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Biological affinities and regional microevolution among pre-Hispanic communities of Colombia's Northern Andes

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Summary: Dental non-metric data were used to examine the biological continuity of pre-Hispanic peoples of Colombia's Northern Andes, including highland, lowland and coastal peoples. This report contributes to studies regarding the peopling of South America by establishing a benchmark comparison that includes pre-Hispanic populations of the Northern Andes. The sample consisted of a total of 583 individuals from 56 cemeteries ranging in time from the Early Holocene (10,000 BP) to the Final Late Holocene (500 BP). Permanent dentitions from individuals between 5 and 40 years of age were scored for 87 dental traits based on the ASUDAS. A divergence matrix was programmed using the Smith's Mean Measure of Divergence equation (MMD). Bartlett's adjustment and Ascombe transformation were considered into MMD calculations. Principal Coordenate analysis was applied based on MMD matrix scores. A clear group was found that associated Initial Late Holocene samples with Final Late Holocene samples. Early Holocene samples are very different to that, and Middle Holocene samples show as morphologically intermediate series. A comparison of the frequencies by time and period showed that a limited biological continuity existed. Interbreeding among initial populations of the same regions is expressed in similar frequencies of dental traits within Early Holocene and Middle Holocene samples. Early Holocene samples did not match with Sinodont pattern according to discriminant function analysis. These findings help us to better understand the settlement process of human groups in the Northern Andes and its relationship with migratory movements in South America.

Key words: Dental non-metric data, biological continuity, interbreeding, migratory movements.

Introduction

Most archaeological studies in Colombia have focused on communities that existed during the Initial Late and Final Late Holocene periods (last 3,000 years before present). The relative lack of research on Middle Holocene (7,000–3,000 BP) and Early

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Holocene (10,000–7,000 BP) groups may be due to a shortage of deposits (Rodríguez Flórez & Rodríguez 2010, Rodríguez Flórez 2012a). Therefore, data from the Early and Middle Holocene groups have had little impact on the reconstruction of the pre-Hispanic history in Colombia (Correal 1979, Correal 1989, Correal & van der Hammen 1977, Neves et al. 2007).

In Colombia, a very small number of studies have attempted to explain the biological relationships between pre-Hispanic groups (Broca, 1875, Correal & van der Hammen 1977, Correal 1979, Boada 1987, Boada 1995, Groot 1992, Rodríguez Cuenca 1992, Rodríguez Cuenca 2007, Rodríguez Flórez & Rodríguez 2010, Rodríguez Flórez 2012a). These studies have been limited by the small number of crania curated in the collection and their poor state of preservation, as well as cranial deformation that inhibits craniometrics for biological distance studies.

Bioarchaeological studies in Colombia have focused on the diseases, diet and daily activities of past populations inhabiting the West Andes and Cauca Basin (Rodríguez Flórez 2001, Rodríguez Flórez 2003, Rodríguez Flórez 2004, Rodríguez Flórez 2005, Rodríguez Flórez 2008, Rodríguez Flórez 2009, Rodríguez Flórez 2010, Rodríguez Flórez 2012a, Rodríguez Flórez 2012b, Rodríguez Flórez & Gavilanes 2002, Correal et al. 2003, Rodríguez Cuenca 2005, Rodríguez Flórez & Colantonio 2007, Rodríguez Flórez & Pulgarin 2011, Barreto et al. 2010), Central Andes (Polanco et al. 1990, Rodríguez Cuenca 1992, Rodríguez Cuenca 2007, Delgado 1996, Gonzales-José et al. 2005, Neves et al. 2007, Delgado et al. 2010, Casas-Vargas et al. 2011), South Andes (Rodríguez Flórez 2012b), and Magdalena Basins (Sacchetti 1988).

Since the 1970s, craniometrics have suggested that in Colombia the differences between Early and Late Holocene skulls were caused by an adaptive process due to changes in the diet. In an argument analogous to that advanced by Carlson & Van Gerven (1977) for Sudanese Nubia, Rodríguez Cuenca (1992, 2007) described how the dolicocephalic form of early skulls changed to a gracile brachycephalic form solely by the influence of agriculture and sedentary lifestyle. This hypothesis has not been tested so far. This interpretation may be designed as the unalterable biological continuity throughout the Holocene hypothesis (here in after as UBCTH).

In Colombia, genetic research has yielded information that both supports and refutes the UBCTH. Most genetic studies support a single initial migration model without major changes in the mitochondrial DNA (Salzano 1957, Kirk et al. 1981, Jobim et al. 1981, Yunis et al. 2001, Keyeux et al. 2002, Matheus-Pereira et al. 2005, Melton et al. 2007, Gaya-Vidal et al. 2011). Nevertheless, several studies using mitochondrial DNA show more than a single initial migration process (Lehman & Marquer 1960, Botolini et al. 2003, Vona et al. 2005, Callegari-Jacques et al. 2007, Barreto et al. 2010, Casas-Vargas et al. 2011). Other DNA markers have not been studied so far.

This project seeks to address two issues: The first is to evaluate the UBCTH of pre-Hispanic Holocene communities in Andean Colombia through the observation and analysis of dental non-metric traits. The second is to test the assertion that all Native American populations possess dentitions whose non-metric traits may be considered Sinodontic as defined by Turner (1990). Dental non-metric traits have the potential to reveal microevolutionary trends (Hanihara 1968, Turner 1969, Turner 1987, Turner 1990, Berry 1978, Irish 1997, Guatelli-Steinberg et al. 2001, Hanihara & Ishida 2005). Most permanent crown traits have been found to be hereditary and are believed to have a strong genetic component in their occurrence and expression (Scott 1973, Harris 1977, Corruccini et al. 1986, Brown et al. 1987, Nichol 1990, Townsend 1992, Scott & Turner 1997, Scott & Turner 2006, Alt & Turp 1998). Non-metric dental crown traits are phenotypic forms of the enamel that are inherited and controlled in their location, growth and orientation (Hershkovitz 1971, Townsend & Martin 1992, Maas & Bay 1997, Peterkova et al. 2000, Ferrier & Minguillon 2003, Kolakowsky et al. 2006, Pearson et al. 2009); they result from indirect processes of mineral secretion mediated by proteins during dental morphogenesis (Bader 1965, Alexandersen & Nielsen 1970, Sharpe 1995, Thesleff & Sahlberg 1996), and they are expressed and regulated by the human genome of each individual (Zhang et al. 2001, Venugopalan et al. 2008).

Dental non-metric traits can be described as positive (cusps) or negative structures (pits, furrows and grooves), and they have the potential to be present or absent in a specific place (occurrence), in a different form or grade (expression), and in one or more members of a population group (Hrdlicka 1911, Hrdlicka 1920, Dahlberg 1945, Dahlberg 1950, Biggerstaff 1969, Kanazawa et al. 1990, Irish 1991). More than 100 non-metric dental crown and root traits have been described in the human dentition (Kraus & Furr 1953, Chagula 1960, Morris 1965, Morris 1970, Robinson & Allin 1966, Suzuki & Sakai 1973, Harris & Bailit 1980, Mizoguchi 1985, Turner et al. 1990, Burnett 1996, Valbuena 1998, Zubov 1992, Zubov 2006, Rodríguez Flórez 2012b, Stojanowsky et al. 2013). Non-metric dental crown traits are described using a broad host of names, such as features, characters, variants, aspects, attributes, polymorphisms, anomalies, discrete traits, and epigenetic or phenotype expressions (Rodríguez Flórez 2003, Rodríguez Flórez 2012a).

Studies of non-metric dental crown traits have demonstrated that they are of high taxonomic value and that they can be used to estimate biological relationships among groups (Scott & Turner 1997). The heritable quality of dental crown traits allow researchers to reconstruct and establish intergroup relationships for the comparative analysis of historical, cultural and biological development of ancient and modern human groups (Greenberg et al. 1986, Scott & Turner 1997, Scott & Turner 2006, Scott & Turner 2007). Non-metric dental crown traits seldom exhibit sexual dimorphism; statistical associations between traits are generally low, and there is considerable geographic variation in trait frequencies. Non-metric dental crown traits are easily observed and recorded and as such they thus are useful for establishing population differences according to a group's specific microevolutionary processes, which furnishes information about the displacements and contacts that have taken place (Tocheri 2002, Rodríguez Flórez 2012a).

It should also be discussed the status of the retrieved data, because it is common to find in literature total frequencies of the presence of a trait that grouped the "real" observations of some dental non-metric traits (tooth of young individuals without or very little wear) and the "presumed" observations of dental non-metric traits (individuals with marked tooth wear but with signs of previous tubercles or grooves-forrows). These aspects that cannot be absolutely controlled by the investigators alter the expression frequencies of some traits. The dental wear on scoring morphological features of tooth crowns is one of the effects attributed to missing data in archaeological samples. In a preliminary study carried out on 129 Nubians, Burnett et al. (2013) found a significant difference between in shoveling frequencies of UI1 between teeth scored as wear grades 1–2 versus 3 proposed by Smith in 1984. However, other traits, such as distal accessory ridge on UC, 4 cusped LM2, and hypocone presence on UM2 do not show significant differences. Nevertheless, a relationship between wear and trait grades (at distal loci mainly), and a decline of trait frequencies associated with increasing of occlusal wear is suggested. Although the samples used by Burnett et al. (2013) are not ideal, their conclusions are relevant to the current research. For these reasons it is advisable to select younger individuals when archaeological samples allow for a large number of them.

Turner (1979, 1985, 1987, and 1990) used dental non-metric traits to identify two basis East Asian populations, a southern "Sundadont" population and a northern "Sinodont" population. The Sinodont / Sundadont dichotomy is defined on the basis of eight key morphological traits: shoveling and double shoveling of maxillary incisors, enamel extension of maxillary first molars, root number of maxillary second premolars, pegged / reduced / congenitally absent maxillary third molars, deflecting wrinkle and root number of mandibular first molars, and groove pattern of mandibular second molars. The Sinodont pattern exhibits these traits more commonly and more intensively, whereas the Sundadont pattern exhibits fewer of these features and when present they are less fully developed (Haydenblit 1996, Scott & Turner 1997). Turner maintained that the initial settlement of the Americas was by people with the Sinodontic pattern, and consequently all Native Americans are Sinodonts as well (Turner 1984, Turner 1986, Turner 1989, Turner 1990, Turner 1992, Turner 2002, Scott & Turner 1997, Scott & Turner 2006, Scott & Turner 2007, Stojanowsky et al. 2013). Pre-Hispanic North Andean populations have not as yet been included in this model.

Material and methods

The northern region of the Andes Mountain chain, known as Northern Andes, begins in the Gulf of Guayaquil (Ecuador) and includes that portion of the Andes found in Ecuador, Colombia and Venezuela. This project focuses on different pre-Hispanic communities who lived in the Colombian Andes area. Other areas of the country such as Amazon and the Atlantic and Pacific coasts are excluded by the absence of comparable samples (except by Guajira samples from the Atlantic coast: 2 individuals). Human remains used in this study were excavated between the 1950s and 2000s by numerous archaeologists (see Rodríguez Flórez 2012a for an extensive bibliography), and are curated at multiple Institutions (see Table 1). Although 726 individuals were examined, a total of 583 individuals without several oclusal wear between 5 and 40 years old from 56 pre-Hispanic human cemeteries were included in this study (Fig. 1).

The samples date between 10,000 and 500 BP (Table 1) and are divided in four temporal periods: Early Holocene (10,000–7,000 BP), Middle Holocene (7,000–3,000 BP), Initial Late Holocene (3,000–1,500 BP), and Final Late Holocene (1,500–500 BP).

Despite of the fact that some of sites included in this investigation were excavated by archaeologists prior to modern methods, artifact associations and reported stratigraphic locations allowed for reliable estimates of the temporal contexts. Some samples that do not have calibrated radiocarbon dates were associated with a cultural complex with clear chronology through previous ceramic analyses (Rodríguez 2002), while other were isolated burials that were pooled by sex and age. This is the case of the samples of Dagua (Lopez 2002), Jamundí (Rodríguez 2002), Tierradentro (Lehmann & Marquer 1960), Quindio, Abra, Curumani, Gamarra, Cueva de Sasaima, Cueva del Indio, Cueva del Santuario, Cutiri, Malpaso, Perlas de Cuba, Turbay, Manaure, Tolima (Book of Entries, Instituto de Ciencias Naturales, Universidad Nacional de Colombia, Bogota). Because the number of the samples are small and many individuals were incomplete due to the nature of preservation in archaeological samples, we combined the isolated samples into Final Late Holocene group.

Table 1. Samples observed in this research.

Samples (Code)	Province	Chronology*	Culture / Period	Method	Location	N	n
Checua (1)	Cund.	7,800	Preceramic / EH	C14	LabUNAL	14	7
Guavio (2)	Cund.	9,360	Preceramic / EH	C14	ICNMUNAL	39	33
Nemocon (3)	Cund.	7,530	Preceramic / EH	C14	ICNMUNAL	7	5
San Pedro de Gachala (4)	Cund.	9,360	Preceramic / EH	C14	ICNMUNAL	2	2
Sueva (5)	Cund.	10,090	Preceramic / EH	C14	ICNMUNAL	1	0
Tequendama (6)	Cund.	9,740	Preceramic / EH	C14	ICNMUNAL	8	5
					Total EH	71	52
Chia III (7)	Cund.	5,040	Preceramic / MH	C14	ICNMUNAL	2	2
Aguazuque (8)	Cund.	5,030	Preceramic / MH	C14	ICNMUNAL	82	37
Mosquera-Vistahermosa (9)	Cund.	3,410	Pre-Herrera /MH	C14	ICNMUNAL	4	2
Zipacon (10)	Cund.	3,270	Pre-Herrera /MH	C14	ICNMUNAL	5	2
					Total MH	93	43
Apuló (11)	Cund.	2,400	Herrera / ILH	C14	ICNMUNAL	3	3
Malagana (12)	VC	2,500	Yotoco / ILH	C14	MN-ICANH	13	13
Cerrito (13)	VC	2,000	Ylama / ILH	RM	LabUNAL	10	9
Coronado (14)	VC	2,000	Ylama / ILH	RM	LabUNAL	42	34
Hacienda Santa Barbara (15)	VC	2,000	Ylama / ILH	RM	LabUNAL	16	12
Estadio Deportivo Cali (16)	VC	2,000	Ylama / ILH	C14	LabUNAL	10	7

Table 1. Continued.

Samples (Code)	Province	Chronology*	Culture / Period	Method	Location	N	n
					Total ILH	94	78
Guacanda (17)	VC	1,000–500	Sonso / FLH	C14	MAUnivalle	30	30
Dagua (La Granja) (18)	VC	1,000–500	Sonso / FLH	RM	MAUnivalle	3	3
La Escopeta 14 (19)	VC	1,000–500	Bolo / FLH	RM	MAUnivalle	27	27
Obando (Dardanelos) (20)	VC	1,000–500	Quimbaya / FLH	C14	MAUnivalle	93	93
Guacari (21)	VC	1,000–500	Quimbaya / FLH	RM	LabUNAL	17	15
Jamundi (22)	VC	1,000–500	Bolo / FLH	RM	MAUnivalle	13	11
Tierradentro, Corinto, Arrayanes, Cauca (23)	Ca.	1,000–500	Bolo / FLH	RM	MHNUcauca	16	16
Morro de Tulcan (24)	Ca.	1,000–500	Bolo / FLH	RM	MHNUcauca	9	9
Tambo – Alto del Rey (25)	Ca.	1,000–500	Bolo / FLH	RM	MHNUcauca	21	18
Palestina 4.1 – 4.2 (26)	Cal.	1,000–500	Quimbaya / FLH	C14	PAAerocafe	27	22
Quindío ICANH (27)	Qui.	1,000–500	Quimbaya / FLH	RM	MN-ICANH	4	4
Autopista del Café (28)	Qui.	1,000–500	Quimbaya / FLH	RM	UCaldas	3	3
Las Delicias (29)	Cund.	1,000–500	Muisca / FLH	C14	MN-ICANH	12	11
Candelaria La Nueva (30)	Cund.	1,000–500	Muisca / FLH	C14	MN-ICANH	33	27
Soacha Portoalegre (31)	Cund.	1,000–500	Muisca / FLH	C14	MN-ICANH	84	66
Marín (32)	Cund.	1,000–500	Muisca / FLH	C14	MN-ICANH	15	8
Nemocon (Ubaque) (33)	Cund.	1,000–500	Muisca / FLH	RM	MN-ICANH	2	2
Soacha Portoalegre (34)	Cund.	1,000–500	Muisca / FLH	C14	ICNMUNAL	4	3
Boavita (35)	Cund.	1,000–500	Muisca / FLH	RM	ICNMUNAL	1	1
Funza (36)	Cund.	1,000–500	Muisca / FLH	RM	ICNMUNAL	1	1
Abra (37)	Cund.	1,000–500	Muisca / FLH	RM	MN-ICANH	2	1
Cueva La Trementina (38)	Ce.	1,000–500	Tamalameque / FLH	RM	LabUNAL	3	3
Curumani (39)	Ce.	1,000–500	Tamalameque / FLH	RM	ICNMUNAL	2	1
Gamarra (40)	Ce.	1,000–500	Tamalameque / FLH	RM	ICNMUNAL	2	1
Cueva de Sasaima (41)	Sant.	1,000–500	Guane / FLH	RM	ICNMUNAL	1	1
Cueva del Indio (42)	Sant.	1,000–500	Guane / FLH	RM	ICNMUNAL	1	1
Cueva del Santuario (43)	Sant.	1,000–500	Guane / FLH	RM	ICNMUNAL	5	2

Table 1. Continued.

Samples (Code)	Province	Chronology*	Culture / Period	Method	Location	N	n
Cutiri (44)	Sant.	1,000–500	Guane / FLH	RM	ICNMUNAL	1	0
Malpaso (45)	Sant.	1,000–500	Guane / FLH	RM	ICNMUNAL	1	0
Perlas de Cuba (46)	Sant.	1,000–500	Guane / FLH	RM	ICNMUNAL	1	1
Turbay (47)	Sant.	1,000–500	Guane / FLH	RM	ICNMUNAL	1	1
Manaure (48)	Gua.	1,000–500	Wayuu / FLH	RM	ICNMUNAL	1	0
Tierranueva (49)	Gua.	1,000–500	Wayuu / FLH	RM	ICNMUNAL	1	1
Aranda (50)	Nar.	1,000–500	Piartal-Tuza / FLH	RM	MAUnivalle	2	2
Botanilla (51)	Nar.	1,000–500	Piartal-Tuza / FLH	RM	MAUnivalle	7	6
Catambuco (52)	Nar.	1,000–500	Piartal-Tuza / FLH	RM	MAUnivalle	4	4
Jamondino (53)	Nar.	1,000–500	Piartal-Tuza / FLH	RM	MAUnivalle	2	2
Las Marianas (Maridiaz) (54)	Nar.	1,000–500	Piartal-Tuza / FLH	C14	UMarianas	11	9
Nariño ICANH (55)	Nar.	1,000–500	Piartal-Tuza / FLH	RM	MN-ICANH	4	3
Tolima (56)	Tol.	1,000–500	Tolima / FLH	RM	ICNMUNAL	1	1
					Total FLH	468	410
					Total sample	726	583

*Years before present. **Provinces:** Cund: Cundinamarca, VC: Valle del Cauca, Ca: Cauca, Cal: Caldas, Qui: Quindio, Ce: Cesar, Sant: Santanderes, Gua: Guajira, Nar: Nariño, Tol: Tolima. **Periods:** EH: Early Holocene, MH: Middle Holocene, ILH: Initial Late Holocene, FLH: Final Late Holocene. **Dating method:** C14: Radiocarbon method, RM: Relative method. **Locations:** LabUNAL: Laboratorio de Antropología Fisica, Universidad Nacional de Colombia, Bogotá; ICNMUNAL: Instituto de Ciencias Naturales y Museo, Universidad Nacional de Coombia, Bogotá; MN-ICANH: Museo Nacional e Instituto Colombiano de Antropología e Historia, Bogota; MAUnivalle: Museo Arqueologico, Universidad del Valle, Cali; MHNUcauca: Museo de Historia Natural, Universidad del Cauca, Popayán; UCaldas: Universidad de Caldas; PAAerocafe: Proyecto Arqueologico Aerocafe, Palestina, Caldas; UMarianas: Universidad Las Marianas, Pasto.

Fig. 1. Location of pre-Hispanic samples of Colombia used in this study. Sampling areas are shown in gray.

The permanent teeth of 583 individuals between 5 and 40 years of age were retained for analysis of dental non-metric trait frequencies. All individuals were scored by the first author. Following the procedure of Scott & Turner (1997), if the expression of the trait was symmetrical, only one score represented the feature for the tooth in the individual. If an individual exhibited asymmetry in trait expression, the greater expression was used to represent the feature for a tooth. If only one of an antimeric pair were present, the score for the trait of that tooth represented the individual. Thus, all frequencies and averages are based on counts per individual. The decrease in the number of individuals suitable for the morphology analysis was due to the fact that in some cases the skulls had no teeth by either antemortem or postmortem tooth loss. Some teeth could not be included due to severe occlusal wear that often accompanied individuals of advanced biological age. Not all of the traits were observed in each individual. Table 1 refers to total sample, sample size, and presence.

The dental traits examined are listed in Table 2. Selection of 87 dental traits was based on the ASUDAS method (Turner et al. 1991, Scott & Turner 1997), except for traits mesial and medial trigonid crests in LM1 and LM2 (Zubov 2006). These methods were used to score the expression or grade of all dental non-metric traits. Brakpoints suggested in Scott & Turner (1997) were used to determine the dichotomized "presence" of each trait (see Table 2).

Table 2. Dental non-metric traits observed in this research.

Abbrev.	Trait	Reference	Dichotomy	Presence
1	Winging UI	Turner et al. 1991	0–1	1
2	Shoveling UI1	Turner et al. 1991	0–6	3–6
3	Shoveling UI2	Turner et al. 1991	0–6	3–6
4	Shoveling UC	Turner et al. 1991	0–6	3–6
5	Labial convexity UI1	Turner et al. 1991	0–4	1–4
6	Double shoveling UI1	Turner et al. 1991	0–6	2–6
7	Double shoveling UI2	Turner et al. 1991	0–6	2–6
8	Double shoveling UC	Turner et al. 1991	0–6	2–6
9	Tuberculum dentale UI1	Turner et al. 1991	0–6	2–6
10	Tuberculum dentale UI2	Turner et al. 1991	0–6	2–6
11	Tuberculum dentale UC	Turner et al. 1991	0–6	2–6
12	Mesial ridge (Bushmen) UC	Turner et al. 1991	0–3	1–3
13	Distal accesory ridge UC	Turner et al. 1991	0–5	2–5
14	UTO-Aztecan UP1	Turner et al. 1991	0–1	1
15	Metacone absence UM1	Turner et al. 1991	0–5	0–1
16	Metacone absence UM2	Turner et al. 1991	0–5	0–1
17	Hypocone absence UM1	Turner et al. 1991	0–5	0–1
18	Hypocone absence UM2	Turner et al. 1991	0–5	0–1
19	Metaconule UM1	Turner et al. 1991	0–5	1–5
20	Metaconule UM2	Turner et al. 1991	0–5	1–5
21	Carabelli's trait UM1	Turner et al. 1991	0–7	5–7
22	Carabelli's trait UM2	Turner et al. 1991	0–7	5–7
23	Parastyle UM1	Turner et al. 1991	0–5	1–5
24	Parastyle UM2	Turner et al. 1991	0–5	1–5
25	Parastyle UM3	Turner et al. 1991	0–5	1–5
26	Enamel extension UM1	Turner et al. 1991	0–3	2–3
27	Enamel extension UM2	Turner et al. 1991	0–3	2–3
28	Premolar root number UP1	Turner et al. 1991	1–3	2–3
29	Premolar root number UP2	Turner et al. 1991	1–3	2–3
30	Paracone accesory ridges UP1	Scott & Turner 1997	0–1	1
31	Paracone accesory ridges UP2	Scott & Turner 1997	0–1	1
32	Mesial accesory marginal tubercle UP1	Scott & Turner 1997	0–1	1
33	Distal accesory marginal tubercle UP1	Scott & Turner 1997	0–1	1
34	Mesial accesory marginal tubercle UP2	Scott & Turner 1997	0–1	1
35	Distal accesory marginal tubercle UP2	Scott & Turner 1997	0–1	1
36	Mesial accesory tubercle UM1	Scott & Turner 1997	0–1	1
37	Mesial accesory tubercle UM2	Scott & Turner 1997	0–1	1
38	Protoconule UM1	Scott & Turner 1997	0–1	1
39	Protoconule UM2	Scott & Turner 1997	0–1	1
40	Paraconule UM1	Scott & Turner 1997	0–1	1
41	Paraconule UM2	Scott & Turner 1997	0–1	1
42	Winging LI	Turner et al. 1991	0–1	1
43	Shoveling LI1	Turner et al. 1991	0–6	3–6
44	Shoveling LI2	Turner et al. 1991	0–6	3–6

Table 2. Continued.

Abbrev.	Trait	Reference	Dichotomy	Presence
45	Shoveling LC	Turner et al. 1991	0–6	3–6
46	Labial convexity LI1	Turner et al. 1991	0–4	2–4
47	Double shoveling LI1	Turner et al. 1991	0–6	2–6
48	Double shoveling LI2	Turner et al. 1991	0–6	2–6
49	Double shoveling LC	Turner et al. 1991	0–6	2–6
50	Tuberculum dentale LI1	Turner et al. 1991	0–6	2–6
51	Tuberculum dentale LI2	Turner et al. 1991	0–6	2–6
52	Tuberculum dentale LC	Turner et al. 1991	0–6	2–6
53	Mesial ridge LC	Turner et al. 1991	0–3	1–3
54	Distal accesory ridge LC	Turner et al. 1991	0–5	2–5
55	Lingual cusp variation LP1	Turner et al. 1991	0–9	2–9*
56	Lingual cusp variation LP2	Turner et al. 1991	0–9	2–9*
57	Deflecting wrinkle LM1	Turner et al. 1991	0–3	3
58	Deflecting wrinkle LM2	Turner et al. 1991	0–3	3
59	Distal trigonid crest LM1	Turner et al. 1991	0–1	1
60	Distal trigonid crest LM2	Turner et al. 1991	0–1	1
61	Protostylid LM1	Turner et al. 1991	0–7	2–7
62	Protostylid LM2	Turner et al. 1991	0–7	2–7
63	Hypoconulid LM1	Turner et al. 1991	0–5	1–5
64	Hypoconulid LM2	Turner et al. 1991	0–5	1–5
65	Entoconulid LM1	Turner et al. 1991	0–5	1–5
66	Entoconulid LM2	Turner et al. 1991	0–5	1–5
67	Metaconulid LM1	Turner et al. 1991	0–4	1–4
68	Metaconulid LM2	Turner et al. 1991	0–4	1–4
69	Enamel extension LM1	Turner et al. 1991	0–3	2–3
70	Enamel extension LM2	Turner et al. 1991	0–3	2–3
71	Mesial trigonid crest LM1	Zubov 2006	0–1	1
72	Mesial trigonid crest LM2	Zubov 2006	0–1	1
73	Medial trigonid crest LM1	Zubov 2006	0–1	1
74	Medial trigonid crest LM2	Zubov 2006	0–1	1
75	Interruption groove UI1	Turner et al. 1991	0–4	1–4
76	Interruption groove UI2	Turner et al. 1991	0–4	1–4
77	Interruption groove UC	Turner et al. 1991	0–4	1–4
78	Interruption groove LI1	Turner et al. 1991	0–4	1–4
79	Interruption groove LI2	Turner et al. 1991	0–4	1–4
80	Interruption groove LC	Turner et al. 1991	0–4	1–4
81	Groove pattern LM1 (X) grouping X4, X5, X6	Turner et al. 1991	0–1	1
82	Groove pattern LM1 (Y) grouping Y4, Y5, Y6	Turner et al. 1991	0–1	1
83	Groove pattern LM1 (+) grouping +4,+5, +6	Turner et al. 1991	0–1	1
84	Groove pattern LM2 (X) grouping X4, X5, X6	Turner et al. 1991	0–1	1
85	Groove pattern LM2 (Y) grouping Y4, Y5, Y6	Turner et al. 1991	0–1	1
86	Groove pattern LM2 (+) grouping +4,+5, +6	Turner et al. 1991	0–1	1
87	4-Cusped LM2	Turner et al. 1991	4–(5,6,7)	4

Presence / absence data were coded in Microsoft Excel (2007). The triangular matrix of pairwise Smith's Mean Measure of Divergence values (follow as MMD) were calculated with Bartlett's adjustment and Ascombe transformation for traits with fixed frequencies (i.e., 0 % or 100 %) in a sample, to normalize differences between pairs of samples, and to facilitate more proportionate comparisons (Harris & Sjovold 2004).

Principal coordinates analysis (PCA) was applied to the MMD matrix with Paleontological Statistics (PAST) Software 1.78 (Hammer et al. 2001). Finally, a discriminant function analysis (SPSS v.15) was applied to a data set of six dental non-metric traits suggested by Turner (1990) to determinate whether the Colombian samples out to be classified into Sinodont or Sundadont categories.

Actually, Turner suggests eight defining traits for the Sinodont / Sundadont division (Turner 1990), but traits as PRC UM3, three roots in LM1 were not included in analysis because they have not been observed in Colombian samples yet. Remaining features used in this classification analysis were shoveling UI1, double shoveling UI1, root number UP1, enamel extension UM1, four cusps in LM2 and deflecting wrinkle LM1. All 41 samples in Turner (1990) were included in the analysis (23 Sundadonts and 18 Sinodonts).

Results

All data frequencies are consigned in Table 3.

The MMD matrix of pooled pairwise differences between periods yields statistical differences between Early Holocene vs. Initial Late Holocene and Final Holocene samples. All other differences are statistically insignificant (Table 4).

Table 3. Distribution of dental non-metric trait frequencies in the samples.

	Early Holocene			Middle Holocene			Initial Late Holocene			Final Late Holocene		
	10,000–7,000 BP			7,000–3,000 BP			3,000–1,500 BP			1,500–500 BP		
Trait	n	k	%	n	k	%	n	k	%	n	k	%
1	41	7	0.17	30	12	0.40	38	17	0.45	176	65	0.37
2	31	12	0.39	36	25	0.69	49	40	0.82	311	289	0.93
3	20	4	0.20	22	9	0.41	31	18	0.58	193	129	0.67
4	24	5	0.21	21	4	0.19	26	5	0.19	199	27	0.14
5	31	13	0.42	36	11	0.31	49	11	0.22	308	43	0.14
6	30	7	0.23	32	13	0.41	45	20	0.44	302	142	0.47
7	18	2	0.11	22	8	0.36	30	11	0.37	190	83	0.44
8	21	9	0.43	21	6	0.29	25	5	0.20	198	47	0.24
9	30	16	0.53	34	15	0.44	47	20	0.43	308	133	0.43
10	21	6	0.29	21	11	0.52	31	17	0.55	193	111	0.58
11	22	8	0.36	20	7	0.35	24	12	0.50	190	88	0.46
12	24	3	0.13	21	1	0.05	25	1	0.04	198	5	0.03
13	23	5	0.22	21	12	0.57	24	10	0.42	190	98	0.52
14	36	0	0.00	32	0	0.00	42	0	0.00	211	2	0.01
15	43	3	0.07	38	7	0.18	65	16	0.25	318	81	0.25
16	39	3	0.08	35	4	0.11	60	6	0.10	304	28	0.09
17	42	2	0.05	38	1	0.03	64	2	0.03	312	26	0.08
18	39	3	0.08	36	4	0.11	60	13	0.22	304	68	0.22
19	41	8	0.20	38	10	0.26	64	28	0.44	300	126	0.42
20	38	1	0.03	36	1	0.03	57	2	0.04	301	8	0.03

Table 3. Continued.

	Early Holocene			Middle Holocene			Initial Late Holocene			Final Late Holocene		
	10,000–7,000 BP			7,000–3,000 BP			3,000–1,500 BP			1,500–500 BP		
Trait	**n**	**k**	**%**	**n**	**k**	**%**	**n**	**k**	**%**	**n**	**k**	**%**
21	43	8	0.19	38	8	0.21	65	12	0.18	315	95	0.30
22	39	1	0.03	36	1	0.03	59	2	0.03	302	27	0.09
23	40	1	0.03	38	1	0.03	65	0	0.00	316	2	0.01
24	38	0	0.00	34	0	0.00	60	1	0.02	315	3	0.01
25	13	1	0.08	16	2	0.13	21	1	0.05	108	7	0.06
26	32	4	0.13	31	6	0.19	54	21	0.39	273	114	0.42
27	30	3	0.10	28	4	0.14	51	17	0.33	246	99	0.40
28	7	7	1.00	9	8	0.89	23	20	0.87	58	48	0.83
29	5	5	1.00	11	10	0.91	15	13	0.87	24	22	0.92
30	36	4	0.11	22	9	0.41	44	16	0.36	233	149	0.64
31	37	1	0.03	28	2	0.07	46	11	0.24	247	123	0.50
32	36	0	0.00	22	1	0.05	43	4	0.09	229	18	0.08
33	35	0	0.00	22	1	0.05	43	3	0.07	225	11	0.05
34	37	0	0.00	28	0	0.00	46	1	0.02	246	12	0.05
35	37	0	0.00	28	1	0.04	45	3	0.07	246	18	0.07
36	42	37	0.88	38	30	0.79	64	55	0.86	310	229	0.74
37	24	16	0.67	30	18	0.60	54	21	0.39	301	112	0.37
38	42	6	0.14	38	6	0.16	60	11	0.18	300	59	0.20
39	22	2	0.09	30	2	0.07	50	3	0.06	302	14	0.05
40	40	2	0.05	36	2	0.06	60	5	0.08	303	26	0.09
41	21	2	0.10	28	1	0.04	50	3	0.06	302	7	0.02
42	33	2	0.06	35	1	0.03	63	2	0.03	129	17	0.13
43	32	2	0.06	38	4	0.11	66	14	0.21	223	63	0.28
44	12	1	0.08	22	1	0.05	41	8	0.20	112	23	0.21
45	17	1	0.06	16	1	0.06	58	7	0.12	218	23	0.11
46	32	3	0.09	36	1	0.03	65	4	0.06	221	13	0.06
47	32	2	0.06	34	1	0.03	65	11	0.17	221	28	0.13
48	12	1	0.08	22	2	0.09	41	2	0.05	112	7	0.06
49	17	1	0.06	16	1	0.06	58	4	0.07	218	12	0.06
50	30	0	0.00	34	2	0.06	61	4	0.07	220	12	0.05
51	12	0	0.00	22	2	0.09	41	4	0.10	110	12	0.11
52	16	1	0.06	16	1	0.06	52	6	0.12	210	23	0.11
53	17	0	0.00	16	0	0.00	52	1	0.02	214	3	0.01
54	17	0	0.00	16	0	0.00	52	0	0.00	214	1	0.00
55	28	4	0.14	21	3	0.14	42	13	0.31	193	55	0.28
56	32	3	0.09	28	3	0.11	49	19	0.39	216	43	0.20
57	31	5	0.16	22	4	0.18	33	14	0.42	276	132	0.48
58	18	2	0.11	19	1	0.05	26	2	0.08	89	9	0.10
59	31	1	0.03	22	1	0.05	32	4	0.13	270	31	0.11
60	18	0	0.00	18	0	0.00	25	0	0.00	90	1	0.01
61	32	2	0.06	19	1	0.05	26	5	0.19	88	12	0.14
62	18	0	0.00	19	0	0.00	26	1	0.04	90	1	0.01
63	32	30	0.94	22	21	0.95	33	31	0.94	274	261	0.95
64	18	11	0.61	19	10	0.53	26	17	0.65	89	59	0.66
65	32	13	0.41	22	10	0.45	33	15	0.45	275	149	0.54
66	18	1	0.06	19	1	0.05	26	3	0.12	88	8	0.09
67	32	1	0.03	22	1	0.05	33	1	0.03	270	4	0.01

Table 3. Continued.

	Early Holocene			Middle Holocene			Initial Late Holocene			Final Late Holocene		
	10,000–7,000 BP			7,000–3,000 BP			3,000–1,500 BP			1,500–500 BP		
Trait	**n**	**k**	**%**	**n**	**k**	**%**	**n**	**k**	**%**	**n**	**k**	**%**
68	18	0	0.00	18	1	0.06	26	3	0.12	88	7	0.08
69	21	2	0.10	14	1	0.07	22	2	0.09	165	17	0.10
70	11	1	0.09	12	1	0.08	14	1	0.07	49	3	0.06
71	31	0	0.00	22	0	0.00	33	1	0.03	275	4	0.01
72	18	0	0.00	19	1	0.05	26	1	0.04	89	1	0.01
73	31	0	0.00	22	0	0.00	33	1	0.03	275	2	0.01
74	18	0	0.00	19	0	0.00	26	0	0.00	89	1	0.01
75	31	1	0.03	36	1	0.03	49	1	0.02	311	9	0.03
76	20	5	0.25	22	5	0.23	31	19	0.61	193	116	0.60
77	24	1	0.04	21	1	0.05	26	2	0.08	199	5	0.03
78	32	0	0.00	38	0	0.00	66	0	0.00	223	1	0.00
79	12	1	0.08	22	1	0.05	41	1	0.02	112	3	0.03
80	17	1	0.06	16	1	0.06	58	2	0.03	218	5	0.02
81	31	4	0.13	19	2	0.11	33	5	0.15	276	35	0.13
82	31	25	0.81	19	14	0.74	33	26	0.79	276	218	0.79
83	31	2	0.06	19	3	0.16	33	2	0.06	276	23	0.08
84	18	1	0.06	22	2	0.09	26	1	0.04	89	11	0.12
85	18	5	0.28	22	7	0.32	26	5	0.19	89	17	0.19
86	18	12	0.67	22	13	0.59	26	20	0.77	89	61	0.69
87	18	11	0.61	22	10	0.45	26	6	0.23	86	19	0.22

Table 4. MMD matrix calculated. Values include Barttlet correction and Ascombe transformation.

	EH	MH	ILH	FLH
EH	0	–0.0190962	0.0220114	0.0558121
MH	0.0449308	0	–0.0085869	0.0119676
ILH	0.0167286	0.0318799	0	–0.003809
FLH	0.0290314	0.0131468	0.0052473	0

Above zero are MMD values. Below zero are 2SD values.

The PCA pairwise MMD values by chronological period show that there are no clear groups in the first principal component (PC1 = 68.1 %). The second principal component (PC2 = 25 %) shows a weak affinity between the Initial Late Holocene and Final Late Holocene periods. Periods were very distant from one another in the graph. The PCA analysis shows one possible group that associates the Initial Late Holocene with Final Late Holocene samples (Fig. 2).

The discriminant function analysis identifies the Early Holocene samples as Sundadonts (Table 5), while other samples were classified as Sinodonts. Classification probability and Mahalanobi's distance from centroid indicates that FLH samples are the most Sinodontic populations, even more than ILN or MH samples. EH samples show typical Sundadontic dentitions.

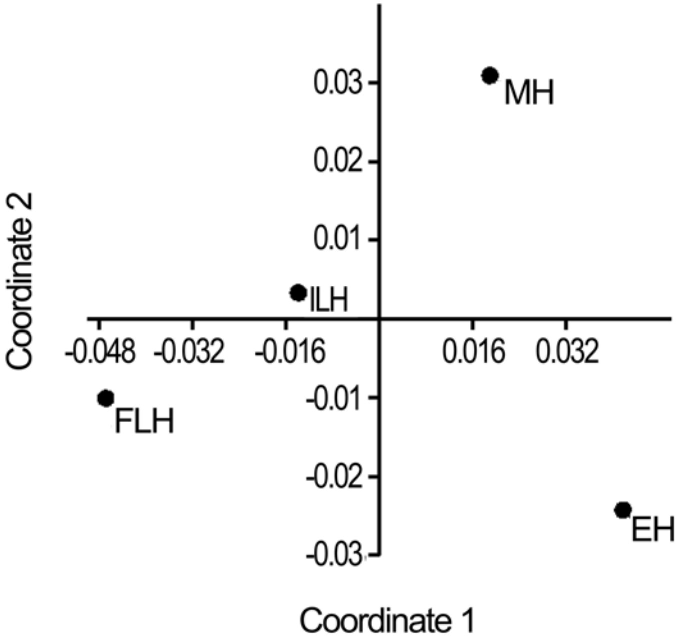

Fig. 2. PCA analysis.

Table 5. Discriminant analysis of five dental morphological traits between pre-Hispanic Colombian Northern Andes samples and Asian populations.
a. Detailed discriminant analysis using Turner's published dental frequencies for Sinodont and Sundadont populations. Distances from centroids and classification probability.

Sample	Initial group	Predicted group	Classification probability	Mahalanobi's distance from centroid
Early Thailands	Sundadont	1	0.9877	0.0002
Bangkok	Sundadont	1	0.1724	1.8619
Thai recent	Sundadont	1	0.9877	0.0002
Early Laos / Vietnam	Sundadont	1	0.6814	0.1686
Cambodia / Laos	Sundadont	1	0.6814	0.1686
Annam / Tonkin	Sundadont	2	0.2833	1.1512
Burma	Sundadont	1	0.2067	1.5943
Andaman	Sundadont	1	0.4439	0.5862
Early Malay Arch.	Sundadont	1	0.6301	0.2319
Malay / Java	Sundadont	1	0.4439	0.5862
Leang Tjadang	Sundadont	1	0.9311	0.0075
Borneo	Sundadont	1	0.7883	0.0721
Philippines	Sundadont	1	0.2215	1.4945
Taiwan prehistoric	Sundadont	2	0.3898	0.7395
Jomon	Sundadont	1	0.7110	0.1372
SW Jomon	Sundadont	1	0.5805	0.3054

Table 5.a. Continued.

Sample	Initial group	Predicted group	Classification probability	Mahalanobi's distance from centroid
Jomon Tsukomo	Sundadont	1	0.4439	0.5862
Jomon Yoshiko	Sundadont	1	0.1601	1.9730
Jomon Hokkaido	Sundadont	1	0.9557	0.0031
Ainu 1 / 2	Sundadont	1	0.8434	0.0390
Ainu Sakhalin	Sundadont	2	0.6644	0.1883
Ainu Hokkaido 1	Sundadont	1	0.0288	4.7772
Ainu Hokkaido 2	Sundadont	1	0.8193	0.0522
South China 1 / 2	Sinodont	2	0.6758	0.1748
Hong Kong recent	Sinodont	2	0.1985	1.6537
An-yang China	Sinodont	2	0.1799	1.7988
China	Sinodont	2	0.7704	0.0852
Chinese (Thai)	Sinodont	2	0.5647	0.3317
Lake Baikal	Sinodont	2	0.1380	2.1999
Buriat 1 / 2	Sinodont	2	0.3241	0.9725
Urga / Mongol 2	Sinodont	2	0.4394	0.5978
Mongol 3	Sinodont	2	0.3164	1.0039
Japan	Sinodont	2	0.5279	0.3983
Japan Hiogo	Sinodont	2	0.9497	0.0040
Japan Kamakura	Sinodont	2	0.2833	1.1512
Japan recent	Sinodont	2	0.9497	0.0040
Japan Kanto	Sinodont	2	0.7704	0.0852
Amur	Sinodont	2	0.6644	0.1883
NE Siberia	Sinodont	2	0.4728	0.5154
Eskimo / Greenland	Sinodont	2	0.8252	0.0488
Aleut	Sinodont	2	0.8933	0.0180
EH-Colombia	Ungrouped	1	0.5596	0.3404
MH-Colombia	Ungrouped	2	0.8808	0.0225
ILH-Colombia	Ungrouped	2	0.4394	0.5978
FLH-Colombia	Ungrouped	2	0.1201	2.4155

Table 5.b. Discriminant analysis using Turner's published dental frequencies for Sinodont and Sundadont populations: Percentage of correct discrimination among populations (n = 45). Maximum classification achieved: 100 %, with 5 discriminant dental traits.

Classification		Predicted groups	
Actual group	**n**	**1**	**2**
Sundadont (1)	23	20	3
Sinodont (2)	18	0	18
Ungrouped	4	1	3
TOTAL	45	21	24

Table 5.c. Classification of the Colombian Northern Andes samples using the function derived from Turner's data.

Population	Predicted group allocation	
	Sundadonts	***Sinodonts***
Early Holocene	X	–
Middle Holocene	–	X
Initial Late Holocene	–	X
Final Late Holocene	–	X
TOTAL	1	3

Discussion

In a general way (all periods pooled), Northern Andes pre-Hispanic dentitions are characterised by high frequencies of shoveling on UI1 (85.7 %), root number on UP1 (85.6 %) and UP2 (90.9 %), and the hypoconulid on LM1 (95 %). There are differences in the incidence of dental morphological traits of the permanent dentition among the four pre-Hispanic periods studied here (Early Holocene, Middle Holocene, Initial Late Holocene and Final Late Holocene). Early Holocene samples exhibit significant differences in the frequencies of some dental morphological traits. Such differences may be due to the fact that the Early Holocene populations have a different origin than the Late Holocene populations in Northern Andes region. Middle Holocene populations show intermediate frequencies, so it is possible to assume that during the Middle Holocene period the morphological pattern in the dentition of Northern Andes human groups change drastically. This phenomenon was possibly caused by contact between dentally different groups.

From a regional point of view, the results obtained in this research run contrary to the expectations of the UBCTH, as the results accord better with a dental model showing that the process of pre-Hispanic settlement of the South America involved more than one specific biological component (Rodríguez Flórez 2013, Rodríguez Rodríguez Flórez & Colantonio 2013, Rodríguez Flórez & Tabarev 2012, Rodríguez Flórez & Tabarev 2014). Differences in dental morphological variation can be suggested in pre-Hispanic populations from Northern Andes. Recent robust data from molecular biology, osteology, and archaeology converge to suggest that the peopling of the Americas occurred in two possible pulses during the Holocene (Pitblado 2011). Some recent molecular evidence supports the finding of this research (Bortolini et al. 2003, Jones 2003, Bandelt et al. 2003, Foster 2004, Starikovskaya et al. 2005, Derenko et al. 2007, O'Rourke 2009, Perego et al. 2009), and may corroborate the appearance of an Early Holocene population possessing a Sundadontic dental pattern far different from the Sinodontic dental pattern found among the new groups during the Middle Holocene that appear to have resulted in a progressive replacement of these early Sundadontic population.

In the context of the Northern Andes, the molecular data suggest a joint process, with a genetic continuity of mitochondrial markers B and C, coupled with a later addition of markers A and D in Central Andes of Colombia (Casas-Vargas et al. 2011). In a continental context, some craniometric findings support this approach, in the sense that they have described two biological components that differ between the early and subsequent late pre-Hispanic groups in the Americas (Lahr 1995, Powell & Neves 1999, González-José et al. 2001, González-José et al. 2005, González-José et al. 2008, Sardi et al. 2005, Sardi et al. 2006, Neves et al. 2007, Perez et al. 2007, Hubbe et al. 2007, Hubbe et al. 2011, Varela et al. 2008, Pucciarelli et al. 2010, de Azevedo et al. 2011).

The dental analysis conducted here shows that some trait frequencies in the Middle Holocene sample (see Table 3), such as shoveling on UI1, UI2, double shoveling on UC, metacone absence on UM1, hypocone absence on UM2, metaconule on UM1, enamel extension on UM1, shoveling on LI1, deflecting wrinkle on LM1, interruption groove on UI2, show intermediate frequencies, indicating limited genetic continuity between groups of Early Holocene and Middle Holocene. Such findings suggest that the entrance of different migrant populations may have occurred prior (or during) to the Middle Holocene period, in some places of the Northern Andes, especially at the Atlantic coasts, in the Western and Central Andes and their corresponding interandean valleys in the Cauca and Magdalena basins. At this point, it is possible to consider that the biological continuity between pre-Hispanic groups of Colombia has been defined by two major different populations: people with dentitions with a similar pattern to Sundadonts (Early Holocene samples), and people with a clear Sinodont pattern (all other samples); and at some point, the contact and replacement occur during the Middle Holocene period.

The original gene pool of pre-ceramic hunter-gatherers was enriched by the contribution of new groups that began its foray into these territories. Unfortunately, inland vs coastal comparisons could not be performed in this research, because the coastal samples are very few (6 individuals): Cueva Trementina (3), Curumani (1), Gamarra (1), and Tierranueva (1). Nevertheless, further research needs to be carried out regarding these assumptions.

Focus on Northern Andes Area; a previous work (Rodríguez Flórez 2012a) compared 15 dental non-metric traits among Initial Late and Final Late Holocene pre-Hispanic samples of Colombia. The samples were grouped by archaeological cultures, and the results indicated that there were at least two biological components present in this time (3,000– 500 BP). The first includes groups from the North coast, West-Central and Central Andes of Colombia, who appear to have arrived in this region from Central America and the Caribbean to which they share closest affinities. The second includes groups of the South-West of Colombian Andes, that express a genetic mobility in a South to North way on the Colombian Andes, very close to Central Andes samples (Peru and Ecuador samples principally). In this research, a linear regression analysis was made, and the odontochronologic calculation of the time of divergence of both biological components was estimated at 4,126 years BP (r = 68 %). These analyses only consider 15 comparable dental non-metric traits included in the ASUDAS methodology (Rodríguez Flórez 2012a).

Consequently, our findings using dental traits correspond to some archaeological interpretations on migrations in the region. By incorporating the dental data into an archaeological scenario, it is possible to fit the initial process of settlement of Northern Andes during the Early Holocene period. The pre-ceramic record shows that the Atlantic coast of Colombia served as a corridor and population dispersion in two main directions: part of these groups addressed in West-East direction following the route of the Atlantic coast, surrounding the Guajira peninsula until reach the gulf of Venezuela branching out later in the Amazon (Reichel-Dolmatoff 1965, Langebaek

1992, Jaimes 1999), while the other groups proceeded toward the interandean valleys following a North-South route, aided by the main rivers such as the Atrato (Bedoya & Naranjo 1985), Sinu (Correal 1977), San Jorge (Plazas & Falchetti 1981), the Canal del Dique, the Delta of the Magdalena (Reichel-Dolmatoff 1997, Stahl & Oyuela 2007), and the Ciénaga Grande de Santa Marta (Bischof 1966). This process allowed people to reach other parts of Colombia, such as the Pacific coast and the Macizo Antioqueño (Correal 1989), as well as the higher thermal floors in the Western and Central arms of Andes by following the middle of the Cauca River (Salgado 1986, Salgado et al. 1995, Herrera et al. 1992, Gnecco 1999) until they reached the Colombian Macizo in the South of the country (Reichel-Dolmatoff 1978, Gnecco & Salgado 1989, Uribe & Lleras 1984). Following the route of the Magdalena River they reached other parts of the Central and East arms of Andes (Schottelius 1946, Correal 1979, 1989, Correal & van der Hammen 1977, Castaño & Davila 1984, Cadavid 1989, Henderson & Ostler 2005).

The Early and Middle Holocene samples included in this research provide evidence of this first human movements and settlement in the region of the Sabana de Bogota principally (Central Andes of Colombia). A period of pre-ceramic cultural stability is set in these areas of Colombia during the Middle Holocene (Correal 1979, Neves et al. 2007). At the beginning of the Initial Late Holocene (designated in Colombian archaeology as Formative or Early Regional Development Period), drastic cultural changes appeared that influenced the development of societies in all areas of the country. From then on, human populations are characterised by high and increasingly cultural diversity, coupled with trade over long distances throughout these territories (Mora 1985, Herrera 1987, Eckert & Trinborn 2002, Rodríguez 2002). It is important to note that this process occurs after a period of 2,000 years (between 6,283 and 4,080 BP) of intense volcanic activity in the Central and Western arms of Andes in Colombia, especially in the Colombian Macizo in the Southern of the country (Banks et al. 1997).

As noted earlier, six dental traits recorded here were compared with the Sinodont / Sundadont patterns using as reference the values of Asian Sinodonts and Sundadonts (Turner 1990). This comparison identified Early Holocene samples as Sundadonts, while Middle Holocene, Initial Late and Final Late Holocene samples are all Sinodonts. Nevertheless, Early Holocene dentitions do not follow a strict Sinodont classification. That is, the most ancient Northern Andean populations they fit the Sundadont pattern described by Turner (1984, 1986, and 1990) and colleagues (Scott & Turner 1997, Scott & Turner 2006, and Scott & Turner 2007). It is clear that the number, form, timing, route, and origin of early migrants into the New World are still controversial issues in human evolution (Hydenblit 1996).

Observing the Early Holocene samples of Northern Andes, frequencies of shoveling on UI1 (39 %) are similar to those reported by Turner (1987, 1990) in Jomon (36.1 %), Philippines (42.7 %), recent Thailand (37 %), and by Matsumura & Hudson (2005) in Early and Middle Holocene Flores and Malay (37 %), Early Holocene Vietnamese and Laotians (38.4 %), Loyalty Islanders (38.9 %), and Andaman Islanders (42.8 %). Frequencies of double shoveling UI1 (23 %) in EH samples are similar to those reported by Turner (1987, 1990) in NE Siberia (25 %), S China (24.2 %), Thai recent (25.4 %), Burma (23.1 %), Jomon (22.2 %), Ainu Hokkaido 2 (23.3 %), and by Scott & Turner (2006) in Southeast Asia (20.7 %). The trait enamel extension UM1 in EH (13 %), and MH (19 %) samples of Northern Andes shows similar frequencies to those reported by Turner (1990) in Jomon (13.1 %), and Jomon Hokkaido (13.4 %). The trait deflecting wrinkle LM1 in EH (16 %), and MH (18 %) samples of Northern Andes shows similar frequencies to those reported by Turner (1987, 1990) in recent Japan (14.9 %), S China (17.9 %), Philippines (18.9 %), recent Thailand (18.8 %), Australia Torres (16.2 %), Thai recent (17 %), Andaman (16.7 %), Japan Hiogo (15.9 %), and Japan Kanto (15.6 %), and by Matsumura & Hudson (2005) in Negritos (16.7 %). Finally, the trait four cusps LM2 in EH (33.3 %), and MH (42 %) samples of Northern Andes shows similar frequencies to those reported by Turner (1987, 1990) in Early Mainland Southeast Asia (38.7 %), recent Southeast Asia (31.6 %), East Malay (45.8 %), early Thailand (37.7 %), early Laos and Vietnam (33.3 %), Anam and Tonkin (33.3 %), Malay/Java (36.8 %), Jomon Yoshiko (34 %), Jomon Hokkaido (35.6 %), and by Scott & Turner (2006) in Southeast Asia (32.7 %). The data reported here suggest that the Sinodont pattern in Northern Andes area show chronological and geographical limits.

On the other hand, some methodological aspects may be mentioned from the findings obtained in this research. A high number of young individuals (especially preceramic hunter-gatherers of the Early Holocene period) provided the greatest amount of morphological information, since their teeth lacked occlusal wear. It is important to mention that most of the American pre-ceramic samples presented high levels of wear (Scott & Turner 1997), and did not allow for the observation of some traits examined with the methodology used here.

The Early and Middle Holocene collections of Colombia, in particular those of the Sabana de Bogota, presented a good conservation status and a large number of young individuals that facilitated comparative analyses (some individuals included in this research present mixed dentitions = deciduous and permanent teeth). With regard to the implementation of the methodologies used here, it is necessary to admit that some of the traits were difficult to observe in these archaeological samples, in particular root traits, since in most cases, the conditions for the preservation of teeth out of the alveoli is bad (samples of Initial Late and Final Late Holocene especially).

As mentioned by Turner (2002), methodological impediments as dental wear can produce dental trait frequencies that can make a Sinodontic population appear as a Sundadontic population. Regarding the observation of dental traits, it is important to note that the weak degrees (grades 1–3 in most cases) are presented in large proportion between the samples of the Early Holocene. The strong degrees (grades 4 or more) were expressed with greater frequency in the Initial Late and Final Late Holocene samples. This differential expression of degrees of some ASUDAS traits as shoveling, tuberculum dentale, the metaconule, and the Carabelli's trait on upper arcade, the hypoconulid, and the entoconulid in the lower arcade can be related to the geography and the period of cultural develop. Contrary, some present traits such as labial convexity, the protostylid, and interruption groove are very marked in samples of Early Holocene and Middle Holocene, and weak in Initial Late and Final Late Holocene samples. The main of occlusal wear effects in scoring dental non metric traits may also have some kind of effect on these observations, even though the individuals selected were mostly young.

In conclusion, this project was designed to address microevolutionary processes among the people of Colombia. These data add to the discussion regarding the peopling of the South America and clarify the settlement processes in the Northern Andes prior to the Spanish conquest. The UBCTH in Colombian Northern Andes is rejected by this study on dental morphological trait frequencies. Instead, our data suggest a scenario of limited biological replacement of initial Early Holocene (10,500–7,000 BP) Sundadontic groups by Sinodontic groups during the subsequent Middle Holocene period (7,000–3,000 BP).

The interpretation may have to be revised in the future when Pacific Coast, Atlantic Coast and the Amazon pre-Hispanic samples are available. As such, the current interpretation only applies to the Colombian Andean area and its extensions into Venezuela and Ecuador.

Dental data reported here can be aligned with other linguistic, archaeological, and genetic data to contribute to the understanding of the processes of human settlement in the past of Northern Andes.

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