Faculty of Medicine - University of Coimbra

Integrated Master in Dentistry

Accuracy of intraoral digital impressions and conventional impressions: at the level of partial removable prostheses.

Supervisor: Pedro Miguel Gomes Nicolau, DMD, PhD

Co-Supervisor: Rita Joana Amaral Reis, DMD

Author: Vera Lúcia Azevedo de Sousa

Coimbra, 2017

Accuracy of intraoral digital impressions and conventional impressions: at the level of partial removable prostheses.

Sousa V*; Reis R**; Nicolau P***

*5th year student of Integrated Master in Dentistry at the Faculty of Medicine of the University of Coimbra - Area of Dentistry

**DMD, Invited Assistant, Faculty of Medicine of the University of Coimbra – Area of Dentistry

*** DMD, PhD, Auxiliary Professor, Faculty of Medicine of the University of Coimbra – Area of Dentistry

Institution Adress:
Area of Dental Medicine, Faculty of Medicine, University of Coimbra

Av. Bissaya Barreto, Blocos de Celas
3000-075 Coimbra
Telef: +351 239 484 183

Fax: +351 239 402 910

Coimbra, Portugal

E-mail: veraazevedodesousa@gmail.com

Summary

Resumo

Introdução: A introdução do sistema CAD/CAM permite utilizar ficheiros STL obtidos por uma câmara intra-oral para confeção de próteses removíveis em modelos 3D, com a ausência do envio de modelos de gesso ou impressões convencionais em silicone ou alginato para o laboratório.

Materiais e Métodos: Realizou-se uma revisão bibliográfica na base de dados *PubMed* com a combinação de palavras-chave e conectores Booleanos: **"removable dentures" OR "removable prostheses" AND ("digital impression technique" OR "CAD/CAM") NOT "fixed prostheses"**, seguida de uma segunda revisão nas bases de dados *PubMed*, *Web of Science*™, *B-On*, *ClinicalKey*® e *ScienceDirect* com a combinação: **"CAD/CAM" AND "Intraoral digital impression" AND "Prosthodontic"**. O estudo clínico piloto consistiu na realização, em 3 doentes, de duas impressões convencionais em alginato e duas impressões digitais intraorais com o scanner Cerec Omnicam (Dentsply Sirona, Wals, Áustria), efetuadas pelo mesmo operador. Os dois modelos de gesso obtidos das impressões convencionais foram digitalizados, pelo mesmo scanner, e as duas imagens resultantes foram sobrepostas, assim como as duas imagens das impressões digitais. Seguiu-se a análise através de medições lineares no software Cerec inLab SW 15.0 (Sirona Dental Systems, Wals, Áustria).

Resultados: Na revisão bibliográfica obtivemos 35 artigos na *Pubmed.* Após leitura do título, abstract e aplicando os critérios de inclusão, selecionamos 4 artigos. Atráves das bases de dados *ClinicalKey*®, *B-On*, *Web of Science*™ *e ScienceDirect* selecionamos 14 artigos e 5 por referência cruzada manual, ficando com 23 artigos. Na análise das imagens, realizamos medições lineares, horizontais e verticais, para verificar a exatidão e a precisão, respectivamente. A exatidão variou em média 0,31mm e 0,49mm entre o modelo de referência e os modelos virtuais obtido pela digitalização do modelo de referência e da digitalização intra-oral, respectivamente. A precisão das impressões digitais intra-orais apresenta melhores resultados do que as impressões convencionais em desdentações parciais com pequenas áreas edêntulas.

Conclusão: Dentro das limitações deste estudo, podemos verificar que análise da precisão das impressões digitais apresentou melhores resultados do que os modelos de referência digitalizados em desdentados parciais com pequenas áreas êdentulas. Neste estudo piloto verificou-se que a precisão da técnica de impressão digital é influenciada pelas condições da cavidade oral e pelo tipo de substrato digitalizado, já as diferenças na exatidão podem atribuir-se à mudança dimensional do alginato e distorção dos modelos de referência. A análise da exatidão da técnica de impressão convencional é influenciada pelos problemas

intrínsecos à mesma e por não terem sido utilizados pontos de referência precisos para efetuar as medições.
Palavras-chave: impressão intraoral digital, impressão convencional, prótese parcial removível, rebordos alveolares, análise digital por sobreposição, medições lineares verticais e horizontais, Cerec Omnicam, Cerec inLab SW15.0.

Abstract

Introduction: The introduction of CAD/CAM technology allows the use of STL files obtained by an intraoral camera for production of fixed and removable prostheses, without sending cast stone models or conventional intraoral impressions in silicone or alginate to the laboratory.

Materials and Methods: A literature review was carried out through the search engine: *Pubmed*, using the combinations of key-words and Boolean connectors: **"removable dentures" OR "removable prostheses" AND ("digital impression technique" OR "CAD-CAM") NOT "fixed prostheses"** and then a second literature review was carried out through the search engines: *PubMed*, *Web of Science^{TM}*, *B-On*, *ClinicalKey®* and *ScienceDirect*, using the combination:**"CAD/CAM" AND "Intraoral digital impression" AND "Prosthodontic".** A clinical pilot study was performed with 3 patients, each patient had two conventional impressions in alginate and two intraoral digital impressions done with the Cerec Omnicam scanner (Dentsply Sirona, Wals, Austria), by the same operator; posteriorly, two stone cast models were also scanned. The two scans of the digital impressions were overlapped as were the two scans the stone cast models and analyzed in the Cerec inLab SW 15.0 software (Sirona Dental Systems, Wals, Austria).

Results: In the literature review, we obtained 35 articles in the *PubMed*. After reading title, abstract and applying the inclusion criteria, we selected 4 articles. Through search engine *ClinicalKey®*, *Web of Science^{TM}*, *B-On* and *ScienceDirect* were selected 14 articles and 5 articles by manual cross reference, staying with 23 articles. In the images analysis, linear measurements, horizontal and vertical were obtained, to verify trueness and precision, respectively. The trueness varied in mean 0.31mm and 0.49mm between the reference model and the virtual models obtained by the scan of the reference model and the intraoral scan, respectively. The precision of intraoral digital impressions are better than conventional impressions in partial edentulous jaws with small edentulous areas.

Conclusion: Within the limitations of this study, we can verify that the precision analysis of intraoral scans was better than the scans of reference model in partial edentulous jaws with small edentulous areas. In this pilot study we verified that the precision of digital impression technique is influenced by the oral cavity conditions and by substrate scanning and the differences in the trueness can be attributed to the dimensional change of the alginate and distortion of the reference models. The trueness analysis of the conventional impression technique was influenced by intrinsic problems and the fact that precise reference points for measurements were not used.

Key-words: intraoral digital impression, conventional impression, partial removable prostheses, alveolar ridges, digital analysis by superimposing, vertical and horizontal linear measurements, Cerec Omnicam, Cerec inLab SW 15.0.

Introduction

The introduction of CAD/CAM technology in dental medicine has increased the treatment options available to the clinicians and has developed in several areas like fixed and removable prosthodontics, implantology and orthodontics.[1,2,3]

In removable prosthodontics, an important step is the impression taking. A good impression should capture soft tissues, contours of remaining teeth, funtional depth and width of the edentulous areas without applying excessive pressure on the soft tissues. However, during the conventional impression technique with a tray, there is always some pressure on the soft tissues not only due to the viscosity of the impression materials but also due to the pressure performed by the clinician. The ability of digital impression to perform accurate impressions without applying pressure on soft tissues suggests the application of intraoral cameras at this stage and some researchers advocate that may result in the best seat of a partial removable prostheses.[4]

Digital intraoral impression is the first step of the CAD/CAM system[2], allowing the use of STL files obtained by an intraoral camera for production of fixed and removable prostheses, without sending stone cast models or conventional intraoral impressions in silicone or alginate to the laboratory, instead sending the digital data to a milling machine for fabrication.[2,5]. There are two methods to take digital impression, direct intraoral scanning, eliminating some problems associated with conventional impressions, as distortion of impression material and disproportionate water/powder ratio of dental alginate and dental plaster, and indirect extraoral scanning of the stone cast model, after impression taking.[2,3,6,7,8] The careful data acquisition and accurate implementation of clinical procedures are essential for a successful rehabilitation.[1]

According to the literature, the digital intraoral impressions have the following advantages: decrease of worktime with absence of tray selection, material prey, disinfection and sending to laboratory; cost savings associated with absence of trays, impression material,[5,9] shipping and delivery costs[5,6]; allows to store processed data for later use in the follow up period[5]; eliminates problems associated with impression materials like disproportion in the mixture of different components, tray distortion, inappropriate soft tissue handling, dimensional changes after polymerization and stone cast distortion. [2,5,9,10,11]. All these factors contribute to the loss of impression accuracy.[5] An additional advantage is the improvement of patient confort,[5,6,9] in some clinical situations, like for patients with gag reflex,[2,5] those with special needs or anxiety[1], allergy to certain impression materials[1,2,12,13] and in cases of trauma or extensive surgical procedures that cause severely limited mouth opening[14,15]. The scanner obtains images in real time, allowing the clinician to identify poor areas and perform additional scans.[1,2,5,9] Rapid and better communication with the laboratory, where the design of the structure can be approved and modified before the manufacturing. [9,11,12]

However, despite its advantages, the digital intraoral impressions also present some limitations like the costs of the hardware and software and the difficulty to capture smooth-surface structures covered with blood and saliva[3,5,15] and the dynamic registration of soft tissue.[3,12,13] In fact, in Kennedy Class I or II, there is an inability to digitalize the physiologic extensions of soft tissue.[1] Another limitation is the large size of the intraoral scanner tip, that may prevent the complete scanning of palatal tissue morphology in patientes with deep palate[10,12,13] and accuracy decreases when in gingiva and palate there are no clear anatomic landmarks[2]. As accuracy depends on the operator and the system used, so the clinician and the dental technician need a learning curve in order to become proficient in the digital workflow.[10,12,13]

Accuracy is described by precision and trueness. Precision represents the degree of reproducibility between repeated measurements of test scan and trueness is defined as the closeness between reference scan and the test scan.[2,3,6,7,9,10,16,17,18,19,20]

Generally, the accuracy of conventional and digital impressions is studied by *in-vitro* techniques.[10,20] A reference model is fabricated, which is scanned with a highly accurate scanner. Conventional impressions are made and the same highly accurate reference scanner scans the respective stone cast models and these scans are compared with the scan of the fabricated reference model. The same happens with intraoral digital impressions, which are compared with the scan of the fabricated reference model. The scans are converted to STL file and a 3D evaluation software is used. [6, 7,18, 19,20, 21,22] Some authors present good results in clinical situations, such as partial removable prostheses in Kennedey Class III, modified Kennedy Class I and II and implant-supported fixed complete dental prostheses, because the capture of physiological extensions of the soft tissue is not so critical.[1,12]

At present, the bibliography at this digital age has undergone overwhelming growth. However there are yet some unanswered questions like: “Are digital impressions as accurate as conventional impressions in the rehabilitation of patients with removable dentures?” In the literature review carried out, considering the small number of articles and the low scientific evidence revealed, it was not possible to obtain articles comparing conventional impressions and digital impressions, in terms of accuracy in edentulous areas, *in vivo*.

For this reason, this literature review and pilot study aim to evaluate the precision/reproducibility of either two consecutive conventional impressions and two digital intraoral impressions of edentulous areas, performed by the same clinician, and thus evaluate the trueness within each method, in terms of horizontal and vertical linear measurements.

Materials and Methods

1. Literature review

At a first phase, a literature review was carried out through the following search engine: *PubMed*, using the following combination of key-words and Boolean connectors:

“removable dentures” OR “removable prostheses” AND (“digital impression technique” OR “CAD-CAM”) NOT “fixed prostheses”.

The inclusion criteria were articles published between 2007-2017, related to partial and total removable prostheses, both portuguese and english and that made the comparison between digital and conventional impression techniques in terms of accuracy.

At a second phase due the low number of articles and low scientific evidence found, a search was made on these search engines: *PubMed*, *Web of Science*™, *B-On*, *ClinicalKey*® and *ScienceDirect*, using the following combination of key-words and Boolean connectors:

“CAD/CAM” AND “Intraoral digital impression” AND “Prosthodontic”

The inclusion criteria were additional articles related with fixed prosthodontics that compare digital and conventional impression techniques.

2. Clinical Protocol

2.1. Patient Selection

In this study three patients were selected with no signs of relevant systemic or oral diseases, including severe periodontal disease, and presented partial edentulous areas.

The procedures and the objectives of the present study were explained to the patients and they agreed and signed an informed consent.

We performed two consecutive conventional impressions (I1 and I2) and two consecutive digital impressions (I1 and I2), on the same day and by the same operator.

2.2. Conventional Impression Technique

For all conventional impressions, the material used was alginate (Sr-dupalflex-Ivoclar®), in the proportion of 3:3 and two equal impression trays for each patient. Type III dental stone (Hydrock-Kerr®) was poured over the impressions in the following 15 minutes and the reference models were obtained. Subsequent, reference models were scanned with the scanner Cerec Omnicam (Dentsply Sirona, Wals, Austria). An ink spray was first applied to allow the scanning of the alveolar ridges without irregularities, obtaining the scan of the reference model. These two scan data were superimposed using manual correlation. Four clear anatomical points were selected on the teeth in each scan and the correlation was made.

2.3. Digital Impression Technique

Digital impression system used for the intraoral digital scan was Cerec Omnicam (Dentsply Sirona, Wals, Austria). The scan process was conducted following the manufacturer`s guidelines. Previously by air syringe, saliva was removed from soft tissues and teeth and through intraoral mirrors mobile structures like tongue and labial mucosa were avoided. The scanning procedure was initiated on the occlusal surface of each tooth, following vestibular and palatal (or lingual) surfaces. Scanning the alveolar ridges was initiated in vestibular surfaces, following occlusal and palatal (or lingual) surfaces always with the scanner tip perpendicular. In some edentulous areas, occasionally digital reading was lost, so we had to return to a tooth area to restart the scanning process. Before completing the whole scan, missed areas were rescanned. The two intraoral impressions obtained were superimposed using also manual correlation.

3. Analysis Protocol

Because Cerec system is a closed sytem[8], once visual control, digital impressions were exported to Cerec inLab SW 15.0 software (Sirona Dental Systems, Wals, Austria)[2,8] and optical artefacts were eliminated operating “Trim” tool. All scans were aligned at the midline incisor and a maxillary line was defined to assurance parallel cuts to the frontal plane, in all scans to linear measurements.

Trueness in this study is defined as comparison, through horizontal linear measurements, between the physical stone cast models (reference model) and the virtual models obtained from the scan of physical stone cast models, and as comparison between the physical stone cast models and the virtual models obtained from the intraoral scans. For this analysis was considered the mean value of both impressions in each technique (I1 and I2) obtained for each patient. Two points were selected on each model in three spaced diameters: Mesial-Distal (MD), transversal anterior (T1), transversal posterior (T2).

In this study, precision is defined as the comparison, through vertical linear measurements, between the two virtual models obtained from the intraoral scans and the comparison between the two virtual models obtained from the scan of physical stone cast models. Then by superimposing these scans, three parallel cuts to the frontal plane were made at random locations on the alveolar ridges, so each two virtual models were cut in the same plane.[6] From the first to the third cut, the distance to the adjacent tooth increases. Afterwards, a random point was measured in each cut at the level of the crest, vestibular and palatal/lingual surface.

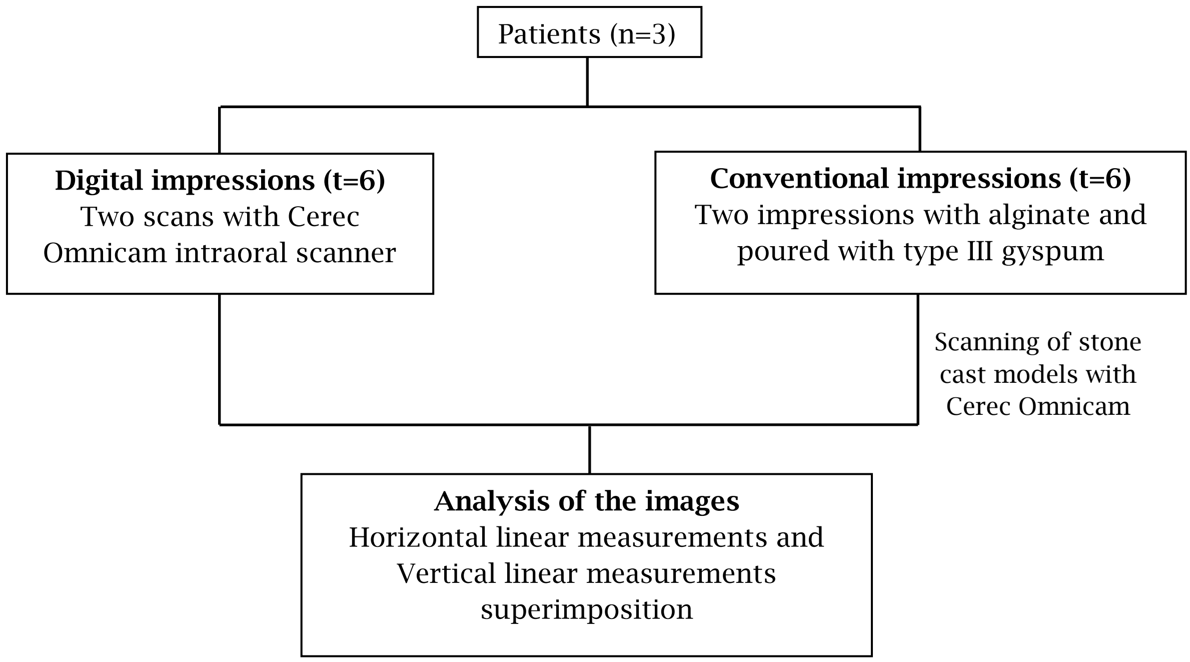


Fig.1: Study set-up

Results

1. Literature review

In the literature review, we obtained 35 articles in the *PubMed*. After reading title and abstract and applying the inclusion criteria, we selected 4 articles. Through search engines *ClinicalKey®*, *Web of Science^{TM}*, *B-On* and *ScienceDirect* were selected 14 articles and 5 more by manual cross reference, with a total number of 23 articles.

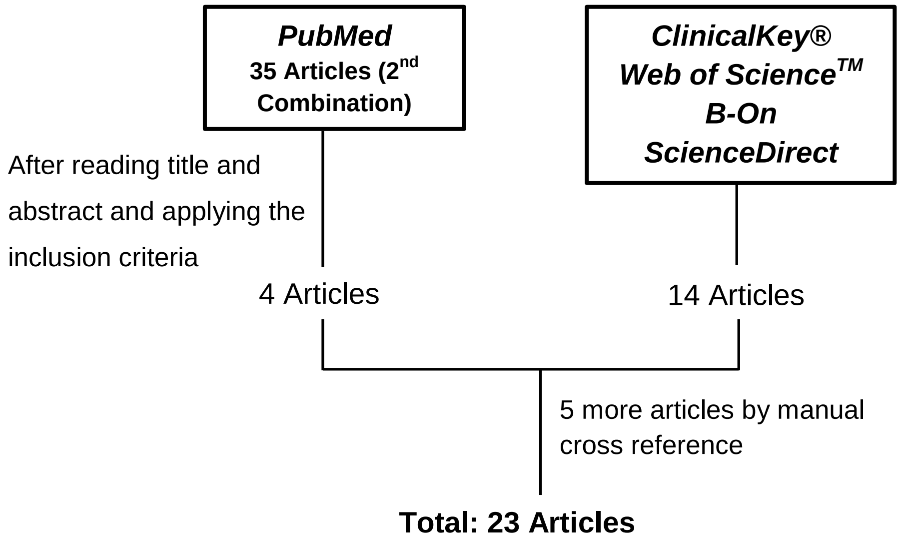


Fig.2: Flow Chart

2. Accuracy of Intraoral digital and conventional impressions

2.1. Trueness Analysis

2.1.1. Patient CS (Kennedy Class II, Modification 2)

Fig.3: Horizontal linear measurement, transversal anterior (T1), in the first reference model obtained from conventional impression (I1) (35,5mm).

Fig.4: Horizontal linear measurement, T1, in the second reference model obtained from conventional impression (I2) (36 mm).

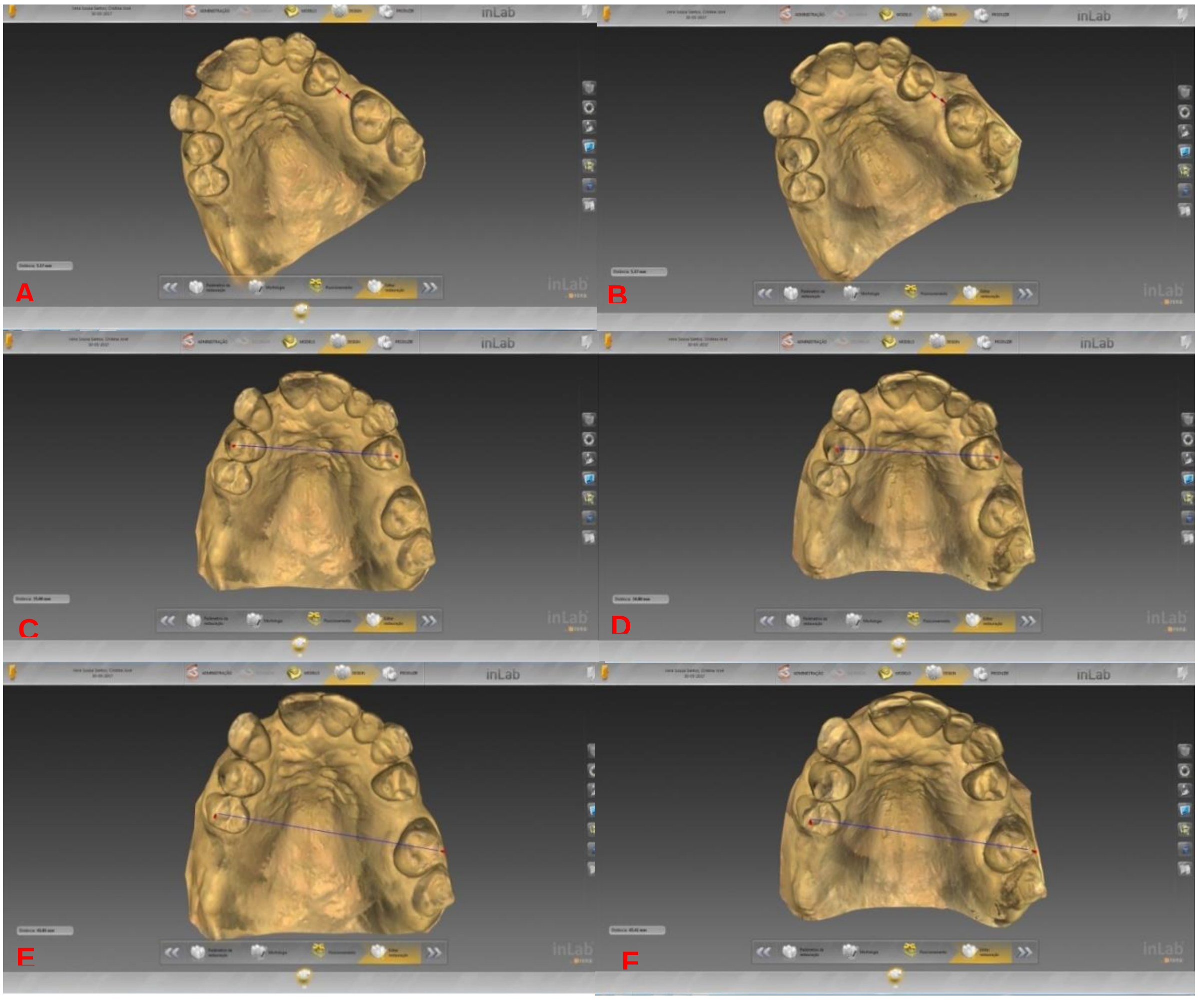


Fig.5: Horizontal linear measurements of virtual models obtained from the scan of stone cast models: A and B - MD between distal surface of 24 and mesial surface of 26, in I1 and I2, respectively; C and D - T1 between tip of the vestibular cusp of 14 and of 24, in I1 and I2, respectively; E and F - T2 between tip of the vestibular cusp of 15 and tip of the disto-vestibular cusp of 26, in I1 and I2, respectively.

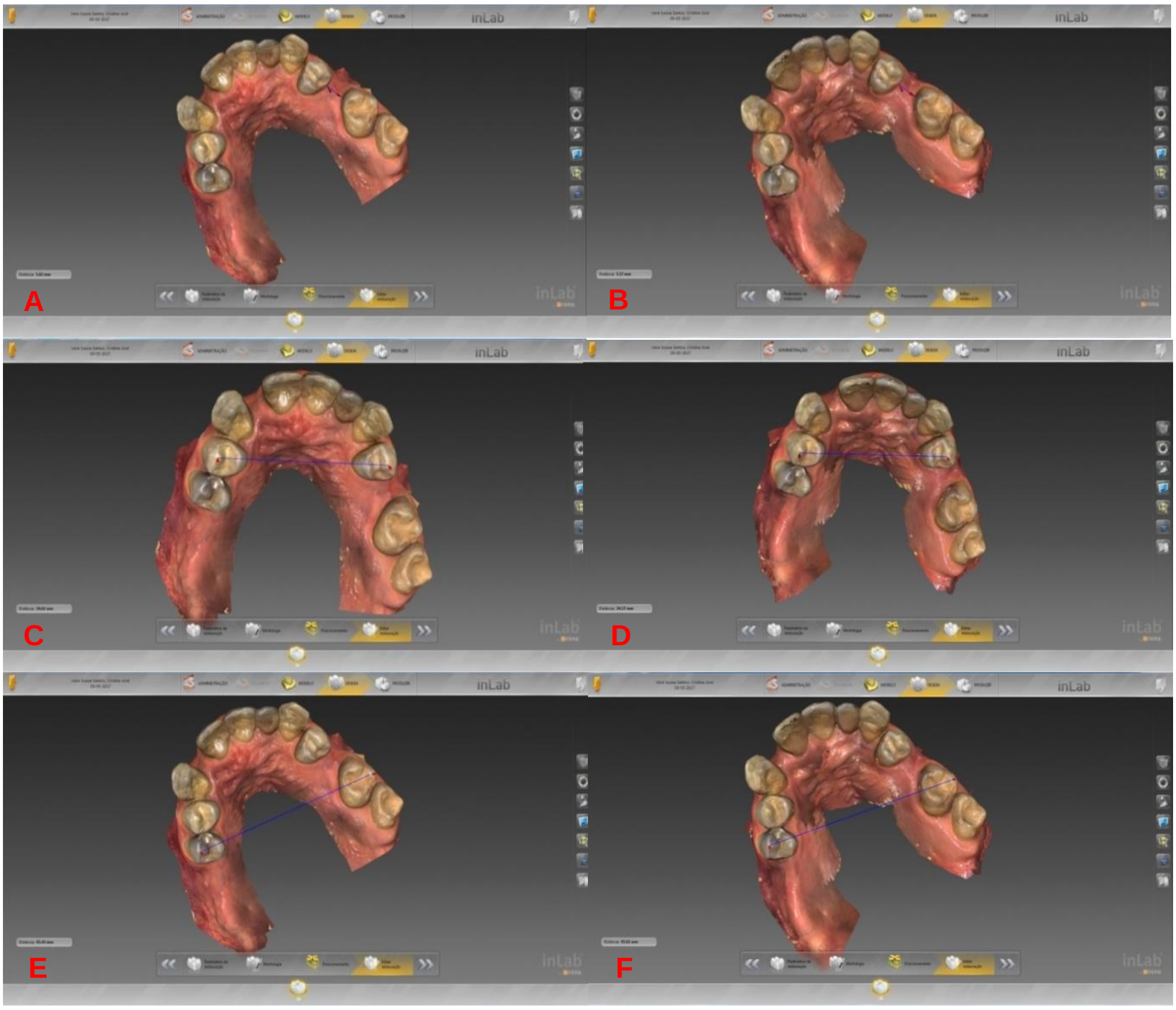
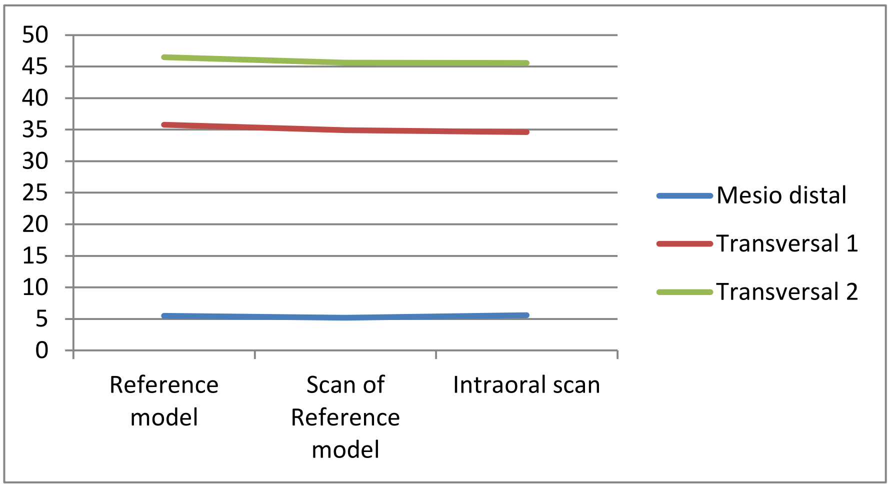


Fig.6: Horizontal linear measurements of virtual models obtained from the intraoral scans: A and B - MD between distal surface of 24 and mesial surface of 26, in I1 and I2, respectively; C and D - T1 between tip of the vestibular cusp of 14 and 24, in I1 and I2, respectively; E and F - T2 between tip of the vestibular cusp of 15 and tip of the disto-vestibular cusp of 26, in I1 and I2, respectively.

Table I: Mean of horizontal linear measurements of between the two reference models, two scans of reference model and two intraoral scans.

	Reference model	Scan of Reference model	Intraoral scan
Mesio distal	5,5	5,17	5,6
Transversal 1	35,75	34,9	34,6
Transversal 2	46,5	45,63	45,54



Graphic 1: Distribution of the mean of horizontal linear measurements between the two reference models, two scans of reference model and two intraoral scans.

2.1.2. Patient ML (Kennedy Class I)

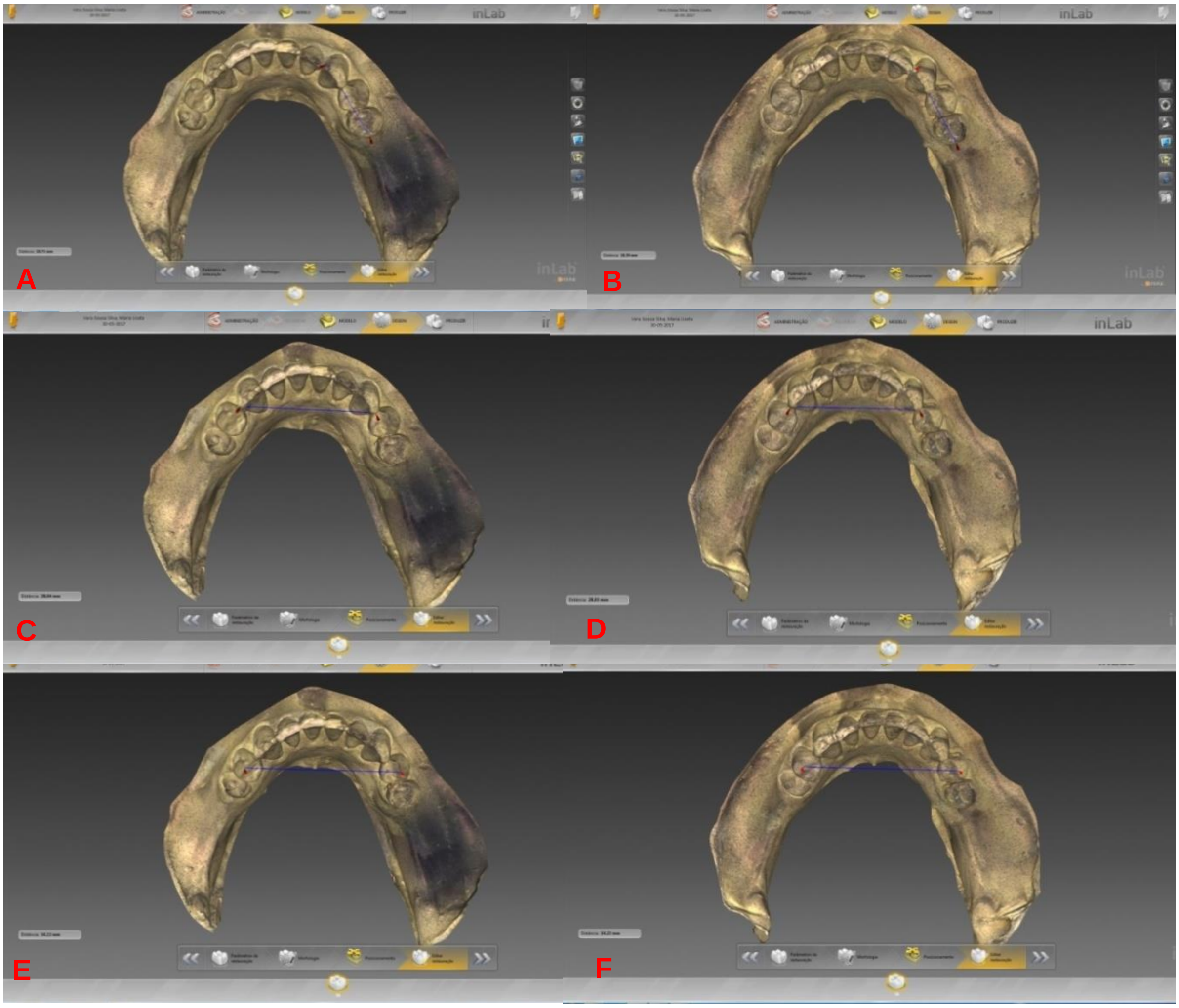


Fig.7: Horizontal linear measurements of virtual models obtained from the scan of stone cast models: A and B - MD between mesial incisal angle of 43 and distal marginal cristal of 45, in I1 and I2, respectively; C and D - T1 between distal incisal angle of 33 and of 43, in I1 and I2, respectively; E and F - T2 between tip of the vestibular cusp of 34 and of 44, in I1 and I2, respectively.

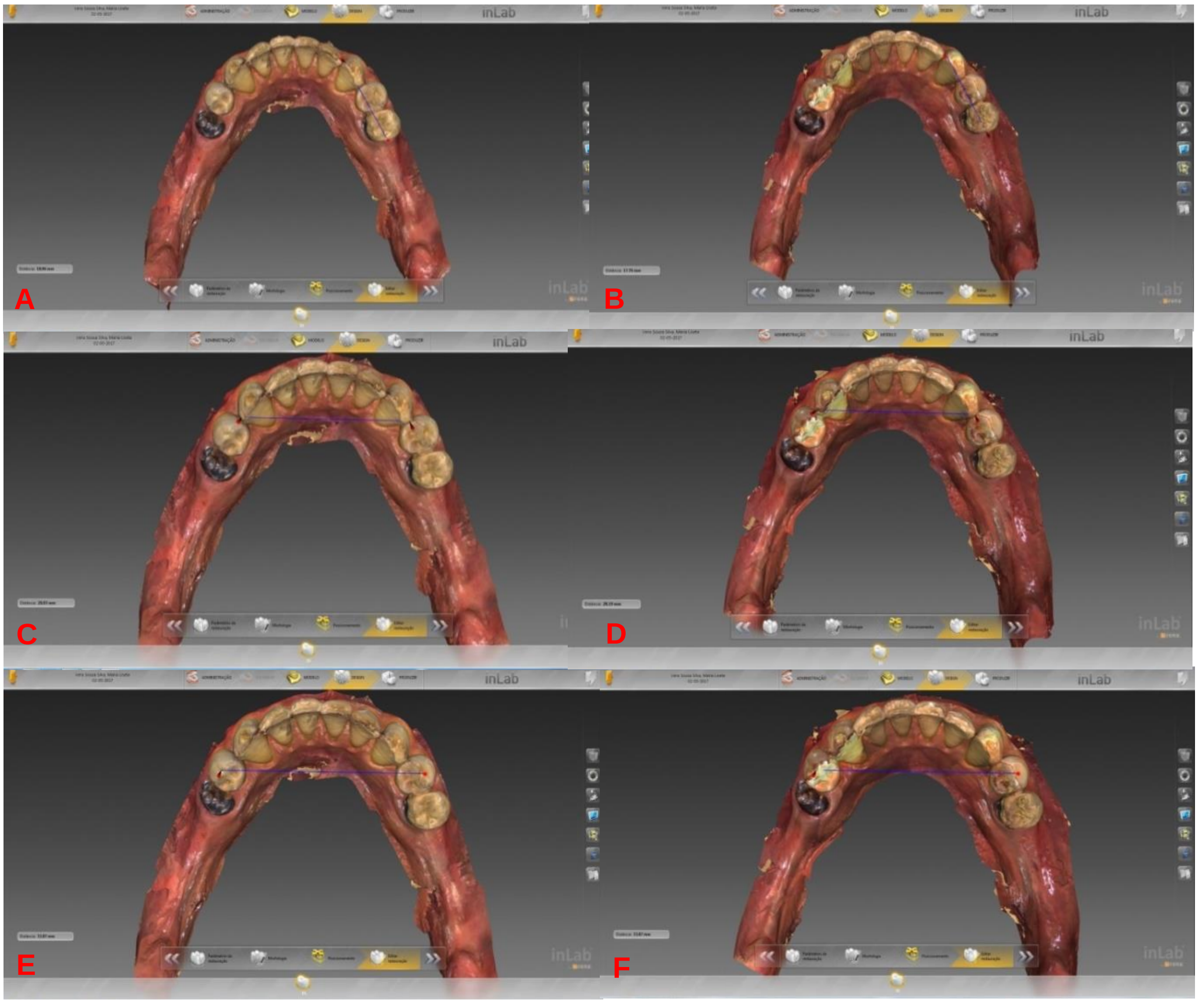
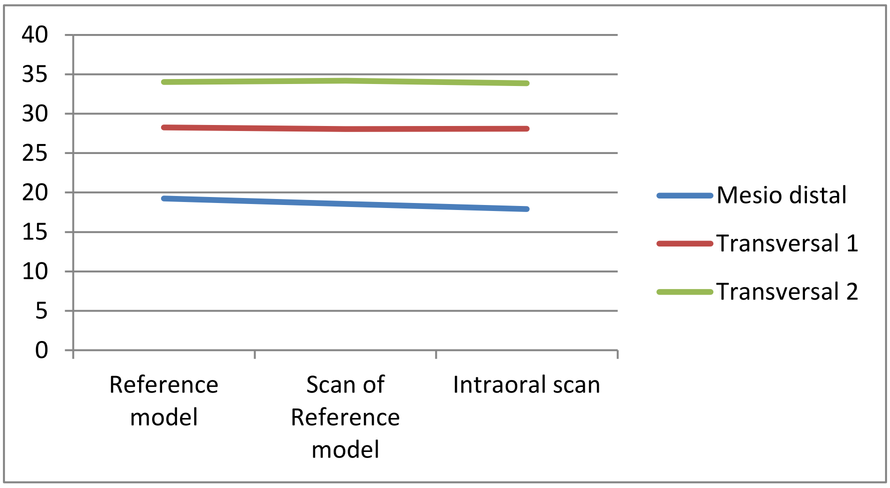


Fig.8: Horizontal linear measurements of virtual models obtained from the intraoral scans: A and B - MD between mesial incisal angle of 43 and distal marginal cristal of 45, in I1 and I2, respectively; C and D - T1 between distal incisal angle of 33 and of 43, in I1 and I2, respectively; E and F - T2 between tip of the vestibular cusp of 34 and 44, in I1 and I2, respectively.

Table II: Mean of horizontal linear measurements of between the two reference models, two scans of reference model and two intraoral scans.

	Reference model	Scan of Reference model	Intraoral scan
Mesio distal	19,25	18,55	17,91
Transversal 1	28,25	28,04	28,11
Transversal 2	34	34,18	33,87



Graphic 2: Distribution of the mean of horizontal linear measurements between the two reference models, two scans of reference model and two intraoral scans.

2.1.3. Patient AP (Kennedy Class I, Modification 1)

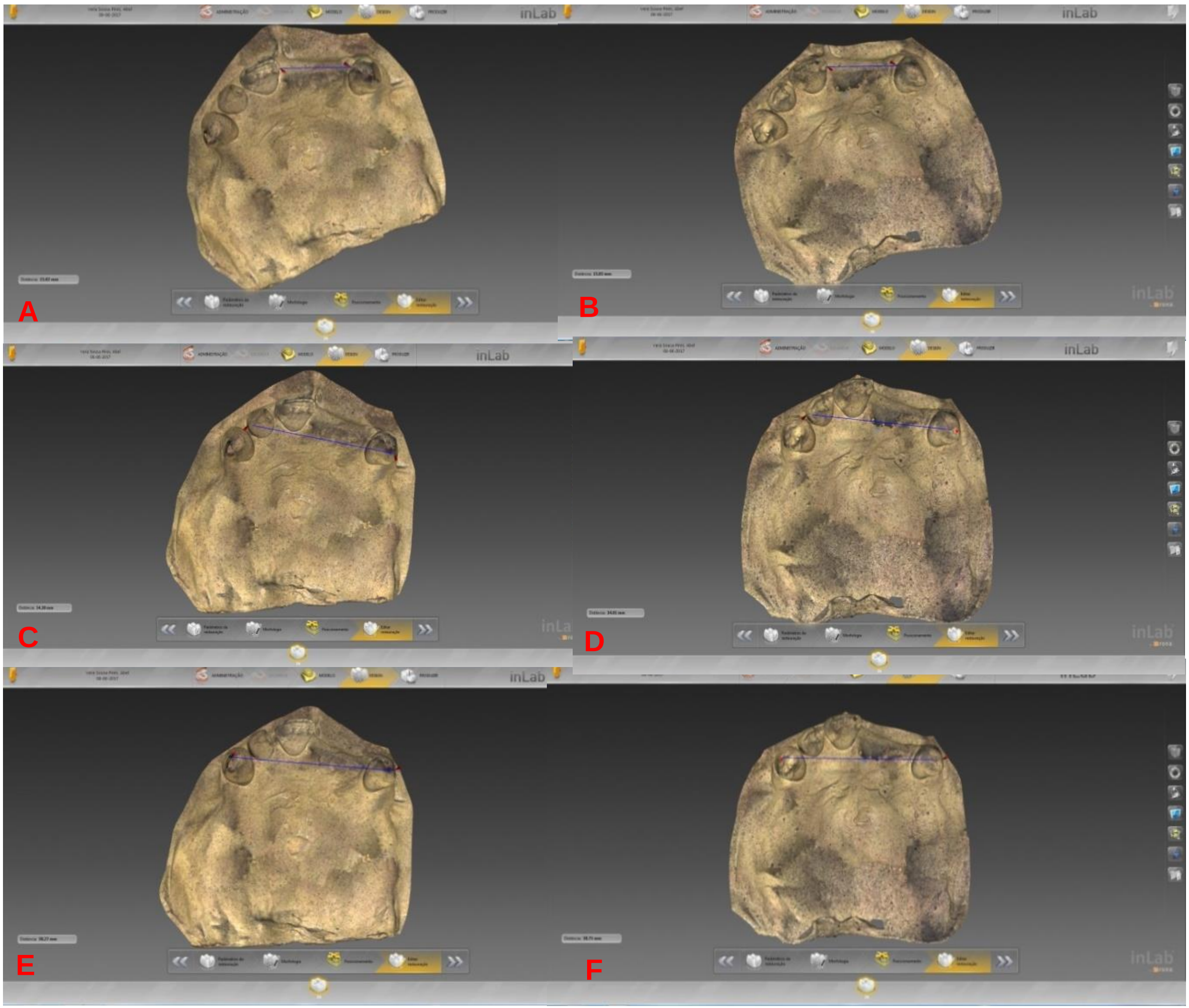


Fig.9: Horizontal linear measurements of virtual models obtained from the scan of stone cast models: A and B - MD between mesial surface of 11 and distal surface of 23, in I1and I2, respectively; C and D - T1 between distal incisal angle of 12 and tip of the cusp of 23, in I1and I2, respectively; E and F - T2 between tip of the cusp of 13 and of 23, in I1and I2, respectively.

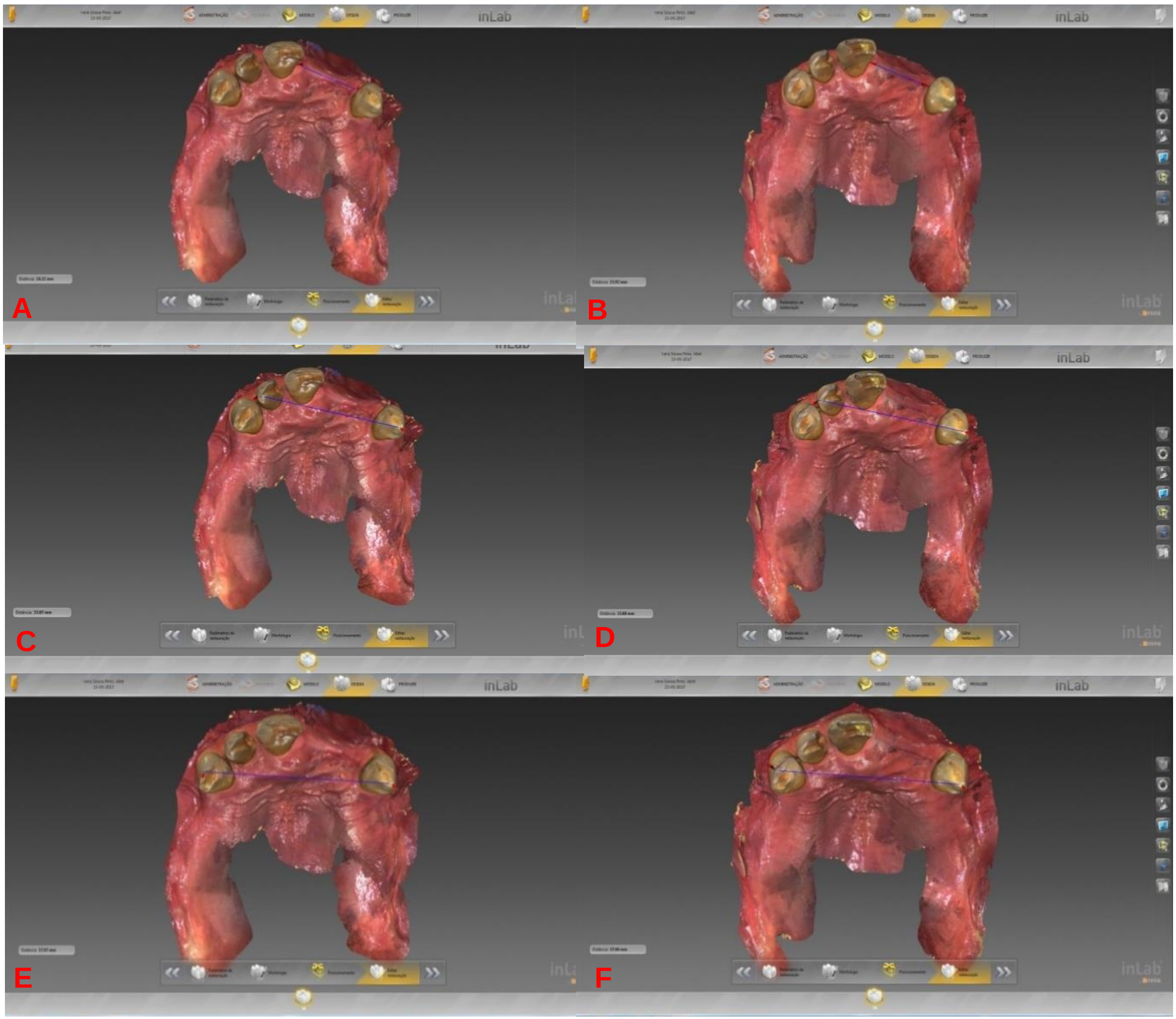
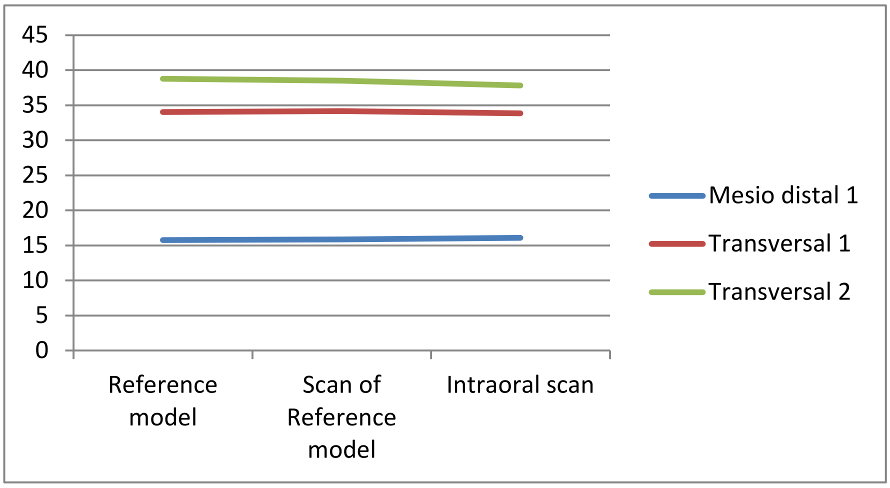


Fig.10: Horizontal linear measurements of virtual models obtained from the intraoral scans: A and B - MD between mesial surface of 11 and distal surface of 23, in I1 and I2, respectively; C and D - T1 between distal incisal angle of 12 and tip of the cusp of 23, in I1 and I2, respectively; E and F - T2 between tip of the cusp of 13 and of 23, in I1 and I2, respectively

Table III: Mean of horizontal linear measurements of between the two reference models, two scans of reference model and two intraoral scans.

	Reference model	**Scan of Reference model**	**Intraoral scan**
Mesio distal 1	15,75	15,83	16,07
Transversal 1	34	34,15	33,84
Transversal 2	38,75	38,51	37,82



Graphic 3: Distribution of the mean of horizontal linear measurements between the two reference models, two scans of reference model and two intraoral scans.

2.2.Precision Analysis

2.2.1. Patient CS

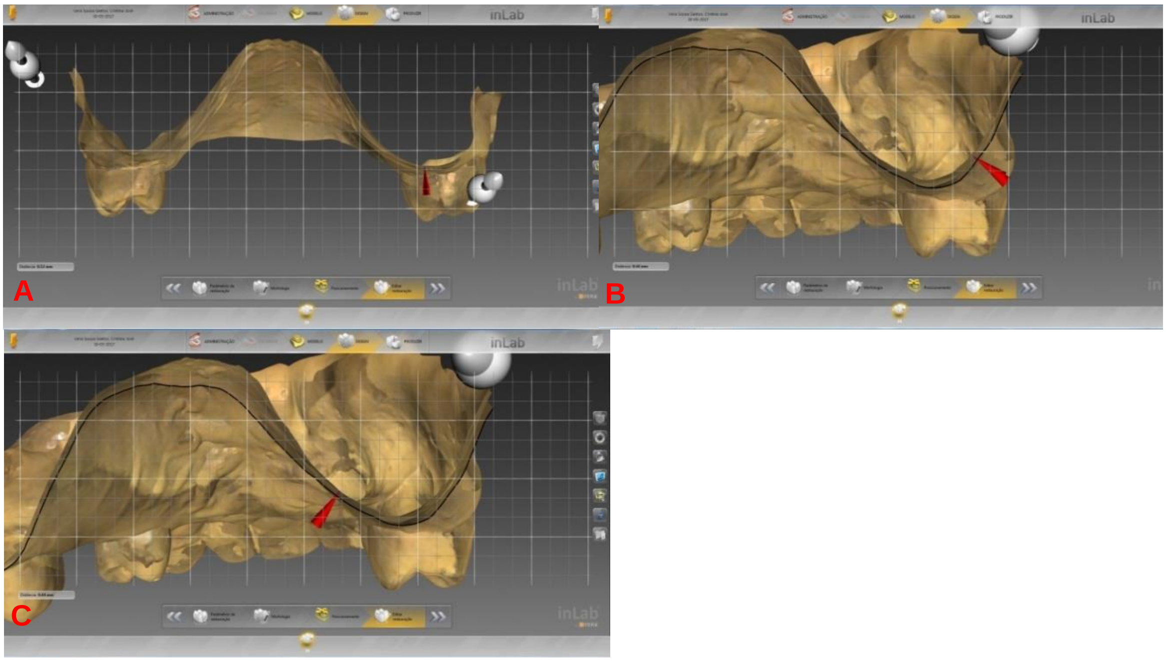


Fig.11: Vertical linear measurements of virtual models obtained from the scan of stone cast models: A - Distance of 0.52 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 1st cut; B - Distance of 0.44 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 2nd cut; C - Distance of 0.44 mm measured between I1 and I2 at a random point at the level of the palatal ridge, in the 2nd cut.

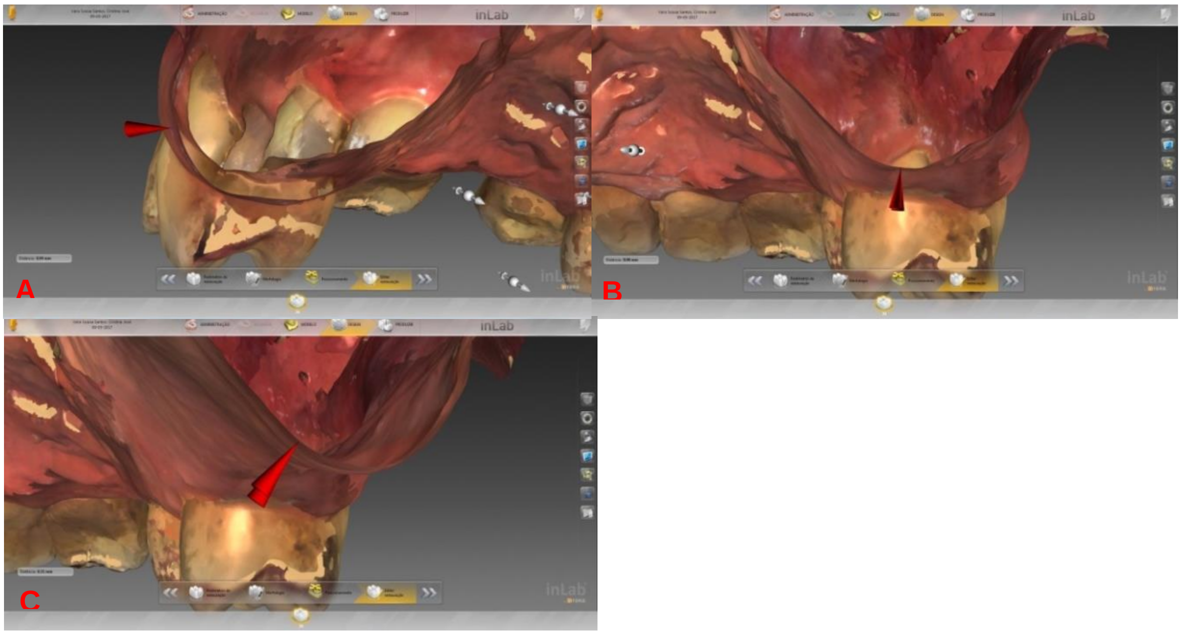
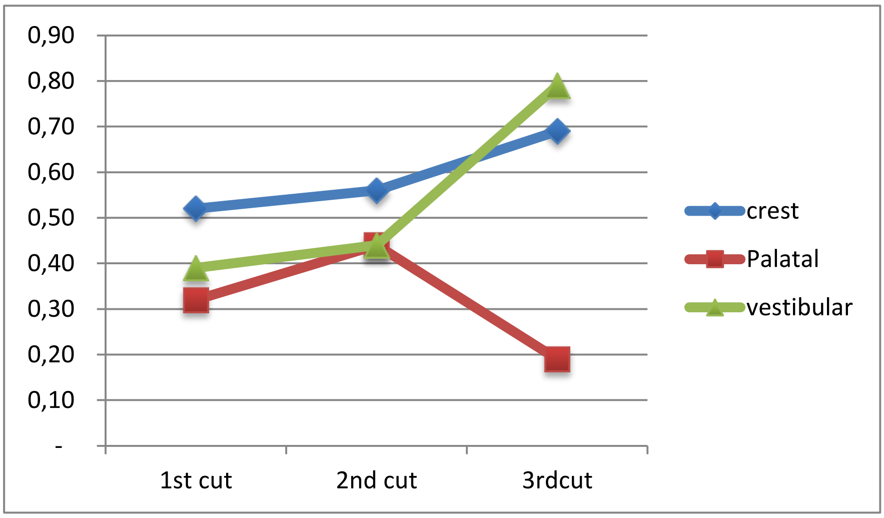


Fig.12: Vertical linear measurements of virtual models obtained from the intraoral scans: A - Distance of 0.04 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 1st cut; B - Distance of 0.08 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 2nd cut; C - Distance of 0.31 mm measured between I1 and I2 at a random point at the level of the palatal ridge, in the 3rd cut.

Table IV: Vertical linear measurements of the overlapping virtual models obtained from the scan of reference model, in random three cuts parallels to frontal plane, in the random point at the level of crest, palatal and vestibular ridge.

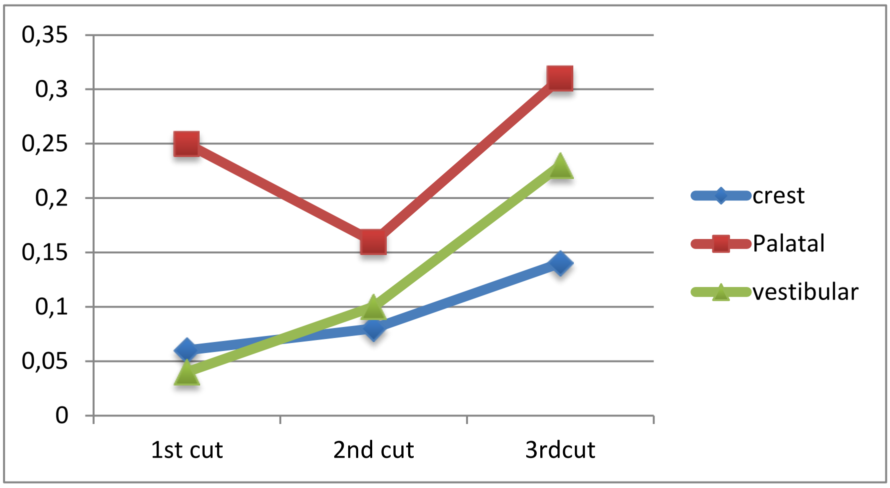
	1st cut	2nd cut	3rd cut
Crest	0,52	0,56	0,69
Palatal	0,32	0,44	0,19
Vestibular	0,39	0,44	0,79



Graphic 4: Distribution of the vertical linear measurements of the overlapping virtual models obtained from the scan of reference model, in random three cuts parallels to frontal plane, in the random point at the level of crest, palatal and vestibular ridge.

Table V: Vertical linear measurements of the overlapping virtual models obtained from intraoral scan, in random three cuts parallels to frontal plane, in the random point at the level of crest, palatal and vestibular ridge.

	1st cut	**2nd cut**	**3rd cut**
Crest	0,06	0,08	0,14
Palatal	0,25	0,16	0,31
Vestibular	0,04	0,10	0,23



Graphic 5: Distribution of the vertical linear measurements of the overlapping virtual models obtained from the intraoral scan, in random three cuts parallels to frontal plane, in the random point at the level of crest, palatal and vestibular ridge.

2.2.2. Patient ML

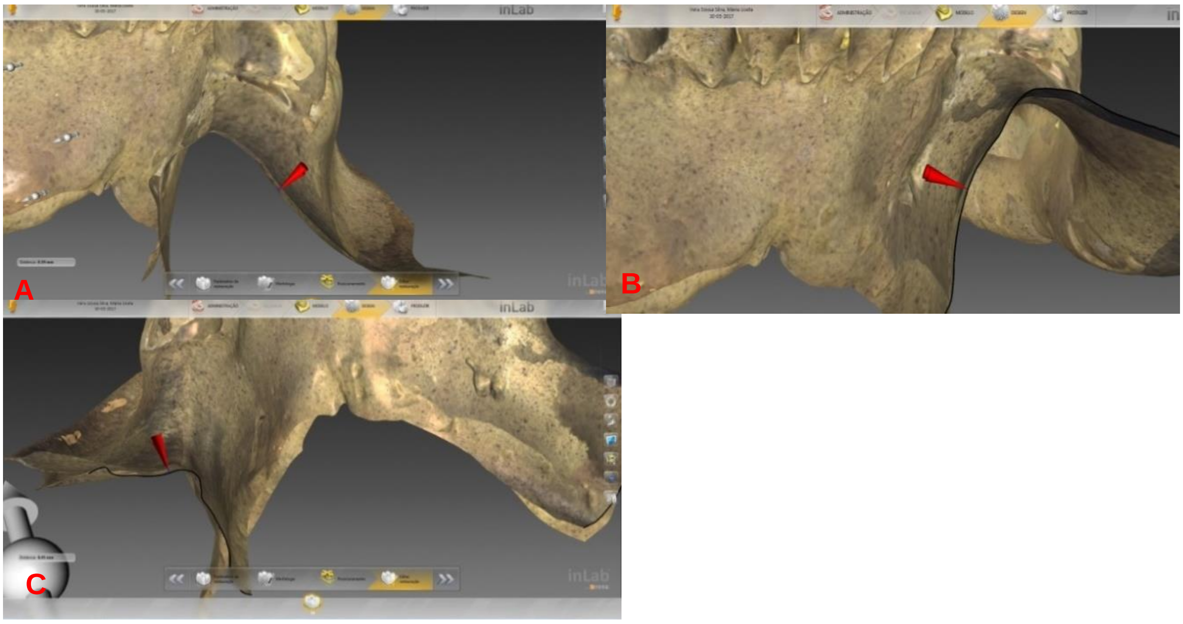


Fig.13: Vertical linear measurements of virtual models obtained from the scan of stone cast models: A - Distance of 0.39 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 1st cut; B - Distance of 0.2 mm measured between I1 and I2 at a random point at the level of the lingual ridge, in the 2nd cut; C - Distance of 0.45 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 3rd cut.

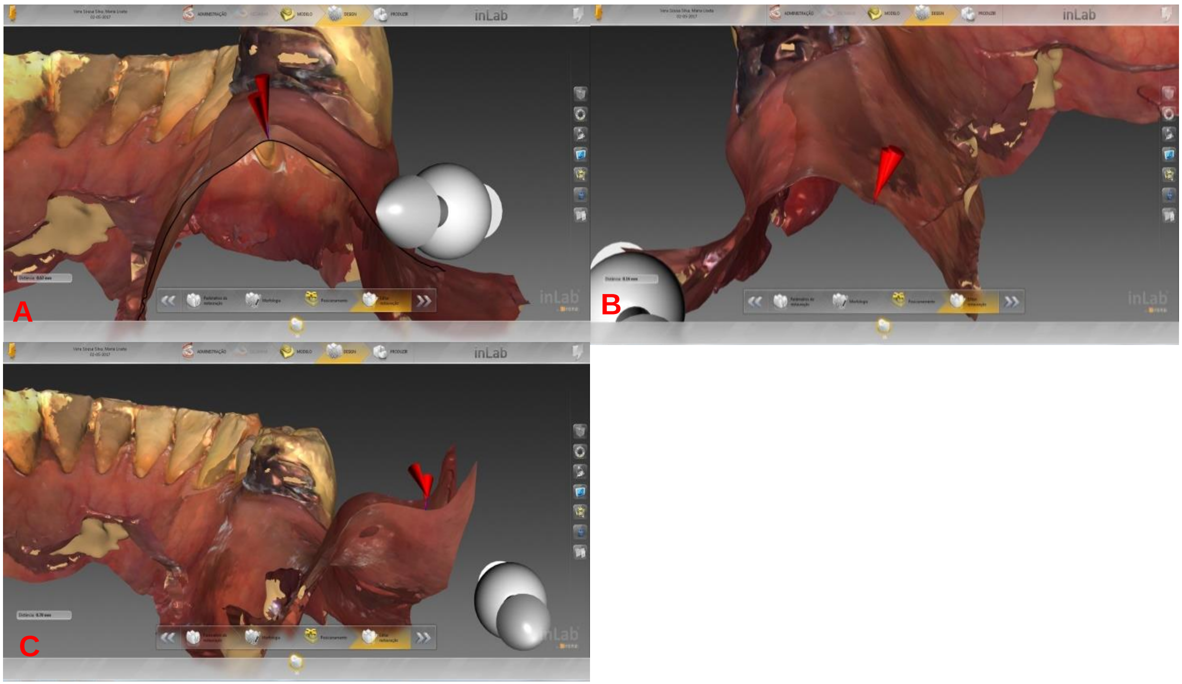
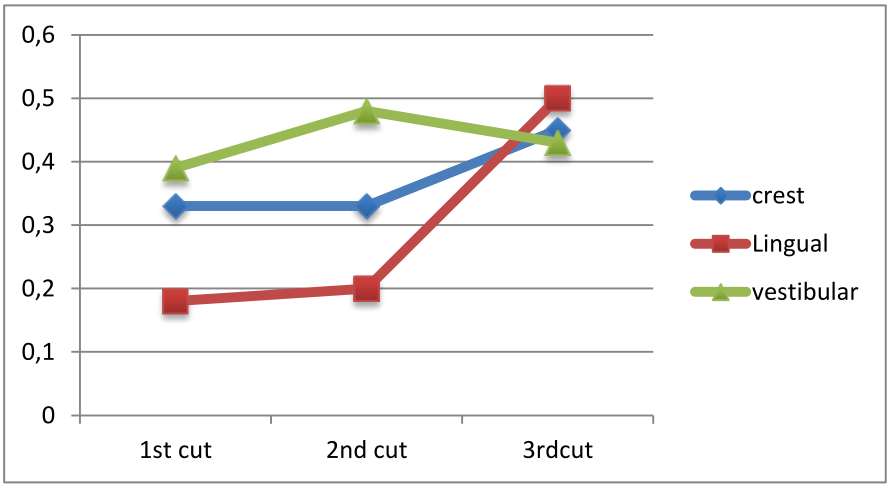


Fig.14: Vertical linear measurements of virtual models obtained from the intraoral scans: A - Distance of 0.63 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 1st cut; B - Distance of 0.16 mm measured between I1 and I2 at a random point at the level of the lingual ridge, in the 2nd cut; C - Distance of 0.7 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 3rd cut.

Table VI: Vertical linear measurements of the overlapping virtual models obtained from the scan of reference model, in random three cuts parallels to frontal plane, in the random point at the level of crest, lingual and vestibular ridge.

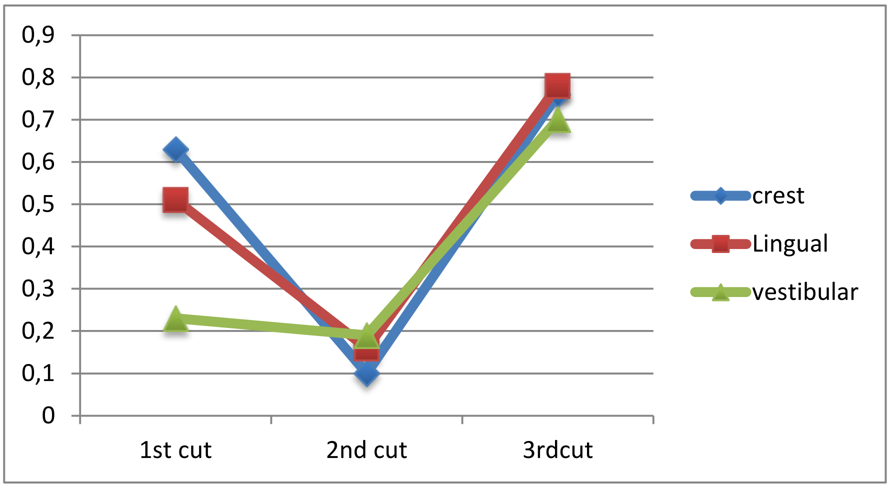
	1st cut	2nd cut	3rd cut
Crest	0,33	0,33	0,45
Lingual	0,18	0,20	0,50
Vestibular	0,39	0,48	0,43



Graphic 6: Distribution of the vertical linear measurements of the overlapping virtual models obtained from the scan of reference model, in random three cuts parallels to frontal plane, in the random point at the level of crest, lingual and vestibular ridge.

Table VII: Vertical linear measurements of the overlapping virtual models obtained from intraoral scan, in random three cuts parallels to frontal plane, in the random point at the level of crest, lingual and vestibular ridge.

	1st cut	2nd cut	3rd cut
Crest	0,63	0,10	0,76
Lingual	0,51	0,16	0,78
Vestibular	0,23	0,19	0,70



Graphic 7: Distribution of the vertical linear measurements of the overlapping virtual models obtained from the intraoral scan, in random three cuts parallels to frontal plane, in the random point at the level of crest, lingual and vestibular ridge.

2.2.3. Patient AP

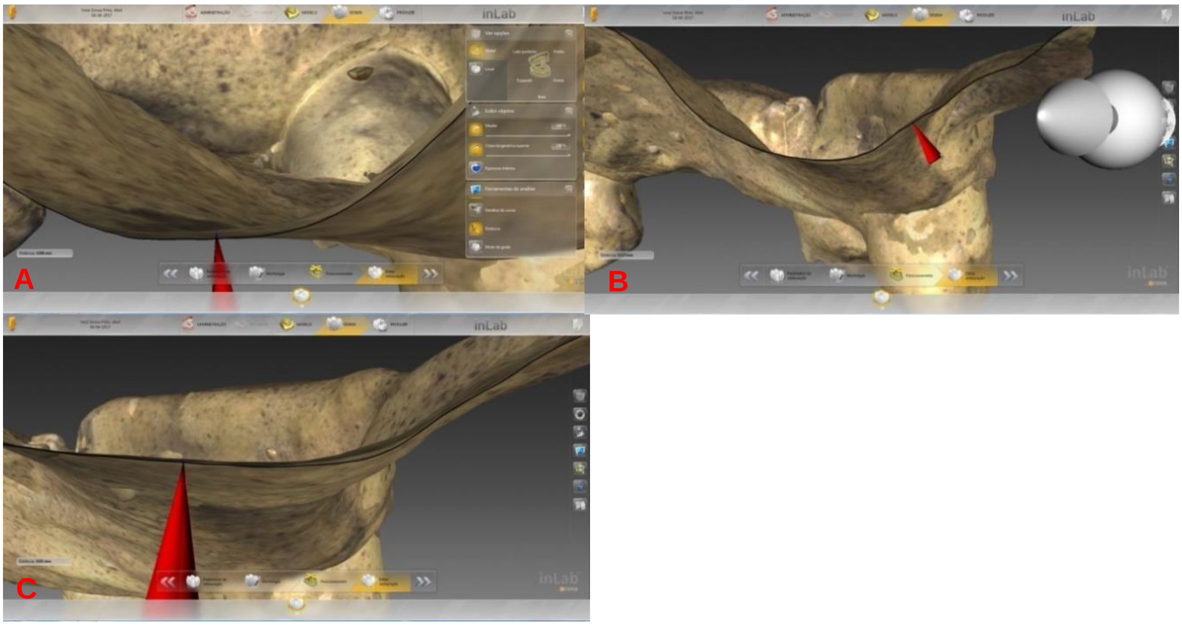


Fig.15: Vertical linear measurements of virtual models obtained from the scan of stone cast models: A - Distance of 0,08 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 1st cut; B - Distance of 0,13 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 2nd cut; C - Distance of 0,05 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 3rd cut.

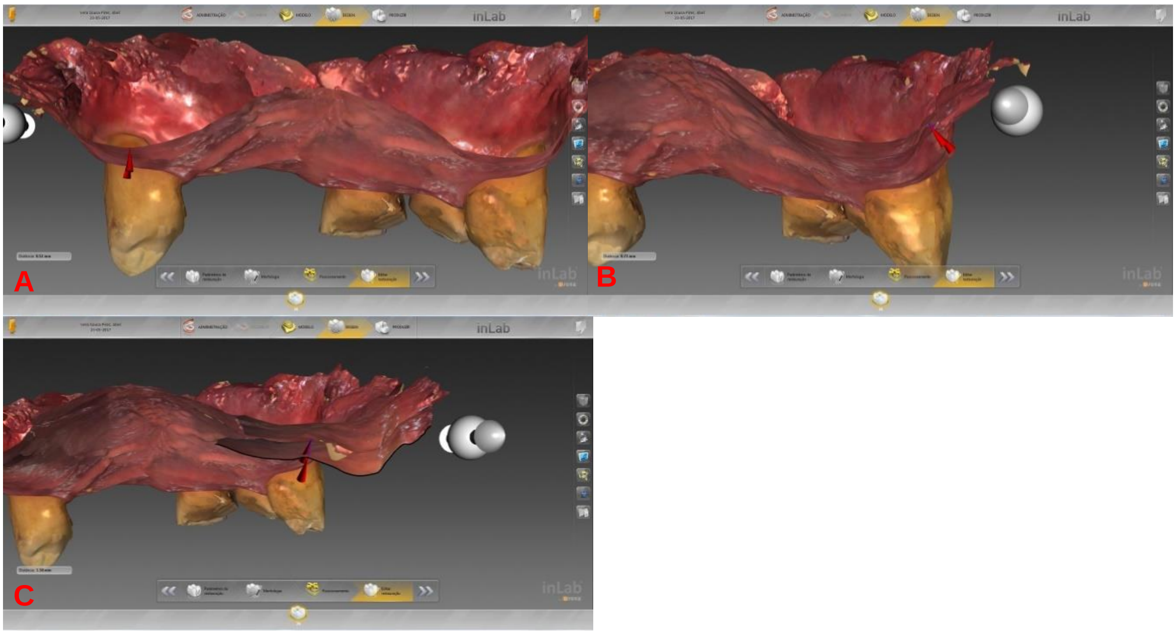
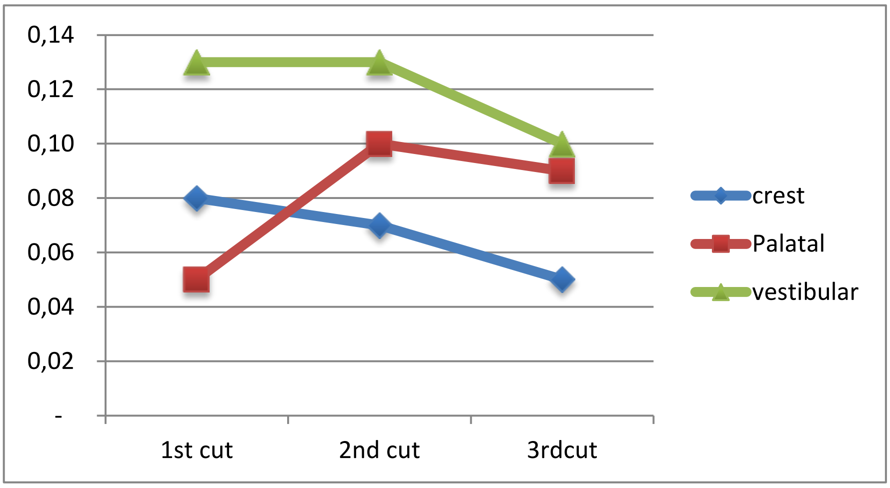


Fig.16: Vertical linear measurements of virtual models obtained from the intraoral scans: A - Distance of 0,52 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 1rd cut; B - Distance of 0,73 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 2nd cut, C - Distance of 1,58 mm measured between I1 and I2 at a random point at the level of the palatal ridge, in the 3rd cut.

Table VIII: Vertical linear measurements of the overlapping virtual models obtained from the scan of reference model, in random three cuts parallels to frontal plane, in the random point at the level of crest, palatal and vestibular ridge.

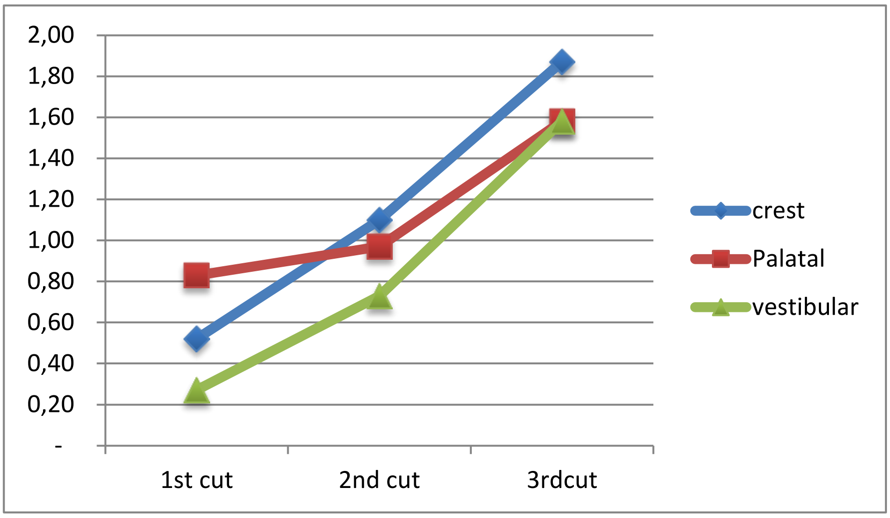
	1st cut	**2nd cut**	**3rd cut**
Crest	0,08	0,07	0,05
Palatal	0,05	0,10	0,09
Vestibular	0,13	0,13	0,10



Graphic 8: Distribution of the vertical linear measurements of the overlapping virtual models obtained from the scan of reference model, in random three cuts parallels to frontal plane, in the random point at the level of crest, palatal and vestibular ridge.

Table IX: Vertical linear measurements of the overlapping virtual models obtained from intraoral scan, in random three cuts parallels to frontal plane, in the random point at the level of crest, palatal and vestibular ridge.

	1st cut	2nd cut	3rd cut
Crest	0,52	1,10	1,87
Palatal	0,83	0,97	1,58
Vestibular	0,27	0,73	1,58



Graphic 9: Distribution of the vertical linear measurements of the overlapping virtual models obtained from the intraoral scan, in random three cuts parallels to frontal plane, in the random point at the level of crest, palatal and vestibular ridge.

Discussion

In the literature review carried out, considering the small number of articles and the low scientific evidence revealed, it was not possible to obtain articles comparing conventional impressions and digital impressions, in terms of accuracy in edentulous areas, *in vivo*. Maybe because it is very difficult to design a protocol that can actually measures in the same matter both impression tecniques with superimposing scans, also a very high number of patients would be needed for this type of study. In the present pilot study, we decided to compare the accuracy in edentulous areas in conventional and digital impressions, among each other, instead of doing this between each method.

In vitro studies have used a steel fabricated reference models, which are scanned with a highly accurate reference scanner (Infinite Focus Standard, Alicona Imaging) [18,20] or a industrial reference scanner (IScan D101, Imetric 3D GmbH, Courgenay, Switzerland[19] and a ATOS II SO, software v7.0; GOM[21]) or with a point-laser scanner connected to a CNC milling device (TwoCam 3D, SCAN technology A/S; Ringsted, Denmark)[6]. Conventional impressions are made and the same highly accurate reference scanner scans the respective stone cast models and these scans are compared with the scan of the fabricated reference model. The same happens with intraoral digital impressions, which are compared with the scan of the fabricated reference model. The scans are converted to STL file and a 3D evaluation software is used (Alicona IFM Software like. [18,20] , Geomagic Qualify™ 2012, Geomagic, Morrisville, USA[6,19,21,22] or Gom Inspect, GOM[7]) by superimposing scans using best-fit algorithms.[23] In our study we used plaster gypsm models as reference models, obtained by alginate impressions, which is the normal clinical procedure in cases of oral rehabilitation with partial removable dentures of these patients. However this could introduce a bias when comparing intraoral scans with the reference model in terms of horizontal linear measurements, made to acess trueness of this method. The fact that we didn't have acess to a more rebost software that used superimposing scans like Geomagic Qualify™ is another drawback in this study.

Clinical outcomes of impressions methods are made indirectly, usually, comparing the fit of the final prostheses. [4,6] However this is a qualitative and not a quantitative comparation of two different impressions methods, and the evaluation of the fit of the final prostheses is influenced by the researchers (more than one) experience and in some cases patient perception. To minimize the risk of operator bias and experience influencing the results, only one investigator with a basic level of experience in the intraoral digital system participated, in our study.

The digital workflow can start with direct or indirect approach. Some *in vitro* studies have demonstrated that intraoral digital impression provides virtual models more accurate than virtual models made by indirect approach, since it eliminates the problems associated with conventional impression.[2,3,6,7,8,23] Other studies demonstrated that extraoral optical scanner accuracy is 5-10μm and intraoral optical scanner accuracy is 50 μm.[3] In our work, the software used, doesn't allow measurements in this order of microns, so we were limited to an error of at least 50 microns (0,05mm). This makes it difficult to compare quantitatively measurements with some of the studies in the literature. However we could verify qualitatively that the discrepancy between the overlapping images of the 1st virtual model obtained from scan of stone cast model and the 2nd one is smaller than the overlapping images of the virtual models obtained from intraoral scans, in patient ML (Fig.13 and 14) and AP (Fig.15 and 16) and as we can see in Graphic 6, 7, 8 and 9.

In direct approach, the time-consumed and the costs of materials are smaller[8] and, it was verified that the longer the arch to scan, the less accurate the two methods.[6] An *in vitro* study about propagation of error in a digital workflow demonstrated that direct scanning had less systematic error than indirect approach.[17] The direct approach was also the method used in our study and we also found that the longer the arch to scan, the less accurate the two methods.

In a full arch with complete dentition, digital impressions present similar accuracy to conventional impressions with polyether materials and greater accuracy when is used alginate material.[2,9] However, this just reflects precision, not trueness. It is difficult to obtain an accurate reference model, because patient can't be assessed with a tactile or other high precision optical laboratory scanner. In our study, as in other *in vivo* studies, stone cast models obtained from conventional impressions are used as reference data.[10,23] *In vitro* studies present superior accuracy compared to *in vivo* studies due to the challenge of the oral cavity environment.[10] Accuracy of completely edentulous arches is limited due mobile tissue[2,9,15] and the higher the edentulous distance the smaller the accuracy scan[2,9], more time-consuming to capture and more predictable to obtain overlapping images due lack of clear anatomic landmarks.[2] To overcome this difficulty some alternatives are described as for example the use of artificial landmarks[2] or capture the soft tissue morphology passively to obtain a mucostatic impression[12] or mix pressure-indicating paste and interim zinc oxide-eugenol cement (Temp-Bond; Kerr Corp) and draw irregular shapes on the residual ridges connect them with lines toward the center of the palate with the mixture.[13] Nevertheless, in these two last alternatives, digital impression presents overextended soft tissue morphology[12,13], being necessary a posterior query[12] and more studies to confirm the accuracy of these methods. An *in vitro* study that determines the effect of an artificial landmarks has shown an improvement in the trueness and precision of the intraoral scanner in the edentulous areas, however intraoral scan data in the oral cavity are different due the saliva, blood and frenum and tongue movement.[2] Patzelt *et al* report that in edentulous jaws, accuracy of scanners differ significantly, and although edentulous jaw scanning was feasible, the high levels of inacuracy recommended more studies for *in vivo* use.[3,11]

This study also presents some limitations. The same scanner was used to scan directly the oral cavity and stone cast models. The fact that we didn't use a highly accurate scanner on the model, could explain why the horizontal values measured were usually higher in the model than in the virtual models obtained intraorally.

For intraoral scanning Cerec Omnicam uses a continuous data acquisition to generate a 3D model and it's possible to have a powder-free scanning of natural tooth structures and gengiva, with a live colour stream.[6,8] Different scanners have different combination of speed, trueness and precision.[9] According to the literature Cerec Omnicam can be used on a single tooth, quadrant or full arch[8] and afford best combination of these three characteristics in sextant and quadrant scans[9,10] and 3Shape TRIOS 3 (3Shape North America) provides the the best combination in complete-arch scans. But on this theme more studies are necessary and every conclusion must to be interpreted on the same scanning scenario, because the results are influenced by different scanning substrate variability, arch configurations[9], scanner protocol, number of additional scans, automatic corretion of missing data, patient movement and saliva.[6] Koch GK *et al* reported that software, scanner and mainly, milling machine influence error's propagation.[17]

In this study, the scanner couldn't read in edentulous alveolar ridges without irregularities in gypsum models, so we used an ink spray to allow the scanner. But, we don't know the influence of this spray in accuracy and, according Ting-shu S. *et al*, scanning devices dispensing spray are desirable to improve the performance of devices[8] and Luthard *et al* showed that the use of the spray can lead to errors up to 40 μm.[7] In our study we also experienced difficulties with intraoral impressions, for example we could not digitalize all parts of the palatal due of lack anatomic landmarks. Gang *el al* demonstrated that in a full arch with complete dentition, arch width can influence the precision of intraoral scanner, while palatal vault heigh might have no effect. They used a new scanner (TRIOS3) with a smaller scanning head that allow to capture the images of the top of the palate with better quality.[3]

Some studies measure the whole deviation, others use surface points, and some others use linear distance measurements[6,16] to evaluate the trueness and precision. Linear distance measurements is the best way to detect distortions of the arch,[6] however in this method if there aren't clear reference points it is difficult to have correct repeated measurements.[16] Surface points with high trueness, overcome this limitation, by helping measuring software to superimposes each test scan with the reference scan, in STL format, using a best-fit algorithm.[6,16]

The software Cerec inLab only allows measurements of linear distances and when we choose reference points, there is a certain optical illusion, for example, it is necessary to confirm that the measure line is vertical and not oblique, through the rotation of the models. Also, this software only allows measurements in milimeters and manual correlation that can influence the accuracy of the overlap.

We just measured trueness by using a horizontal linear distances, because we didn't have acess a high precision scanner, to allow reference model scanning and subsequent overlapping of each test-scan with the reference scan.

Due to low number of patients, it was not possible to perform statistical analysis, so we did a trend analysis. According to our results, conventional impressions demonstrated horizontal linear distance measure closer to the reference model compared to intraoral digital impressions, showing a better trueness in conventional technique with horizontal linear measurements. However, the precision of the conventional impression technique is influenced by intrinsic problems, and this it self may result in inaccurate reference models relative to the real intraoral situation. These measurements varied in mean 0.31mm and 0.49mm between the reference model and the virtual models obtained by the scan of the reference model and the intraoral scan, respectively. As we can see in Figures 5-10 and Graphics 1, 2 and 3.

In vertical linear measurements, in patient CS, virtual models obtained from scan of reference model has less precision than virtual models obtained from intraoral scan (Fig.5 and 6). In this method, the discrepancy is greater at the palatal ridge level as we can see in Graphic 5 and difference between I1 and I2, both on scan of reference model and on intraoral scan, are higher when the cut is made further away from adjacent tooth (Graphic 4 and 5). This can be explained by more frequent scanner reading lost during digitilization. In patient ML and AP, the virtual models obtained from intraoral scan have less precision (Fig.13-16), the difference between I1 and I2, on both scan of reference model and on intraoral scan, is higher when the cut is made further away from the adjacent tooth (Graphic 6, 7, 9). The discrepancies are more in patient ML and AP, probably, because in patient ML a mandibular jaw was scanned, that is more difficult to control de saliva and to capture the soft tissue and in patient AP, there are less reference points for scanning and for manual correlation. In all patients, we can observe that in the palatal ridge, the discrepancy is smaller in scan of reference model than intraoral scan, mainly in the first cut (Graphic 4, 6, 8). This could be explained by more tissue resistence of palatal ridge to impression material compression, in conventional impressions. Intraoral digital impression at the palatal ridge, almost always presents a greater discrepancy and this can be explained by more frequency of the scanner reading lost during digitilization, in this area.

These results are in agreement with the articles found and suggest the need for future research comparing the accuracy between this two impression techniques to validate the use of this technology in clinical pratice daily. The great evolution in technology CAD/CAM system allow a full digital workflow that suggest a potential improvement to the standard of treatment, simplify clinical procedures, reduce the worktime treatment and allow new methods, materials of production, and new treatment concepts.[1,6]

In present vivo study, there are differences in accuracy for edentulous areas between conventional impressions and digital impressions, when analysed separately among each other.

However, for a more accurate analysis, future studies, should use artificial landmarks, which allow to reduce edentulous distances and possibly increase the accuracy of the scanning, capturing images in a faster way and to help the superimposing of images due to the greater number of precise reference points. We also think that a more rebost software would help on the superimposing scans and allow 3D evaluation like Geomagic Qualify™, for example, and the use of highly accurate industrial scanner like IScan D101, Imetric 3D GmbH to scan the reference model, because the trueness between reference model and scan of reference model can also be influence by the type of scanner used.

Conclusion

According to literature review carried out, it is feasible to use the intraoral scanner to obtain intraoral digital impressions in the full-arch with complete dentition. In edentulous areas, most of the studies are *in vitro*, and do not take in account oral cavity conditions, and the application of this new method is more limited.

Within the limitations of this study, we can verify that the precision analysis of intraoral scans were better than scans of reference model in partial edentulous jaws with small edentulous areas. The use of digital impression in partial edentulous jaws with large edentulous areas presents low precision and actually it is not indicate in clinical pratice daily. Precision is influenced by the oral cavity conditions and by substrate scanning; and in conventional impression technique precision is influenced by intrinsic problems. The values of trueness for both impression techniques are clinically significant. The differences in the trueness, in digital impression can be attributed to the dimensional change of the alginate and distortion of the reference models and the differences of trueness, in conventional impression, can be attributed to absence of precise reference points for measurements.

Although digital impression has advantages over conventional impression, such as minimization soft tissue pressure, there are technical limitations and the obtained models are not devoid of errors that can compromise the sucess of the rehabilitation with removable prosthese. Further studies with validity and scientific quality and study of alternatives to allow, easily, digitalization of alveolar ridges, are required.

References

1. Kattadiyil MT, Mursic Z, Alrumaih H, Goodacre CJ. Intraoral scanning of hard and soft tissues for partial removable dental prosthesis fabrication. J Prosthet Dent [Internet]. 2014;112(3):444–8. Available from: http://dx.doi.org/10.1016/j.prosdent.2014.03.022

2. Kim J, Amelya A, Shin Y. Accuracy of intraoral digital impressions using an arti fi cial landmark. :1–7.

3. Gan N, Xiong Y, Jiao T. Accuracy of Intraoral Digital Impressions for Whole Upper Jaws , Including Full Dentitions and Palatal Soft Tissues. 2016;1–15.

4. Mansour M, Sanchez E, Machado C. The Use of Digital Impressions to Fabricate Tooth-Supported Partial Removable Dental Prostheses: A Clinical Report. J Prosthodont. 2016;25(6):495–7.

5. Bds TFA, Cam CAD. ScienceDirect Advancements in CAD / CAM technology : Options for practical implementation. J Prosthodont Res [Internet]. 2016;60(2):72–84. Available from: http://dx.doi.org/10.1016/j.jpor.2016.01.003

6. Dmd V, Cam CAD. ScienceDirect Original article Comparison of the accuracy of direct and indirect three-dimensional digitizing processes for CAD / CAM systems – An in vitro study. 2016;1–8.

7. Oliveira L, Bohner L, Canto DL. Computer-aided analysis of digital dental impressions obtained from intraoral and extraoral scanners. J Prosthet Dent [Internet]. :1–7. Available from: http://dx.doi.org/10.1016/j.prosdent.2016.11.018

8. Ting-shu S, Jian S. Intraoral Digital Impression Technique : A Review. 2014;(3):1–9.

9. Renne W, Ludlow M, Fryml J, Schurch Z, Mennito A, Kessler R, et al. Evaluation of the accuracy of 7 digital scanners : An in vitro analysis based on 3-dimensional comparisons. :1–7.

10. Atieh MA, Ritter A V, Ko C. Accuracy evaluation of intraoral optical impressions : A clinical study using a reference appliance. J Prosthet Dent [Internet]. 2014;1–6. Available from: http://dx.doi.org/10.1016/j.prosdent.2016.10.022

11. W. PS. VS. SS. A. Assessing the feasibility and accuracy of digitizing edentulous jaws. J Am Dent Assoc. 2013;

12. Lin W, Chou J, Metz MJ, Harris BT, Morton D. Use of intraoral digital scanning for a

CAD / CAM-fabricated milled bar and superstructure framework for an implant-supported , removable complete dental prosthesis. :509–15.

13. Lee J. Improved digital impressions of edentulous areas. J Prosthet Dent [Internet]. :1–2. Available from: http://dx.doi.org/10.1016/j.prosdent.2016.08.019

14. Dds JW, Dds YL, Dds YZ. Use of intraoral scanning and 3-dimensional printing in the fabrication of a removable partial denture for a patient with limited mouth opening. J Am Dent Assoc [Internet]. 2017;148(5):338–41. Available from: http://dx.doi.org/10.1016/j.adaj.2017.01.022

15. Kim JE, Kim NH, Shim JS. Fabrication of a complete, removable dental prosthesis from a digital intraoral impression for a patient with an excessively tight reconstructed lip after oral cancer treatment: A clinical report. J Prosthet Dent [Internet]. 2016;1–4. Available from: http://dx.doi.org/10.1016/j.prosdent.2016.07.001

16. Betensky RA, Gianneschi GE, Gallucci GO. Accuracy of digital versus conventional implant impressions. 2014;1–5.

17. Koch GK, Gallucci GO, Dent M, Lee SJ. Accuracy in the digital work fl ow : From data acquisition to the digitally milled cast. J Prosthet Dent [Internet]. 2010;115(6):749–54. Available from: http://dx.doi.org/10.1016/j.prosdent.2015.12.004

18. Ender A, Mehl A. Accuracy of complete-arch dental impressions : A new method of measuring trueness and precision. J Prosthet Dent [Internet]. 109(2):121–8. Available from: http://dx.doi.org/10.1016/S0022-3913(13)60028-1

19. Patzelt SBM, Emmanouilidi A. Accuracy of full-arch scans using intraoral scanners. 2014;1687–94.

20. Ender A, Mehl A, Mehl E. RESTORATIVE DENTISTRY In-vitro evaluation of the accuracy of conventional and digital methods of obtaining full-arch dental impressions. 2015;46(1):9–17.

21. Nedelcu RG, Persson ASK. Scanning accuracy and precision in 4 intraoral scanners : An in vitro comparison based on 3-dimensional analysis. J Prosthet Dent [Internet]. 2011;112(6):1461–71. Available from: http://dx.doi.org/10.1016/j.prosdent.2014.05.027

22. Cho SH, Schaefer O, Thompson GA, Guentsch A. Comparison of accuracy and reproducibility of casts made by digital and conventional methods. J Prosthet Dent [Internet]. 2015;113(4):310–5. Available from:

http://dx.doi.org/10.1016/j.prosdent.2014.09.027

23. Kuhr F, Schmidt A, Rehmann P, Wöstmann B, Cam CAD, Cam CAD. A new method for assessing the accuracy of full arch impressions in patients. J Dent [Internet]. 2016; Available from: http://dx.doi.org/10.1016/j.jdent.2016.10.002

Annex

1. Abbreviations list

CAD/CAM: Computer Aided Design, Computer Aided Manufacture

STL: surface tessellation language

CNC: computer numerical control

I1: first conventional impression and first intraoral digital impression

I2: second conventional impression and second intraoral digital impression

2. Figures list

Fig.1: Study set-up.

Fig.2: Flow Chart.

Fig.3: Horizontal linear measurement, transversal anterior (T1), in the first reference model obtained from conventional impression (I1) (35,5mm).

Fig.4: Horizontal linear measurement, T1, in the second reference model obtained from conventional impression (I2) (36 mm).

Fig.5: Horizontal linear measurements of virtual models obtained from the scan of stone cast models: A and B - MD between distal surface of 24 and mesial surface of 26, in I1 and I2, respectively; C and D - T1 between tip of the vestibular cusp of 14 and of 24, in I1 and I2, respectively; E and F - T2 between tip of the vestibular cusp of 15 and tip of the disto-vestibular cusp of 26, in I1 and I2, respectively.

Fig.6: Horizontal linear measurements of virtual models obtained from the intraoral scans: A and B - MD between distal surface of 24 and mesial surface of 26, in I1 and I2, respectively; C and D - T1 between tip of the vestibular cusp of 14 and 24, in I1 and I2, respectively; E and F - T2 between tip of the vestibular cusp of 15 and tip of the disto-vestibular cusp of 26, in I1 and I2, respectively.

Fig.7: Horizontal linear measurements of virtual models obtained from the scan of stone cast models: A and B - MD between mesial incisal angle of 43 and distal marginal cristal of 45, in I1 and I2, respectively; C and D - T1 between distal incisal angle of 33 and of 43, in I1 and I2, respectively; E and F - T2 between tip of the vestibular cusp of 34 and of 44, in I1 and I2, respectively.

Fig.8: Horizontal linear measurements of virtual models obtained from the intraoral scans: A and B - MD between mesial incisal angle of 43 and distal marginal cristal of 45, in I1 and I2, respectively; C and D - T1 between distal incisal angle of 33 and of 43, in I1 and I2, respectively; E and F - T2 between tip of the vestibular cusp of 34 and 44, in I1 and I2, respectively.

Fig.9: Horizontal linear measurements of virtual models obtained from the scan of stone cast models: A and B - MD between mesial surface of 11 and distal surface of 23, in I1and I2, respectively; C and D - T1 between distal incisal angle of 12 and tip of the cusp of 23, in I1and I2, respectively; E and F - T2 between tip of the cusp of 13 and of 23, in I1and I2, respectively.

Fig.10: Horizontal linear measurements of virtual models obtained from the intraoral scans: A and B - MD between mesial surface of 11 and distal surface of 23, in I1 and I2, respectively; C and D - T1

between distal incisal angle of 12 and tip of the cusp of 23, in I1 and I2, respectively; E and F - T2 between tip of the cusp of 13 and of 23, in I1 and I2, respectively

Fig.11: Vertical linear measurements of virtual models obtained from the scan of stone cast models: A - Distance of 0.52 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 1st cut; B - Distance of 0.44 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 2nd cut; C - Distance of 0.44 mm measured between I1 and I2 at a random point at the level of the palatal ridge, in the 2nd cut.

Fig.12: Vertical linear measurements of virtual models obtained from the intraoral scans: A - Distance of 0.04 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 1st cut; B - Distance of 0.08 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 2nd cut; C - Distance of 0.31 mm measured between I1 and I2 at a random point at the level of the palatal ridge, in the 3rd cut.

Fig.13: Vertical linear measurements of virtual models obtained from the scan of stone cast models: A - Distance of 0.39 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 1st cut; B - Distance of 0.2 mm measured between I1 and I2 at a random point at the level of the lingual ridge, in the 2nd cut; C - Distance of 0.45 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 3rd cut.

Fig.14: Vertical linear measurements of virtual models obtained from the intraoral scans: A - Distance of 0.63 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 1st cut; B - Distance of 0.16 mm measured between I1 and I2 at a random point at the level of the lingual ridge, in the 2nd cut; C - Distance of 0.7 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 3rd cut.

Fig.15: Vertical linear measurements of virtual models obtained from the scan of stone cast models: A - Distance of 0,08 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 1st cut; B - Distance of 0,13 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 2nd cut; C - Distance of 0,05 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 3rd cut.

Fig.16: Vertical linear measurements of virtual models obtained from the intraoral scans: A - Distance of 0,52 mm measured between I1 and I2 at a random point at the level of the crest ridge, in the 1rd cut; B - Distance of 0,73 mm measured between I1 and I2 at a random point at the level of the vestibular ridge, in the 2nd cut, C - Distance of 1,58 mm measured between I1 and I2 at a random point at the level of the palatal ridge, in the 3rd cut.

3. Tables list

Table I: Mean of horizontal linear measurements of between the two reference models, two scans of reference model and two intraoral scans.

Table II: Mean of horizontal linear measurements of between the two reference models, two scans of reference model and two intraoral scans.

Table III: Mean of horizontal linear measurements of between the two reference models, two scans of reference model and two intraoral scans.

4. Graphics list

Graphic 8: Distribution of the vertical linear measurements of the overlapping virtual models obtained from the scan of reference model, in random three cuts parallels to frontal plane, in the random point at the level of crest, palatal and vestibular ridge.

Graphic 9: Distribution of the vertical linear measurements of the overlapping virtual models obtained from the intraoral scan, in random three cuts parallels to frontal plane, in the random point at the level of crest, palatal and vestibular ridge.

Acknowledgements

Com o finalizar desta etapa, cabe a hora dos agradecimentos…Não é fácil passar para o papel, a importância que todas as pessoas tiveram neste percurso.

Em primeiro lugar agradeço aos meus orientadores, Prof. Doutor Nicolau e à Drª Rita, porque sem eles não era possível a conclusão desta etapa. E não foi uma conclusão banal, ao longo deste ano ter visto mais de perto a dedicação, o empenho e vontade de fazer mais e melhor fizeram-me admirar ainda mais estas personalidades. Ao professor Nicolau obrigada pela ajuda sempre presente, pela paciência e pela disponibilidade quando eu tinha dúvidas (e não eram poucas), pela calma que me transmitia e pelo dispensar do seu tempo para eu puder avançar neste projecto e também por corrigir o meu incrível inglês. À Dr.ªRita sempre preocupada em saber como eu estava, por dar-me um travão quando eu queria apressar tudo e não dava tempo à compreensão, a dizer-me aponta tudo para não te esqueceres, pela desmistificação das minhas questões, pela confiança, pela dedicação do seu tempo livre a ajudar-me na aquisição dos dados para a tese. Sinto-me uma sortuda em ter feito esta escolha. Serão sempre uma inspiração, um porto a alcançar na minha vida profissional por toda a excelência de trabalho que foram sempre demonstrando e pelo carinho e tempo dedicado aos alunos desta escola.

Agradeço ao Sr. Ricardo Alves, técnico da Sirona, que explicou-me tudo sobre o programa para eu puder realizar a aquisição e análise das imagens.

Agradeço a todos os professores que fizeram parte deste percurso. Os seus ensinamentos, disponibilidade, entusiasmo e preocupação, tornou-nos melhores como alunos. O que sou hoje e como serei como futura profissional devo a cada um dos professores que me deu um pouquinho do seu conhecimento e que são um pilar da minha futura vida profissional.

Agradeço à minha família, os meus pais, irmãos, cunhadas, avó, sobrinho, padrinhos…e não terminaria. Dizem que a minha família é grande, é verdade, mas enorme é o carinho e apoio que todos os dias me deram ao longo de todos os anos da minha vida. E nestes últimos 5 anos não foi exceção. Nunca me exigiram ser a melhor, sempre diziam: faz tudo sentindo que te esforçaste ao máximo, se conseguires ou não, o orgulho é o mesmo. Apoiaram-me em todas as minhas escolhas, mesmo torcendo um bocadinho o nariz em algumas, pelas poucas horas de sono e menos tempo para mim. Serão sempre, sem dúvida, a minha base da vida, que me dão o carinho e a motivação para fazer mais e melhor.

Agradeço a todos os meus colegas, que me ajudaram a crescer como ser humano. Aos amigos que estiveram presentes quando era preciso, sem ser necessário uma palavra sequer, que foram um porto de abrigo e um colinho para dar-me força. A um grupo de amigas, carinhosamente chamado d"As Fixes", um grande e sentido obrigado, sempre que um dia terminava lá estavam elas para me ouvir e dar os melhores conselhos.

E por último e não menos importante agradeço há pessoa que me acompanha desde sempre, até frequentamos o mesmo curso e desenvolvemos a mesma paixão pela medicina dentária, à minha irmã gémea, que apesar das nossas grandes diferenças, o apoio, carinho e preocupação foi sempre uma constante entre nós e será para sempre. Agora sim veremos como somos separadas.

Um Enorme Obrigada a todas as pessoas que fizeram parte do meu percurso…

Index