called phonological development. The speech patterns of children reflect the way they simplify the productions of these sounds which they are unable to produce correctly (Ingram, 1976 as cited by Marriel,

2007). Phonological processes are statements about regularities in a child's phonology as compared to adult productions (Smit, 2004). Application of phonological processes simplifies the difficult production and results in articulation errors (Marriel, 2007). A phonological process is applied on several sounds and is divided into three types of processes; Syllable Structure Processes, Substitution processes and Harmony processes.

1) **Syllable Structure Processes: T**hese processes are related to syllable structure which a child opt to simplify the speech. Syllable structure processes include final consonant deletion, initial consonant deletion and cluster reduction. For example the child may omit the sounds /p/ of all words ending at /p/ such as cap, cup, sip, etc. again the child may omit /t/ sound at the end of let, rat, and fit, so the process is considered a **final consonant process**. Similarly a child produce _et for let, _able for table, _poon for spoon and _un for sun and this process is called **initial consonant deletion**. Similarly if a child misses consonants in clusters in middle position of words, e.g b_ack for black, and mi_k for milk, child is omitting /l/ in clusters. The process is called **cluster reduction**.

2) **Substitution processes**: Substitution processes affect the syllable and cluster shapes and affect the intelligibility of speech. Substituting all front sounds /t/ and /d/ in a word (initial, medial and final) by the back sounds /k/ and /g/ ,e.g., saying "cap" for "tup" or "gis" for "dis" is called **backing**. Similarly substituting the unvoiced consonants /f/ and /s/ with voiced consonants /v/ and /z/ e.g. "van" for "fan" and "zip" for "sip' is called **voicing**. Substituting a stop for a fricative is labeled as **stoping**. For example "do" for "zoo". Another common process is **depalatalization** which is substitution of an alveolar for a palatal sound. For example "tair" for "chair" and" load" for "raod". And substituting an alveolar for a velar sound is called **fronting**, such as "tup" for "cup".

3) **Harmony processes:** Harmony includes assimilation and reduplication processes. **Assimilation** process is changing a consonant to make it similar to another consonant in the word's other syllable e.g. "cake" for "take". There are many types of assimilation as velar assimilation and alveolar assimilation. Reduplication means the production of CVCV form. In full reduplication process two CVs syllables are the same as children simplifies "bobo" for "bottom" and "pepe" for "pencil". So these are some common articulation and phonological process which are encountered by most children with speech impairments.

Assessment of Phonological Processes

Phonological analysis is most popular approach in assessment. It analysis the natural phonological simplifying processes in child's speech patterns. These processes include fronting, cluster reduction, assimilation and stopping (Grunwell, 2003). Elbert and Gierut (1986) presented the assessment of productive phonological knowledge as an analysis of the child's sound system as a unique phonology (Grunwell, 2003). Grunwell (1985) has introduced Phonological Assessment of Child Speech (PACS). This system includes analysis and assessment procedures such as phonetic inventory and phonetic distributions, system of contrastive phones, contrastive assessment, phonetic analysis and assessment, phonological process analysis, developmental assessment, assessment of feature contrasts, assessment of variability and assessment of homophony (Grunwell, 2003).

Interventions of all speech disorders in based on 'phonetic transcription'. It is a highly specialized clinical tool based on careful watching of and listening to a child's oral output. So, a number of analysis procedures including analysis based on developmental sequence of sounds, analysis of distortion, substitution and omissions, analysis based on distinctive features and place, manner and voicing, analysis of phonological processes and analysis of child's phonological knowledge are considered in articulation assessment.

Articulation Disorders

Articulation disorders are difficulties in the way sounds are formed and strung together. Any errors occurring during the production of speech sounds are referred to as articulation errors. Production of phoneme (a smallest phonetic unit that can carry meaning-a speech sound that distinguishes one word from another) is vague in one or several ways when articulation error occurs (Marriel, 2007). Type of articulation errors includes the following.

1) Substitution: In substitution, the intended phoneme is replaced by another or an appropriate phoneme is replaced by an inappropriate phoneme. For example child says "give me pear" when she wants to say "give me bear". The /p/ is replaced by /b/. This substitution leads to a misunderstanding of intended word as the two phonemes in two words serving as contrastive elements and change the meaning of the word.

2) Distortion*:* Distortion occurs when a phoneme is misproduced in a way that makes a phoneme sound different but not different enough to shift the production into another phoneme (Marriel, 2007). For example the child says 'give me pencil' n /p/ in pencil is nasalized and not produced in standard manner, but phoneme is perceived as appropriate phoneme. Although the sound /p/ is distorted, yet the word is understood correctly by listener.

3) Omissions*:* Omission is non production of phonemes, when a sound is missed or omitted in a production, the error is called omission (Marriel, 2007). For example if a child says "give me ca_" now it's not possible to know what the child is asking for? a cap or a cat? This type of error affects the intelligibility.

Articulation Assessment

The purpose of articulation assessment is to obtain the samples of a child's speech to identify vowel and consonant productions for decision making. In most of articulation tests, more attention is given to consonants because they play more important part in intelligibility (MsReynolds, 1985 as cited by Marriel, 2007). Speech of severely deaf children is known to be especially challenging in terms of assessment and treatment. The speech therapist has to face multiple and complex errors in order to assess and treat children with hearing impairment due to the heterogeneous population and speech.

Articulation test or Phonemic Assessment is the traditional assessment procedure for child speech. This test involves the elicitation of a speech sample from the children through a picture naming game. The words to be elicited have been selected to provide a representative sample of the adult pronunciation system. Usually every single consonant phoneme in initial, middle and final positions in some words syllables and clusters. A child's production of these target sounds are rated correct or in correct against the adult norm and the total correct score is

calculated and assessed by comparing to the standardized score for the child's age group (Grunwell, 2003).

Language and culture appropriate assessment tools are necessary for accurate diagnosis of speech and language disorder and to plan intervention thereafter (Noveen, 2012). Almost all commercially available articulation tests sample articulation in picture naming responses. The pictures used in tests have the drawings of single word name objects. Usually each sound is tested in all three positions in a word such as initial, medial and final. The first sound in a word is the initial position; the last sound is the final position, whereas medial refers to the middle sound. Most of articulation tests available commercially are designed slightly differently but the test to elicit the similar responses. Noveen (2012) says children can recognize speech sounds of familiar language through lip reading or listening, therefore a culture and language appropriate test is required for assessment of speech sound disorders. Test for Assessment of Articulation and Phonology in Urdu (TAAPU) is the only test to assess Articulatory and Phonological Disorder in Urdu language. TAAPU is a non published test. Its validity and reliability has been inferred in a pilot study and its standardized is in process (Noveen, 2012).

Articulation of Hearing Impaired Children

Children with hearing impairment show a wide range of spoken language abilities, some have highly intelligible speech while others have un intelligible speech (Monser, 1983). Children with hearing impairment commonly present with articulation disorders. Speech of deaf children is different from normal speech because of the different sensory conditions under which it must be learnt as partial or absent auditory feedback. Articulation skills of deaf children have historically been a primary area of difficulty for them (Maschark, Lang, & Albertini, 2002). A number of factors influence the development of speech in deaf individuals. These factors include etiology and degree of hearing loss, extent of motivation to communicate orally, and related abilities such as linguistic, motor, perceptual and cognitive (Ellis, 2009). Intervention factors also play a part for example age of detection, amount and frequency of intervention, and treatment rationale (Ellis, 2009). The reason for poor articulation in the speech of hearing impaired children is low articulatory movements and the slow articulation of syllables (Osberger & McGarr, 1982 as cited by Ellis, 2009).

According to Ellis (2009) the phonatory, oro-nasal and articulatory speech production processes can be affected due to hearing loss. This may results in errors which can be detectable at the segmental level (level of individual speech sounds) and at the supra segmental level (level of rhythm, intonation, stress, and speech rate). Deaf children tend to rely on somato-sensory feedback information to compensate for lack of auditory feedback for coordination of articulatory movements. An over reliance on this may lead to over produced or effortful speech.

Hearing impaired children experienced difficulties for both consonants and vowels in terms of the effect on individual speech sounds. Most frequently discussed consonant errors in literature are omissions, substitutions, distortions, final consonant deletions and voicing errors. Omission of the consonants is the most frequently found error, especially for velar sounds such as k, g and ng and for consonants in word final position. Most severe articulation disorders are omissions followed by substitution as they seriously affect the target sound and

the overall intelligibility while distortion affect the target sound by only one feature and affect intelligibility slightly (Pena Brooks &Hedge, 2000). Nasality also occurs in speech of children with hearing impairment (Flecher).

Articulation of children using hearing aids

Articulation skills of deaf children have been a primary area of difficulty for this population historically (Maschark, Lang & Albertini, 2002). There is very limited research on the articulation of children using hearing aids. The results of the studies show a poorer intelligibility of the children with hearing aids in comparison with children with cochlear implants which is probably due to the occurrence of more phonetic and phonological disorders. The speech of prelingualy deaf and hearing impaired children **using** hearing aid is often characterized by the presence of articulation, phonation and resonance disorders (Leder & Spitzer, 1990).

In an analog circuit, the signal is represented and amplified as continuously varying amplitude over time. Analog circuitry amplifies in a linear fashion. It can distort sound. On the contrary, a digital hearing aid receives the sound as an analog signal, converts it into digital representation, processes the signal into computer language and then converts back into analog sound wave before delivering it to ear (Agnew, 2002).

Many issues such as internal self generated noise levels, current consumptions, the battery size and user control limit the further development in analog technology. Available features are generally limited to telecoils and manual volumes controls. Analog hearing aids are least effective in difficult listening environments (Marion et al., 2003; Dalebout, 2009).

Some analog hearing aids can be digitally programmed; the digital programmer can adjust the gain, frequency response, and output of the analog circuit. Some analog hearing aids may also have multiple channels (frequency bands) that can be digitally programmed. An analog aid is that the analog signals from the microphone are converted into a digital form by an analog-to-digital converter. Once in the digital form, the signals are manipulated by sophisticated processing algorithms and then converted back to analog form by digital-to-analog conversion. So 90% of current hearing aid technology is digital.

Objectives of the Study

The study was carried out with the following objectives;

1. To compare the articulation of children using digital hearing aid and analog hearing aid.
2. To identify the effects of age of amplification fitting on articulation development of children with hearing impairment.

Hypothesis of the Study

H_o: There is no significant difference in articulation of children using digital hearing aid and those using analog hearing aid.

H_1: There is a significant difference in articulation of children using digital hearing aid and those using analog hearing aid.

Research Method

The research was designed to compare the articulation among children using digital and analog hearing aids. The type of research was causal comparative that involves collecting data in order to test hypothesis.

Population of the Study

The population of the study comprised of 144 hearing impaired children using hearing aids with age ranging from 8 to 13 years, studying **in Lahore** at Hamza Foundation, Academy for the Hearing Impaired Children.

Sample of the Study

The purposive sampling technique was used to **select** sample. The research sample included 30 prelingal hearing impaired children using hearing aids of both **male and female** (17 Boys, 13 girls) with ages varying from 8 to 13 years who did not show any additional disorders. All children were receiving speech therapy at their school by speech therapist 4 days a week. The sample was **divided** in two groups. Group A included 15 children (8 Boys, 7 Girls) with age range (8-13years) with sensor neural severe to profound hearing loss using digital BTE hearing aids. Group B included 15 children (9 Boys, 6 Girls) with age range (8-13 years) with severe to profound sensor neural hearing loss using analog (pocket or BTE) hearing aids. An initial assessment form was developed **and used** in order to select sample on the basis of same characteristics i.e. chronological age, degree, type and nature of hearing loss, age of amplification, type of amplification, age of intervention, frequency of hearing aid use, duration and frequency of speech therapy, and fitting of hearing aid.

Instrumentation

The Picture Articulation Test (PAT) made by speech therapist was used. This involves naming the pictures of common words and subjective assessment of articulation by listener.

Pilot Testing

Before administering the test, a pilot study was conducted on eight children with severe to profound sensorineural hearing loss with age ranging from 8-13 years using digital and analog hearing aids **including** both **gender**. Results of pilot testing showed that in children using Analog hearing aids, the fricatives [f] , [Z], [S] , [Z], the nasal [}] and [K] & [R] are the most frequently error consonants. While children with analog have produced these sounds relatively less **with** error. Similarly the phonetic analysis showed that in children with digital hearing aids, distortions and substitutions are more relatively **in nature**. While children with analog hearing aid showed more omissions.

Administration of Test and Collection of Data

For assessment of articulation speech sample was elicited by means of picture naming test. The participants were asked to name the pictures of common objects by taking spontaneous responses subjective assessment techniques were used to assess articulation

errors. The responses were transcribed and recorded on phonetic chart. The analysis included independent and relational phonetic and phonological processes analysis.

In the phonetic analysis, the consonants were compared with target production and analyzed for the error type at all segmental levels (Leird, 2005). The error types considered were omissions, substitution and distortions.

In the phonological process analysis when looking for the error pattern beyond segmental level, Ingram's 1982 classification were used (Leird, 2005), A process was considered productive if it appeared in four or more time in different words (Leird, 2005). Phonological processes analysis included syllable structure process (Final consonant deletion, Initial consonant deletion, cluster reduction; Substitutions Process (Stopping, fronting, voicing, nasalization and depolarization) & Harmony process (Assimilation & reduplication).

Results

Descriptive and inferential statistics including Independent Sample test and One Way ANOVA were used to compare means of articulation errors in both groups.

Analysis of Demographic Information of Children

The analysis of demographic information i.e. gender, chronological age, period of amplification, type of hearing aid, type of hearing aid fitting, and duration of speech therapy is given as under.

Table 1
Demographic Characteristics of Participants (N=30)

S/no.	Demographic variable	Frequency	%
1	**Gender**		
	Male	17	56.7
	Female	13	43.3
2	**Age in years**		
	8 – 9	7	23.3
	9 -10	5	16.7
	10 -11	4	13.3
	11 -12	7	23.3
	12 -13	7	23.3
3	**Type of Hearing Aid**		
	Analog	15	50
	Digital	15	50
4	**Period of Amplification in years**		
	4 -5	4	13.3
	5 -6	4	13.3
	6 -7	10	33.3
	7 -8	12	41.4
5	**Duration of Speech Therapy in years**		
	3 - 4	14	46.7
	4 -5	8	26.7
	5 -6	8	26.7
6	**Hearing aid fitted**		
	Binaurally	15	50

Left	10	33.3
Right	5	16.7

Table 1 shows that more than half 56.7% of the sample comprised of boys while 43.3 % are girls. Among the respondents 13.3% of children fall between ages from 10 -11 years, 16.7% children are of ages between 9-10 years, while 46.6 % of children fall in age ranges of 8 to 9 years and 11- 13 years. So it is found that sample is well representing almost all age ranges.

The table represents both types of hearing aid users comprised the 50% of total participants. The table depicts that maximum percentage 41.4% of children have been fitted with amplification for 7-8 years, 33.3% of children have been amplified for 6-7 years and the minimum percentage 13.3 % of children have been fitted the amplification for the periods of 4-5 and 5-6 years respectively. Therefore it was found that maximum children are amplified at relatively earlier ages. It indicates that most of the children 46.7% are receiving speech therapy services regularly by the therapist for the period of 3-4 years, while the same percentages 26.7% receiving the therapy for the period of 4-5 and 5-6 years. Therefore we can conclude that majority of children in the study have been received services for minimum duration that is 3-4 years. Table describes that half 50% of the children have been fitted with binaural hearing aids, where as among 50% mono aurally fitted children,33.3% using hearing aids at left and 16.7% using hearing aids at right ears. Thus it is found that sample comprised the equal percentages of binaurally and mono aurally fitted children with hearing aids.

Phonetic Analysis

Table 2
Mean of Phonetic Errors (N=30)

Phonetic errors	**Mean Occurrence (%)**			
	AHA n=15		**DHA n=15**	
	M	**SD**	**M**	**SD**
No. of errors	49.5	7.0	42	5.6
No. of Substitution	22.5	10.1	31	6.7
No. of omissions	54.5	11.8	34	12.7
No. of distortions	23	10.7	35.6	11.2

Table 2 indicates that mean percentages of no. of errors out of total production is 49.5 in children using analog hearing aids while children with digital hearing aids show a mean percentage 42. Values SD for analog and digital hearing aids users are 7.0 and 5.6 respectively. So it is found that children with analog hearing aid made more phonetic errors than those of children with digital hearing aids. The mean percentages of substitution errors out of total errors are 22.5 in analog users while it is 31 in digital users. Values of SD represented in table are 10.1 and 6.7 respectively for analog and digital users. So it is found that children with digital hearing aids have substituted more consonants relatively on phonetic inventory.

The mean percentages of omission errors out of total errors are 54.5 in analog users while it is 34 in digital users. Values of SD represented in table are 11.8 and 12.7 respectively for analog and digital users. Thus it is found that children using analog hearing aids have omitted more consonants than those of children with digital hearing aids.

The mean percentage of distortion errors out of total articulation errors is 23 for analog hearing aid users while digital hearing aid users show a mean 35.6. Values for SD are 10.7 and 11.2 respectively for both groups. So these values interpret that children with digital hearing aid have more distorted consonant production than children with analog aids.

Phonological Analysis

Table 3
Phonological Processes

Phonological processes	Mean occurrence (%) N=30	AHA Mean occurrence (%) n=15	DHA Mean occurrence (%) n=15
No process	3.3	0	6.7
1 process	3.3	0	6.7
2 processes	60	60	60
3 processes	33.3	40	26.7

Table 3 shows that majority 60 % of children has encountered 2 processes, 33.3 % has encountered 3 processes, 3.3 % has encounters only 1 phonological process while 3.3 has appeared with no phonological process. In analog hearing aid users more than half 60% has encountered 2 processes wile less than half 40% had 3 phonological processes. In digital hearing aid users, 6.7% have appeared with no phonological processes, 6.7% have only 1 process, 33.3% have 3 processes while majority 60% have appeared with 2 phonological processes. Therefore **it** can **be** concluded that majority 60% of both users have encountered 2 phonological processes.

Table 4
Syllable Structure Processes

Syllable structure processes	Mean occurrence N=30	AHA Mean occurrence (%) n=15	DHA Mean occurrence (%) n=15
No process	20	0	40
1 process	46	40	53.5
2 processes	30	60	0
3 processes	3.3	0	6.7

Table 4 depicts that 20% children has encountered no productive syllable structure process, l46% has 1 process, and 30 % has 2 processes, while only 3.3% has 3 processes of syllable structure. Among analog hearing aid users less than half 40% have appeared with 1 syllable structure phonological process while more than half 60% have appeared with 2 syllable

structure processes. Among digital hearing aid users, less than half 40% have appeared with no syllable structure phonological processes, more than half 53.5% have 1 process where as a small percentage 6.7% has shown three syllable structure phonological processes. So it is found that 100% children with analog aids have syllable structure phonological processes as compared to 60% of children with digital aids.

Table 5
Analysis of Syllable Structure Processes

	Mean occurrence N=30	AHA Mean occurrence (%) n=15	DHA Mean occurrence (%) n=15
F.C.D	36.7	60	33.3
I.C.D	20	33.3	6.7
Cluster Red.	63.3	73.3	53.3

Table 5 describes that more than half 63.35 of children have deleted the final consonants of syllables, 20% have deleted consonants at initial positions and less than half 36.7% have deleted consonants in clusters. Among analog users, 60% have appeared with final consonant deletion, 33.3% have with initial consonant deletion while majority 73.3% has appeared with cluster reduction. Among digital users, 33.3% have appeared with final consonant deletion, 6.7% have with initial consonant deletion while majority 53.3% has appeared with cluster reduction. So it is found that analog users have more productive processes than that of digital users.

Table 6
Substitution Processes

Substitution processes	Mean occurrence N=30	AHA Mean occurrence (%) n=15	DHA Mean occurrence (%) n=15
No process	33.3	53.3	13.3
1 process	60.0	46.7	73.3
2 processes	6.7	0	13.3

Table 6 represents that the 33.3 % children have appeared with no substitution process. 6.7 % have appeared with 2 substitution processes while majority 60% have shown 1 phonological processes among substitution processes. Among analog users, more than half 53.3% have appeared with no substitution process while less than half 46.7% have encountered 1 substitution process. Among digital users, 13.3% have appeared with no, 13.3% have with 2, while majority 73.3% have with 1 substitution process. Thus it is found that most children have shown 1 substitute process and digital users have more than that of analog users.

Table 7
Analysis of Substitution Processes

	Mean occurrence N=30	AHA Mean occurrence (%) n=15	DHA Mean occurrence (%) n=15
Stoping	16.7	13.3	20
Fronting	13.3	20	6.7
Voicing	23.3	6.7	40
Nasalization	3.3	0	6.7
Depalatalization	23.3	20	26.7

Table 7 reveals that 16.7% children have stoping, 13.3%, have fronting, 23.3 have voicing, 23.3% have depalatization while only 3.3% have nasalization as substitution phonological process. Among analog hearing aid users, 13.3% have appeared with stoping, 20% have appeared with fronting and depalatization, 6.7% have voicing, while no children has appeared with nasalization. Among digital users 20% children have stoping, 6.7% have fronting and nasalization, and 26.7% have depalatization while majority 40% has voicing as substitution process.

Table 8
Harmony Processes

Harmony Process	Substitution processes Mean occurrence (%) N=30	AHA Mean occurrence (%) n=15	DHA Mean occurrence (%) n=15
No process	83.3	100	66.7
1 process	16.7	0	33.3

Table 8 depicts that 83.3% of children have encountered no harmony process while 16.7% have presented only 1 harmony process. Among analog hearing aid users, no child has appeared with any harmony process while among digital users only 33.3 % children have elicited 1 harmony process.

Table 9
Analysis of Harmony Processes

	Mean occurrence N=30	AHA Mean occurrence (%) n=15	DHA Mean occurrence (%) n=15
Assimilation	16.7	0	33.3
Reduplication	3.3	0	6.7

Table 9 shows that 16.7% children have appeared with assimilation and only 3.3% children with reduplication. No analog user has showed any of these process so it is found that only children with digital hearing aids have encountered assimilation and reduplication processes.

Comparing Articulation of Children using Digital and Analog Hearing Aids

Table 10
Comparison of Phonetic Analysis

Analysis	AHA Mean occurrence of errors %	DHA Mean occurrence of errors%	Comparison t
Phonetic			
Num of errors/ total production	49.5	42	.003*
Num of Substitution/ t. errors	22.5	31	.012
Num of omissions/t. errors	54.5	33	.000***
Num of distortions/ t. errors	23	35	.004*

*****significant difference

Table 10 shows that comparing means by independent sample t test has revealed significant difference in articulation errors of children among children using analog and digital hearing aid. Ho is rejected. Ho is rejected for omission and distortion errors too as the value of t shows significant. The difference between two groups is highly significant t=.000 in omission errors. While there is no significant difference found in substitution errors of both group, and **Ho** is accepted.

Table 11
Comparison of Phonological Process

Analysis	AHA Mean occurrence of errors %	DHA Mean occurrence of errors%	Comparison t
Phonological processes	2.4	2.0	.183
Syllable structure Processes	1.6	.73	.001*
F.C.D	.60	.13	.007*
I.C.D	.33	.06	.072
C.D	.73	.53	.271
Substitution processes	.46	1.0	.010*
Stoping	.13	.20	.638
Fronting	.20	.06	.299
Voicing	.06	.40	.031*
Nasalization	.00	.06	.326
Depalatization	.20	.26	.679
Harmony processes	.00	.33	.013*
Assimilation	.00	.33	.013*
Reduplication	.00	.06	.326

*significant difference

Table 11 shows that there significant difference in many phonological processes of children with analog and digital hearing aids. There is significant difference 0.001 in syllable structure

processes which is mainly due to the difference in final consonant deletion. Children with analog hearing aids have encountered relatively more syllable structure processes. The difference in substitution processes is 0.010 and significant which is mainly due to difference in voicing process. More children with digital hearing aids have appeared with voicing process.

There is also significant difference in harmony processes that is .013. Again more children with digital aids show more harmony processes i.e. assimilation. So the ho is rejected for all three: syllable structure, substitution and harmony processes.

Comparing Articulation among Male & Female Children

Table 12
Comparison of phonetic analysis

Analysis Phonetic	Male Mean occurrence of errors %	Female Mean occurrence of errors%	Comparison t
Num of errors/ total production	47	44	.288
Num of Substitution/ t. errors	27.1	26.3	.840
Num of omissions/t. errors	47.4	39.7	.189
Num of distortions/ t. errors	24	35.2	.020

Table 12 shows that values of t>0.05 so there is no significant difference of phonetic errors among boys and girls.

Table 13
Comparison of Phonological Processes

Analysis	Male Mean occurrence of errors %	Female Mean occurrence of errors%	Comparison t
Phonological processes	2.2	2.2	.968
Syllable Stru. Processes	1.2	1.1	.940
F.C.D	.41	.30	.594
I.C.D	.11	.30	.210
C.D	.64	.64	.864
Substitution processes	.64	.84	.362
Stoping	.11	.23	.428
Fronting	.23	.00	.064
Voicing	.11	.33	.092
Nasalization	.05	.00	.391
Depalatization	.23	.23	.978
Harmony processes	.17	.15	.875
Assimilation	.17	.15	.875
Reduplication	.05	.00	.391

Table 13 depicts that value of t>0.05 so there is no significant difference of phonological processes among boys and girls.

Comparing Articulation among Children using Monoauaral and Binaural Hearing Aids:

Table 14
Comparison of Phonetic Analysis

Analysis	Binaurally Mean occurrence of errors %	Mono aural Mean occurrence of errors%	Comparison t
Phonetic			
Num of errors/ total production	44.4	47	.329
Num of Substitution/ t. errors	28	25	.479
Num of omissions/t. errors	41.2	47	.327
Num of distortions/ t. errors	30.2	28.2	.669

Table 14 shows that there is no significant difference of phonetic errors among children using hearing aids mono aurally and binaurally as the values of t>0.05.

Table 15
Comparison of Phonological Processes

Analysis	Binaural Mean occurrence of errors % n=15	Monoaural Mean occurrence of errors% n=15	Comparison t
Phonological processes	2.2	2.3	.793
Syllable stru. Processes	1.0	1.3	.499
F.C.D	.27	.47	.271
I.C.D	.20	.20	1.0
C.D	.67	.60	.716
Substitution processes	.87	.60	.216
Stoping	.20	.14	.638
Fronting	.14	.14	1.0
Voicing	.27	.20	.679
Nasalization	.07	.0	.326
Depalatization	.27	.20	.679
Harmony processes	.10	.20	.638
Assimilation	.14	.20	.638
Reduplication	.00	.07	.328

Table 15 shows that there is no significant difference in phonological processes among children who are fitted binaurally than that of mono aurally fitted children as the value of t>0.05.

Period of Amplification &Articulation

Table 16
Comparison of Phonetic Analysis According to Period of Amplification

		df	Mean Square	F
Phonetic				
Num of errors/ total production	Between groups	3	43.675	.790
	Within Groups	26	55.263	
Num of Substitution/ t. errors	Between groups	3	209.302	.2669
	Within Groups	26	78.419	
Num of omissions/t. errors	Between groups	3	218.053	.868
	Within Groups	26	250.204	
Num of distortions/ t. errors	Between groups	3	260.876	1.803
	Within Groups	26	144.663	

The table 16 shows that there is no effect of period of implantation on phonetic errors as there is no significant difference among children on one way ANOVA as value of F>0.05.

Table 17
Comparison of Phonological Processes according to Period of Amplification

		df	Mean Square	F
Phonological processes	**Between Groups**	**3**	**.213**	**.436**
	Within Groups	26	.489	
Syllable st. processes	Between Groups	3	.508	.793
	Within Groups	26	.640	
F.C.D	Between Groups	3	.695	3.704
	Within Groups	26	.188	
I.C.D	Between Groups	3	.114	.663
	Within Groups	26	.171	
C.R	Between Groups	3	.675	3.550
	Within Groups	26	.190	
Substitution processes	Between Groups	3	.174	.485
	Within Groups	26	.359	
Stoping	Between Groups	3	.041	.267
	Within Groups	26	.155	
Fronting	Between Groups	3	.058	.459
	Within Groups	26	.127	
Voicing	Between Groups	3	.136	.713
	Within Groups	26	.191	

Deplatalization	Between Groups	3	.014	.069
	Within Groups	26	.205	
Harmony processes	Between Groups	3	.131	.904
	Within Groups	26	.145	
Assimilation	Between Groups	3	.281	2.200
	Within Groups	26	.128	
Reduplication	Between Groups	3	.072	2.504
	Within Groups	26	.029	

Table 17 shows that values of F>0.05, so there is no significant difference in phonological processes among groups having different period of amplification.

Discussion

Many previous studies have pointed out the positive impact of digital hearing aids on better speech perception, production and articulation. But the comparison of analog and digital hearing aids on speech and other elements of speech has not discussed and reported much in literature. Most studies focused on digital hearing aids and their effects on overall intelligibility of speech not on the elements of speech.

The present study basically had two main objectives to achieve. First was to compare the articulation among children using analog and digital hearing aids. And second to investigate effects of demographic factors as age, gender, period of amplification and hearing aid fitting on articulation. The study investigated the articulation on phonetic and phonological level. In sample, the demographic information was not significantly different for both groups.

Results on phonetic chart revealed that there is significant difference in both groups regarding % of missing phonemes. Children with AHA have more articulation errors but most children with DHA also missed fricatives /z/, /sh/ and /y/. These results did not match with the Bernardt et al, 2000, who claimed omissions often occur in sounds in word positions of lower intensity and pitch. This is probably because of high frequency and the long noise segments of these sounds **(Leired, 2005 cited kent & Reed 1998)** (Kent & Read, 1998, as cited by Leired, 2005). This is due to that for children with high frequency hearing loss, fricatives are difficult to perceive. According to Turner and Cummings, 1999, providing high frequency speech audibility hearing impaired listener does not always result in improved speech recognition. Thus once a hearing loss becomes severe enough to prevent the sound transmission to brain, provision of amplification even with compression may not benefit for speech recognition. There is another problem with amplifying high frequency sounds that if a hearing aid is set at its maximum gain, even then it's difficult to have consonants especially fricatives perception,

as vowels are more intense than consonants (Leirde, 2005). Fricatives are 30 dB less than vowels.

Children with both groups have most commonly and frequently make omission errors in contrast to study of Leird.2005, who concluded that distortions are far most the most frequently occurred error type in children with hearing aid. Here the distortions are found as least frequent articulation error. The results of independent analysis of phonemes are supporting the results of previous studies of Ellis, 2009, Dagenais & Critz- Croshy, 1991, & Murphy and Dodds, 2007. As children have more omissions occurred especially for velar sounds/k/, /ng/, and fricatives consonants in word final position. Voicing of stops and fronting is far most common and frequent phonological process which is supporting the results of Martina, 2010.

The phonological process analysis of children showed almost same processes overall but children with AHA showed significantly more syllable structure processes especially final consonant deletions while DHA showed More substitution and harmony processes. And presence of phonological processes is also seemed to be one cause of unintelligible speech.

The gender wise comparison of articulation children have shown no significant difference and it seems normal and natural as the all are with almost same age ranges. The comparison of articulation among the unilateral and bilateral using children showed no significant difference and it is surprisingly contrasting the studies of Brooks and Bulmer, 1981, who suggested that bilateral fitted systems have shown improved localization and improved speech recognition.

The results of comparing the articulation according to period of amplification are also much unexpected and does not supporting the results of studies by Spencer & Marchark, 2006 and Wallace, Mann, Yoshinaga & Itano, 2000, who emphasized that early age of amplification, lead to better speech production than that of late amplifications.

Over all there is a significant difference in articulation of both groups found, and hypothesis was accepted, but except the type of hearing aid, a lot of factors may affect the articulation of a child. The cause and onset of deafness, age of identification, type and time of amplification duration of therapy, consistency of hearing aid use and therapy may affect child performance in the test administered. Some of them are discussed controlled and compare in present study. As onset, age, gender, type, degree and nature and onset of hearing loss were included in criteria to select sample. Period of amplification, gender and hearing aid fitting was compared too, but there could be other variables such as family back ground, socioeconomic status, IQ, family, school and community environment, peer relationship, developmental and medical history of child, frequency of using hearing aids, concerns and motivation of parents and family, exposure to auditory stimuli, and training and revision at home all may affect the results f the study. Subjective phonetic transcription in order to assess articulation can also be a factor that can affect results.

Another important factor is the consistency of hearing aid use play an important role in the speech learning process, and this may influence the results of present study. Many parents are not so concerned, and there are also some financial barriers in affordability of batteries which may limit the use of hearing aids at home. Exposure to auditory stimuli and mode of communication at home also influence the spoken language. A very influencing limitation of the study was the great variation of variables and very small sample size of the groups. So the generalization of results should be carefully done. The research can be more generalizeable if the same issues studied on larger groups.

Conclusions

On the basis of findings, following conclusions are made:

Overall there is significant difference among the articulation of children with analog hearing aids and digital hearing aids. In both the AHA and DHA children, all subjects have commonly presented the errors on fricatives / s, z, sh and y/, velar /k/, and nasal /ng/ but the significant difference was found between the amounts of errors that AHA and DHA children were able to produce. The consistency of errors is less in DHA than AHA children. In both AHA children, frequency of omissions errors is significantly high while DHA children more significantly made substitution and distortions.

Regarding phonological processes, most phonological processes of syllable structure are encountered by AHA group, while children with DHA have more significantly appeared with substitution and harmony processes. Cluster reduction is the most commonly encountered process among both groups.

No significant difference of articulation among children with different periods of amplification is found.

Gender wise no significant difference in articulation among both groups of using AHA & DHA was found and there is also no significant difference among these groups children using hearing aids unilaterally and bilaterally.

So the hypothesis of the present study that “there is a significant difference in articulation among children using digital and analog hearing aids” is accepted.

Recommendations

On the basis of findings and conclusions, following recommendation were given:

The provision of digital hearing aids to all children with hearing loss should be assured either by government or other non government organizations in order to develop better spoken language in children.

The provision of digital hearing aid is not sufficient, so the proper speech therapy services by professional therapists should be assured to children with consistency to achieve the optimal results of digital hearing aids.

To aware the parents about importance and early amplification fitting, seminars, meetings by institutes, and media programs can be introduced.

The early identification leads to early intervention, so it is necessary to made early identification universal on national level by providing facilities of neonatal screening, and infant tests in public hospitals.

REFERENCES

Bernhardt, B. H. , Fuller, K. , Loyst, D. , & Williams, R.(2000). Speech productions outcome before and after palatometry for a child with cochlear implant. Journal of the Academy of Rehabilitative Audiology (33), 11-37.

Blamey, P. J. , Macforlane, D. S., Steete, R. B. (2005). An intrinsically digital amplification Scheme for hearing impaired. EURASIR, Journal on Applied Signal Processing. 18, 3026-3033.

Chung, K.(2004). Challenges and recent development in hearing aids. Trends in Amplification, 8(3), part 1, SAGE Publications. DOI: 10.1177/108471380400800302. Retrieved from http://tia.sagepub.com/cgi/content/abstract/8/3/83 at 12/ 11/ 2010.

DeBodt , M., Hernan dez-Diaz , H. , & Van De Heyning , P.(2002). Intelligibility as a linear combination of diminutions in dysartheric speech. Journal of Communication Disorder 35,283-292,

Dwarkin, J. , Marunick, M.T. , & Kouse, J. H.(2004). Velopharyngeal dysfunction: speech characteristics, variables, etiologies, evaluation techniques, and differential treatment. Language , Speech and Hearing services in Schools. 35(4), 333.

Edwards, B.(2007). The future of hearing aid technology. Trends in amplification, 11.3, SAGE Publications. DOI: 10.1177/1084713806298004 retrieved from http://tia.sagepub.com/cgi/content/abstract at 11/1/31

Efrat, A. S.Froma, P., Roth & Nathar, A. Fox, A. (2008). A comparison of the speech and language skills of children with cochlear implants and children with normal hearing. Communication Disorders Quarterly, 29, 195. DOI: 10.1177/1525740108321217.

Ellis, L,(2009). Articulation characteristics of severly and profoundly deaf children and approaches to therapy. Language and Linguistic Compass, 3(5),1201-1210.

Fletcher, S.G. ,Dagernais, P.A. , & Critz-Croshy, P.(1991). Teaching consonants to profoundly Hearing impaired speakers using palatometry. Journal of Speech and Hearing Research,34, 929-942 .

Monsen , R.,B.(1983).The oral speech intelligibility of hearing impaired talkers. Journal of Speech and Hearing Disorder, 48, 286-296.

Grunwell, P. (1993), introduction to section one. In P. Grunwell (2003).Developmental speech Disorders.(eds.)pp3-15. London: Whurr Publishers Ltd.

Kollimier, B. & Mellert, V. (2000). Noise reduction schemes for hearing aids and their use for hearing impaired.

Kuk, K. f. (2004). Amplification devices for the hearing-impaired individual. Retrived from http://famona.tripod.com/ent/cummings/cumm179.pdf at 6/12/2010.

Lamore, P. J. J., Huiskamp, T. M. I., Vanson, N.J.D.M.M. , Bosman, A. J. , Smoorenburg, G. E. (1998). Auditory, visual, & Audiovisual perception of segmental speech features by severly hearing impaired children. Audiology, 37(6).

Lawner, S. (2008). The core of future hearing instrument innovation. Advances for audiologists, 10(1), 42-50.

Leder, S.B., & Spitzer, J.B.(1990).A perceptual evaluation of the speech of adventitiously deaf males. Ear Hear,11, 169-175. Pena-Brooks, A., & Hedge, M. N.(2000). Assessment and treatment of articulation and phonological disorders in children. Texas: Pro-ed.

Lierde, K.M.V. , Vinck, B.M. , Devel, E., Dhooge, I.(2005). Comparison of the overall Intelligibility, articulation, resonance and voice characteristics between children using cochlear implant and those using bilateral hearing aids: A pilot study .International Journal of Audiology, 44, 452-465.

Mascharck, M. , Lang, H.G. , & Albertini, J. A.(2002). Educating deaf students. U.S.A: Oxford University Press.

Merrial, C.E.(2007). Human communication disorders (7^{th} ed). New York: A Bell & Howell Company.

Millen- Hansen. D. R. , Nelson, P. B. , Widen, J. E. , Simon, S.D. (2003). Evaluating the benefits of speech recoding hearing aids in children. American journal of audiology, 12, 106-113.

Murphy, E., Dodds , B.(2007). Hearing Impairments. In B.,Dodds(ed.), Differential diagnosis And treatment of children with speech disorders(pp244-257). London and Philadelphia: Whurr publishers.

Noveen, S. (2012). Test for Assessment of Articulatory and Phonological Disorders in Urdu. An unpublished dissertation submitted at Rehabilitation Sciences Department, Ripha International University, Islamabad.

Souza, P E.(2002). Effects of compression on speech Acoustics, pn intelligibility anfd sound quality. Trends in amplification.6(4), 131-165.

Spencer, P. E. & Marchark, M.(2006). Advances in the spoken language development of deaf and hard of hearing children. New York: Oxford University Press.

Subtenly, J.D.(1980). Speech assessment and speech improvement for the hearing impaired. Washington,D.C.: The Alexender Graham Bell Association for the Deaf.

Turk, O. & Arslan, L. M. (2004). Pronounciation scoring for the hearing impaired. Paper presented at SECOM, 9th conference.

Turner, C. W. & Cumming, K. J.(1999). Speech audibility for listeners with high frequency hearing loss. American Journal of Audiology 8, 47-56.

Turner, C.W. , & Cummings, K.J. (1999). Speech audibility for listeners with High Frequency hearing loss. American Journal of Audiology,(8), 47-56. doi:1059-0889/99/0801-0047.