AAO Foundation Final report
(a/o 6/30/2018)

In an attempt to make things a little easier for the reviewer who will read this report, please consider these two questions before this is sent for review:
Is this an example of your very best work, in that it provides sufficient explanation and justification, and is something otherwise worthy of publication?
Does this Report provide the level of detail, etc. that you would expect, if you were the reviewer?
Type of Award (Check One):
___ Orthodontic Faculty Development Fellowship Award
___ Postdoctoral Fellowship Award
__X_ Biomedical Research Award
___ Center Award
___ Educational Innovation Award
___ Program Award
___ Research Aid Award

Name(s) of Principal Investigator(s): Sarandeep Huja

Institution: Medical University of South

Title of Project: Digital Workflows in Orthodontics: Trueness and Precision of Scanners and Bracket Erase software

Period of AAOF support (e.g. 07-01-19 to 6-30-20): 07-01-21 to **12-31-22**
Amount of AAOF Funding: $29,998.70

PLEASE ADDRESS EACH CATEGORY SEPARATELY (single spaced)
 Abstract:
1. Specific Aims
Aim 1: A single dentate cadaver will be used to examine the following subaims
A: **Determine trueness and precision of three clinical intraoral scanners.** A scan of a maxillary and mandibular arch, to correspond to, no brackets typical to prior to orthodontics, pre-debond and post-debond timepoints will be assessed. The clinical scanners will be compared to an industrial "gold standard" ATOS scanner. B: **Determine the trueness and precision of five bracket erase software**. We will be comparing the pre-bracket placement ATOS scan to the virtual bracket deletes rendering made from the post bracket placement ATOS scan. Each of the 5 different bracket erase software will be used 8 times each per (2) arch for a total of 80 arches of bracket deletes.
Aim 2: **To determine trueness and precision of virtual bracket erase software by examining both the arch (mandibular vs maxillary) and tooth type in scans obtained from patients**. Pre-debond scans from patients will subject to virtual bracket removal and then compared to scans obtained after debond by an experienced clinician. Trends will be analyzed to determine if the software works better on specific teeth or if a specific arch is more accurate/precise. Five commercially available software will be analyzed and compared to determine if a specific software is more accurate/precise at removing brackets and recreating the natural tooth contours.

Detailed results and inferences:
Summarize which studies have already been conducted and results achieved, particularly in reference to specific aims (investigated hypothesis(es) and corresponding findings).
We have completed Aim 1. We have included the details in two attachments
1. Oral Presentation at the 2022 AADOCR meeting that received a prestigious travel award.
2. Poster presentation the Scholars day at MUSC.
Please see the details of the results in these two presentations. I have also included the data collection for Aim 2.

Were the original, specific aims of the proposal realized?
Yes

Were the results published
Not yet, in a manuscript format but yes, in abstract, oral presentation. Manuscript in preparation.

Publications/presentations
Data was presented at the 2022 AADOCR meeting and at MUSC College research day. A possible talk at Midwest Angle meeting in 2024 is planned.

To what extent have you used, or how do you intend to use, AAOF funding to further your career?*
I have been grateful and fortunate to receive AAOF funding throughout my career and I am very grateful. I have made multiple recorded testimonies with the AAOF and other organizations on the value and benefit of the AAOF.

Percentage funding from AAOF and other sources; amount of grant funds already spent
Request/justification for extension of present cycle: do the investigator(s) foresee a time extension for this project and why?

100% spent, the original project budget ran over and was funded by the discretion funds to the PI by about $5500.00

Illustrations, addendum
Please see 3 enclosures

PATIENT 1

Software	'+Avg"	"-Avg"	Arch	Teeth
4	0.3133	-0.0433	Maxillary	Molars
4	0.3006	-0.0505	Maxillary	Molars
4	0.2828	-0.0408	Maxillary	Molars
4	0.3527	-0.0658	Maxillary	Molars
4	0.3292	-0.0429	Maxillary	Molars
4	0.3405	-0.0455	Maxillary	Molars
4	0.3304	-0.0882	Maxillary	Molars
4	0.3181	-0.0516	Maxillary	Molars
3	0.3778	-0.0341	Maxillary	Molars
3	0.3847	-0.0388	Maxillary	Molars
3	0.3225	-0.0336	Maxillary	Molars
3	0.326	-0.0442	Maxillary	Molars
3	0.2875	-0.04	Maxillary	Molars
3	0.3634	-0.0368	Maxillary	Molars
3	0.3669	-0.0354	Maxillary	Molars
3	0.2996	-0.038	Maxillary	Molars
2	0.3328	-0.0355	Maxillary	Molars
2	0.3322	-0.0346	Maxillary	Molars
2	0.3787	-0.0333	Maxillary	Molars
2	0.3117	-0.0354	Maxillary	Molars
2	0.3675	-0.0315	Maxillary	Molars
2	0.3625	-0.0358	Maxillary	Molars
2	0.3786	-0.0332	Maxillary	Molars
2	0.3705	-0.031	Maxillary	Molars
5	0.3275	-0.031	Maxillary	Molars
5	0.3559	-0.0387	Maxillary	Molars
5	0.3686	-0.0413	Maxillary	Molars
5	0.377	-0.0305	Maxillary	Molars
5	0.4488	-0.0373	Maxillary	Molars
5	0.3844	-0.0318	Maxillary	Molars
5	0.3762	-0.0322	Maxillary	Molars
5	0.3268	-0.0399	Maxillary	Molars
1	0.3156	-0.0393	Maxillary	Molars
1	0.2727	-0.0296	Maxillary	Molars
1	0.2847	-0.0275	Maxillary	Molars
1	0.3712	-0.0304	Maxillary	Molars
1	0.2401	-0.0396	Maxillary	Molars
1	0.2983	-0.0302	Maxillary	Molars
1	0.2993	-0.0833	Maxillary	Molars
1	0.2544	-0.0408	Maxillary	Molars
4	0.186	-0.0378	Maxillary	Premolars + Canines
4	0.1932	-0.0317	Maxillary	Premolars + Canines
4	0.2046	-0.0556	Maxillary	Premolars + Canines
4	0.236	-0.0384	Maxillary	Premolars + Canines

4	0.182	-0.0425 Maxillary	Premolars + Canines
4	0.2159	-0.0383 Maxillary	Premolars + Canines
4	0.1846	-0.0256 Maxillary	Premolars + Canines
4	0.2367	-0.0309 Maxillary	Premolars + Canines
3	0.2409	-0.0312 Maxillary	Premolars + Canines
3	0.2251	-0.0237 Maxillary	Premolars + Canines
3	0.2187	-0.0478 Maxillary	Premolars + Canines
3	0.1806	-0.0534 Maxillary	Premolars + Canines
3	0.1892	-0.0377 Maxillary	Premolars + Canines
3	0.2003	-0.0745 Maxillary	Premolars + Canines
3	0.2318	-0.0275 Maxillary	Premolars + Canines
3	0.1729	-0.0917 Maxillary	Premolars + Canines
2	0.1686	-0.0388 Maxillary	Premolars + Canines
2	0.1684	-0.1059 Maxillary	Premolars + Canines
2	0.1599	-0.0787 Maxillary	Premolars + Canines
2	0.1396	-0.1358 Maxillary	Premolars + Canines
2	0.1896	-0.0606 Maxillary	Premolars + Canines
2	0.18	-0.0459 Maxillary	Premolars + Canines
2	0.1595	-0.0155 Maxillary	Premolars + Canines
2	0.1468	-0.0289 Maxillary	Premolars + Canines
5	0.2028	-0.0601 Maxillary	Premolars + Canines
5	0.2711	-0.0453 Maxillary	Premolars + Canines
5	0.2203	-0.0361 Maxillary	Premolars + Canines
5	0.2687	-0.0233 Maxillary	Premolars + Canines
5	0.2183	-0.0138 Maxillary	Premolars + Canines
5	0.2222	-0.0213 Maxillary	Premolars + Canines
5	0.2021	-0.0265 Maxillary	Premolars + Canines
5	0.2233	-0.0681 Maxillary	Premolars + Canines
1	0.1451	-0.0439 Maxillary	Premolars + Canines
1	0.1544	-0.0785 Maxillary	Premolars + Canines
1	0.1941	-0.0275 Maxillary	Premolars + Canines
1	0.1991	-0.0359 Maxillary	Premolars + Canines
1	0.1811	-0.0839 Maxillary	Premolars + Canines
1	0.1928	-0.0225 Maxillary	Premolars + Canines
1	0.1927	-0.0886 Maxillary	Premolars + Canines
1	0.173	-0.0636 Maxillary	Premolars + Canines
4	0.1094	-0.0528 Maxillary	Incisors
4	0.1313	-0.0489 Maxillary	Incisors
4	0.097	-0.0478 Maxillary	Incisors
4	0.1097	-0.0425 Maxillary	Incisors
4	0.1037	-0.0398 Maxillary	Incisors
4	0.1348	-0.0262 Maxillary	Incisors
4	0.1387	-0.032 Maxillary	Incisors
4	0.104	-0.0452 Maxillary	Incisors
3	0.1874	-0.0185 Maxillary	Incisors
3	0.1683	-0.0216 Maxillary	Incisors
3	0.1601	-0.0196 Maxillary	Incisors

3	0.1744	-0.0204 Maxillary	Incisors
3	0.1711	-0.0189 Maxillary	Incisors
3	0.1717	-0.0199 Maxillary	Incisors
3	0.1697	-0.0198 Maxillary	Incisors
3	0.1694	-0.02 Maxillary	Incisors
2	0.1898	-0.0161 Maxillary	Incisors
2	0.1968	-0.0176 Maxillary	Incisors
2	0.1918	-0.0183 Maxillary	Incisors
2	0.1828	-0.018 Maxillary	Incisors
2	0.1887	-0.0214 Maxillary	Incisors
2	0.1828	-0.0169 Maxillary	Incisors
2	0.1863	-0.0169 Maxillary	Incisors
2	0.1886	-0.0162 Maxillary	Incisors
5	0.2086	-0.0232 Maxillary	Incisors
5	0.2278	-0.0211 Maxillary	Incisors
5	0.2277	-0.0369 Maxillary	Incisors
5	0.2541	-0.019 Maxillary	Incisors
5	0.2808	-0.0253 Maxillary	Incisors
5	0.1921	-0.026 Maxillary	Incisors
5	0.2099	-0.0286 Maxillary	Incisors
5	0.2281	-0.0227 Maxillary	Incisors
1	0.1653	-0.02 Maxillary	Incisors
1	0.188	-0.0191 Maxillary	Incisors
1	0.1731	-0.0204 Maxillary	Incisors
1	0.1514	-0.0194 Maxillary	Incisors
1	0.1572	-0.019 Maxillary	Incisors
1	0.1769	-0.0205 Maxillary	Incisors
1	0.1937	-0.0196 Maxillary	Incisors
1	0.184	-0.0194 Maxillary	Incisors
4	0.2266	-0.038 Mandibular	Molars
4	0.2462	-0.0798 Mandibular	Molars
4	0.2866	-0.0386 Mandibular	Molars
4	0.2195	-0.0492 Mandibular	Molars
4	0.2135	-0.0456 Mandibular	Molars
4	0.2148	-0.04 Mandibular	Molars
4	0.1914	-0.0563 Mandibular	Molars
4	0.2298	-0.0521 Mandibular	Molars
3	0.2188	-0.0508 Mandibular	Molars
3	0.183	-0.0432 Mandibular	Molars
3	0.2637	-0.0381 Mandibular	Molars
3	0.2124	-0.0305 Mandibular	Molars
3	0.2961	-0.0286 Mandibular	Molars
3	0.2522	-0.0415 Mandibular	Molars
3	0.2242	-0.0626 Mandibular	Molars
3	0.2038	-0.0357 Mandibular	Molars
2	0.2117	-0.0321 Mandibular	Molars
2	0.2406	-0.0451 Mandibular	Molars

2	0.2657	-0.0434 Mandibular	Molars
2	0.2109	-0.0377 Mandibular	Molars
2	0.2277	-0.0342 Mandibular	Molars
2	0.2183	-0.0275 Mandibular	Molars
2	0.22	-0.0327 Mandibular	Molars
2	0.2157	-0.0306 Mandibular	Molars
5	0.1964	-0.0295 Mandibular	Molars
5	0.1793	-0.0513 Mandibular	Molars
5	0.1518	-0.0341 Mandibular	Molars
5	0.1806	-0.0311 Mandibular	Molars
5	0.1901	-0.0413 Mandibular	Molars
5	0.1593	-0.0413 Mandibular	Molars
5	0.2994	-0.0514 Mandibular	Molars
5	0.1772	-0.032 Mandibular	Molars
1	0.253	-0.0577 Mandibular	Molars
1	0.1229	-0.0339 Mandibular	Molars
1	0.1941	-0.0292 Mandibular	Molars
1	0.1568	-0.0261 Mandibular	Molars
1	0.1255	-0.0323 Mandibular	Molars
1	0.1603	-0.0376 Mandibular	Molars
1	0.1626	-0.0585 Mandibular	Molars
1	0.192	-0.0499 Mandibular	Molars
4	0.1643	-0.0343 Mandibular	Premolars + Canines
4	0.1265	-0.0355 Mandibular	Premolars + Canines
4	0.1383	-0.0286 Mandibular	Premolars + Canines
4	0.1535	-0.0264 Mandibular	Premolars + Canines
4	0.1353	-0.0299 Mandibular	Premolars + Canines
4	0.1728	-0.0211 Mandibular	Premolars + Canines
4	0.1353	-0.0312 Mandibular	Premolars + Canines
4	0.1622	-0.0295 Mandibular	Premolars + Canines
3	0.1054	-0.0328 Mandibular	Premolars + Canines
3	0.0962	-0.0353 Mandibular	Premolars + Canines
3	0.104	-0.0349 Mandibular	Premolars + Canines
3	0.1105	-0.0345 Mandibular	Premolars + Canines
3	0.0985	-0.0338 Mandibular	Premolars + Canines
3	0.0954	-0.0412 Mandibular	Premolars + Canines
3	0.1013	-0.0334 Mandibular	Premolars + Canines
3	0.1087	-0.0339 Mandibular	Premolars + Canines
2	0.0819	-0.0494 Mandibular	Premolars + Canines
2	0.0981	-0.0405 Mandibular	Premolars + Canines
2	0.0944	-0.0469 Mandibular	Premolars + Canines
2	0.0687	-0.0481 Mandibular	Premolars + Canines
2	0.0882	-0.0468 Mandibular	Premolars + Canines
2	0.0917	-0.0483 Mandibular	Premolars + Canines
2	0.0815	-0.0497 Mandibular	Premolars + Canines
2	0.0854	-0.0372 Mandibular	Premolars + Canines
5	0.1198	-0.0469 Mandibular	Premolars + Canines

5	0.1219	-0.0605	Mandibular	Premolars + Canines
5	0.1093	-0.049	Mandibular	Premolars + Canines
5	0.1727	-0.0448	Mandibular	Premolars + Canines
5	0.1808	-0.0364	Mandibular	Premolars + Canines
5	0.1107	-0.0592	Mandibular	Premolars + Canines
5	0.2958	-0.032	Mandibular	Premolars + Canines
5	0.147	-0.0357	Mandibular	Premolars + Canines
1	0.082	-0.0416	Mandibular	Premolars + Canines
1	0.109	-0.0571	Mandibular	Premolars + Canines
1	0.1109	-0.0326	Mandibular	Premolars + Canines
1	0.0969	-0.0511	Mandibular	Premolars + Canines
1	0.0865	-0.0427	Mandibular	Premolars + Canines
1	0.0921	-0.0355	Mandibular	Premolars + Canines
1	0.0734	-0.0523	Mandibular	Premolars + Canines
1	0.0793	-0.0482	Mandibular	Premolars + Canines
4	0.1685	-0.0314	Mandibular	Incisors
4	0.2396	-0.031	Mandibular	Incisors
4	0.2239	-0.0131	Mandibular	Incisors
4	0.1683	-0.024	Mandibular	Incisors
4	0.1719	-0.0475	Mandibular	Incisors
4	0.1997	-0.005	Mandibular	Incisors
4	0.2459	-0.0221	Mandibular	Incisors
4	0.2381	-0.0072	Mandibular	Incisors
3	0.2136	-0.0076	Mandibular	Incisors
3	0.1641	-0.0082	Mandibular	Incisors
3	0.1704	-0.0074	Mandibular	Incisors
3	0.179	-0.008	Mandibular	Incisors
3	0.1791	-0.0069	Mandibular	Incisors
3	0.1765	-0.0085	Mandibular	Incisors
3	0.1771	-0.0082	Mandibular	Incisors
3	0.1545	-0.0073	Mandibular	Incisors
2	0.1999	-0.0058	Mandibular	Incisors
2	0.2173	-0.0065	Mandibular	Incisors
2	0.2769	-0.0081	Mandibular	Incisors
2	0.1994	-0.0069	Mandibular	Incisors
2	0.2806	-0.0042	Mandibular	Incisors
2	0.2191	-0.008	Mandibular	Incisors
2	0.2308	-0.0065	Mandibular	Incisors
2	0.263	-0.0153	Mandibular	Incisors
5	0.2104	-0.0268	Mandibular	Incisors
5	0.2741	0	Mandibular	Incisors
5	0.1918	-0.0152	Mandibular	Incisors
5	0.3105	-0.0376	Mandibular	Incisors
5	0.25	-0.0047	Mandibular	Incisors
5	0.2569	-0.0096	Mandibular	Incisors
5	0.3889	0	Mandibular	Incisors
5	0.2112	-0.0235	Mandibular	Incisors

1	0.1454	-0.0156	Mandibular	Incisors
1	0.234	-0.007	Mandibular	Incisors
1	0.2478	-0.0047	Mandibular	Incisors
1	0.2216	-0.0081	Mandibular	Incisors
1	0.1772	-0.012	Mandibular	Incisors
1	0.2114	-0.0153	Mandibular	Incisors
1	0.1318	-0.0706	Mandibular	Incisors
1	0.1573	-0.0163	Mandibular	Incisors

PATIENT 2

Software	'+Avg"	"-Avg"	Arch	Teeth
4	0.3051	-0.059	Maxillary	Molars
4	0.3346	-0.0382	Maxillary	Molars
4	0.3363	-0.0536	Maxillary	Molars
4	0.3402	-0.0277	Maxillary	Molars
4	0.3561	-0.0543	Maxillary	Molars
4	0.3097	-0.0324	Maxillary	Molars
4	0.3042	-0.042	Maxillary	Molars
4	0.332	-0.0282	Maxillary	Molars
3	0.2376	-0.0268	Maxillary	Molars
3	0.2282	-0.087	Maxillary	Molars
3	0.2051	-0.1295	Maxillary	Molars
3	0.2469	-0.2415	Maxillary	Molars
3	0.1864	-0.1413	Maxillary	Molars
3	0.1986	-0.1298	Maxillary	Molars
3	0.1336	-0.1412	Maxillary	Molars
3	0.1729	-0.1728	Maxillary	Molars
2	0.36	-0.0532	Maxillary	Molars
2	0.3454	-0.0652	Maxillary	Molars
2	0.3456	-0.0499	Maxillary	Molars
2	0.3721	-0.0475	Maxillary	Molars
2	0.3413	-0.0772	Maxillary	Molars
2	0.3476	-0.072	Maxillary	Molars
2	0.365	-0.045	Maxillary	Molars
2	0.3688	-0.0527	Maxillary	Molars
5	0.2607	-0.1051	Maxillary	Molars
5	0.3454	-0.0614	Maxillary	Molars
5	0.2445	-0.0414	Maxillary	Molars
5	0.2848	-0.0575	Maxillary	Molars
5	0.3129	-0.0452	Maxillary	Molars
5	0.2616	-0.0472	Maxillary	Molars
5	0.3476	-0.0544	Maxillary	Molars
5	0.2749	-0.0682	Maxillary	Molars
1	0.2001	-0.064	Maxillary	Molars
1	0.2089	-0.0662	Maxillary	Molars
1	0.2301	-0.0751	Maxillary	Molars
1	0.1997	-0.0484	Maxillary	Molars
1	0.2253	-0.0552	Maxillary	Molars
1	0.2433	-0.0487	Maxillary	Molars
1	0.2452	-0.0574	Maxillary	Molars
1	0.1827	-0.0454	Maxillary	Molars
4	0.293	-0.0234	Maxillary	Premolars + Canines
4	0.2994	-0.0209	Maxillary	Premolars + Canines
4	0.3155	-0.0177	Maxillary	Premolars + Canines
4	0.309	-0.0239	Maxillary	Premolars + Canines

4	0.3163	-0.0698	Maxillary	Premolars + Canines
4	0.3087	-0.0196	Maxillary	Premolars + Canines
4	0.2873	-0.0106	Maxillary	Premolars + Canines
4	0.2898	-0.0297	Maxillary	Premolars + Canines
3	0.152	-0.0912	Maxillary	Premolars + Canines
3	0.1472	-0.1359	Maxillary	Premolars + Canines
3	0.1303	-0.1434	Maxillary	Premolars + Canines
3	0.1339	-0.1125	Maxillary	Premolars + Canines
3	0.128	-0.1249	Maxillary	Premolars + Canines
3	0.1408	-0.1635	Maxillary	Premolars + Canines
3	0.1319	-0.1365	Maxillary	Premolars + Canines
3	0.1068	-0.0924	Maxillary	Premolars + Canines
2	0.1744	-0.1427	Maxillary	Premolars + Canines
2	0.1683	-0.0259	Maxillary	Premolars + Canines
2	0.1315	-0.1374	Maxillary	Premolars + Canines
2	0.1771	-0.0421	Maxillary	Premolars + Canines
2	0.2036	-0.084	Maxillary	Premolars + Canines
2	0.163	-0.07	Maxillary	Premolars + Canines
2	0.2018	-0.0528	Maxillary	Premolars + Canines
2	0.2022	-0.1135	Maxillary	Premolars + Canines
5	0.2398	-0.2101	Maxillary	Premolars + Canines
5	0.2139	-0.2109	Maxillary	Premolars + Canines
5	0.1831	-0.1081	Maxillary	Premolars + Canines
5	0.1994	-0.1277	Maxillary	Premolars + Canines
5	0.178	-0.1469	Maxillary	Premolars + Canines
5	0.2218	-0.2219	Maxillary	Premolars + Canines
5	0.2706	-0.1581	Maxillary	Premolars + Canines
5	0.1956	-0.135	Maxillary	Premolars + Canines
1	0.1012	-0.0945	Maxillary	Premolars + Canines
1	0.1025	-0.0756	Maxillary	Premolars + Canines
1	0.1348	-0.1723	Maxillary	Premolars + Canines
1	0.1184	-0.1394	Maxillary	Premolars + Canines
1	0.1006	-0.0965	Maxillary	Premolars + Canines
1	0.1221	-0.1245	Maxillary	Premolars + Canines
1	0.1206	-0.1426	Maxillary	Premolars + Canines
1	0.1288	-0.0777	Maxillary	Premolars + Canines
4	0.2249	-0.0204	Maxillary	Incisors
4	0.1737	-0.0273	Maxillary	Incisors
4	0.21	-0.0285	Maxillary	Incisors
4	0.2102	-0.0228	Maxillary	Incisors
4	0.2039	-0.0207	Maxillary	Incisors
4	0.1914	-0.0262	Maxillary	Incisors
4	0.1825	-0.0223	Maxillary	Incisors
4	0.1788	-0.0291	Maxillary	Incisors
3	0.114	-0.0233	Maxillary	Incisors
3	0.0913	-0.0253	Maxillary	Incisors
3	0.1073	-0.0231	Maxillary	Incisors

3	0.0849	-0.0251	Maxillary	Incisors
3	0.082	-0.0224	Maxillary	Incisors
3	0.1002	-0.0233	Maxillary	Incisors
3	0.1013	-0.0243	Maxillary	Incisors
3	0.0849	-0.0215	Maxillary	Incisors
2	0.1457	-0.0235	Maxillary	Incisors
2	0.1682	-0.0227	Maxillary	Incisors
2	0.1407	-0.0262	Maxillary	Incisors
2	0.1433	-0.0231	Maxillary	Incisors
2	0.1549	-0.0247	Maxillary	Incisors
2	0.1778	-0.0268	Maxillary	Incisors
2	0.15	-0.0271	Maxillary	Incisors
2	0.153	-0.0258	Maxillary	Incisors
5	0.1542	-0.0425	Maxillary	Incisors
5	0.1792	-0.035	Maxillary	Incisors
5	0.1226	-0.0422	Maxillary	Incisors
5	0.1968	-0.0345	Maxillary	Incisors
5	0.213	-0.0342	Maxillary	Incisors
5	0.1922	-0.084	Maxillary	Incisors
5	0.1995	-0.0357	Maxillary	Incisors
5	0.1484	-0.0269	Maxillary	Incisors
1	0.0971	-0.0347	Maxillary	Incisors
1	0.0767	-0.0277	Maxillary	Incisors
1	0.0594	-0.0409	Maxillary	Incisors
1	0.0599	-0.0345	Maxillary	Incisors
1	0.0762	-0.0275	Maxillary	Incisors
1	0.0989	-0.0368	Maxillary	Incisors
1	0.1042	-0.0299	Maxillary	Incisors
1	0.0709	-0.0276	Maxillary	Incisors
4	0.3378	-0.0351	Mandibular	Molars
4	0.3657	-0.0106	Mandibular	Molars
4	0.351	-0.0113	Mandibular	Molars
4	0.2712	-0.012	Mandibular	Molars
4	0.29	-0.1722	Mandibular	Molars
4	0.3635	-0.0598	Mandibular	Molars
4	0.3676	-0.0521	Mandibular	Molars
4	0.3652	-0.03	Mandibular	Molars
3	0.2618	-0.0666	Mandibular	Molars
3	0.2524	-0.0288	Mandibular	Molars
3	0.2607	-0.1761	Mandibular	Molars
3	0.2483	-0.0405	Mandibular	Molars
3	0.2907	-0.0437	Mandibular	Molars
3	0.2471	-0.0283	Mandibular	Molars
3	0.2709	-0.0417	Mandibular	Molars
3	0.2564	-0.0158	Mandibular	Molars
2	0.3194	-0.0597	Mandibular	Molars
2	0.2732	-0.022	Mandibular	Molars

2	0.2997	-0.0629	Mandibular	Molars
2	0.2674	-0.0928	Mandibular	Molars
2	0.2554	-0.0413	Mandibular	Molars
2	0.2673	-0.0592	Mandibular	Molars
2	0.3052	-0.0801	Mandibular	Molars
2	0.2823	-0.0392	Mandibular	Molars
5	0.3386	-0.0915	Mandibular	Molars
5	0.3386	-0.0155	Mandibular	Molars
5	0.2529	-0.0475	Mandibular	Molars
5	0.2817	-0.0768	Mandibular	Molars
5	0.2563	-0.1145	Mandibular	Molars
5	0.2566	-0.1262	Mandibular	Molars
5	0.2828	-0.1316	Mandibular	Molars
5	0.2599	-0.1279	Mandibular	Molars
1	0.2021	-0.0553	Mandibular	Molars
1	0.2063	-0.0734	Mandibular	Molars
1	0.1812	-0.0637	Mandibular	Molars
1	0.1956	-0.0632	Mandibular	Molars
1	0.1923	-0.0574	Mandibular	Molars
1	0.2142	-0.0663	Mandibular	Molars
1	0.2156	-0.0436	Mandibular	Molars
1	0.2056	-0.0391	Mandibular	Molars
4	0.267	-0.0372	Mandibular	Premolars + Canines
4	0.3082	-0.0299	Mandibular	Premolars + Canines
4	0.2755	-0.034	Mandibular	Premolars + Canines
4	0.2746	-0.0488	Mandibular	Premolars + Canines
4	0.3087	-0.1675	Mandibular	Premolars + Canines
4	0.3274	-0.063	Mandibular	Premolars + Canines
4	0.3004	-0.0392	Mandibular	Premolars + Canines
4	0.3164	-0.0493	Mandibular	Premolars + Canines
3	0.1205	-0.1378	Mandibular	Premolars + Canines
3	0.1078	-0.1205	Mandibular	Premolars + Canines
3	0.1079	-0.1084	Mandibular	Premolars + Canines
3	0.1114	-0.1172	Mandibular	Premolars + Canines
3	0.1087	-0.0851	Mandibular	Premolars + Canines
3	0.1163	-0.1191	Mandibular	Premolars + Canines
3	0.1103	-0.1032	Mandibular	Premolars + Canines
3	0.1044	-0.1192	Mandibular	Premolars + Canines
2	0.1375	-0.0597	Mandibular	Premolars + Canines
2	0.1187	-0.0748	Mandibular	Premolars + Canines
2	0.1277	-0.0694	Mandibular	Premolars + Canines
2	0.0789	-0.0923	Mandibular	Premolars + Canines
2	0.1132	-0.0865	Mandibular	Premolars + Canines
2	0.0918	-0.0799	Mandibular	Premolars + Canines
2	0.125	-0.077	Mandibular	Premolars + Canines
2	0.1284	-0.1099	Mandibular	Premolars + Canines
5	0.2898	-0.0792	Mandibular	Premolars + Canines

5	0.2458	-0.055	Mandibular	Premolars + Canines
5	0.18	-0.0961	Mandibular	Premolars + Canines
5	0.2612	-0.0552	Mandibular	Premolars + Canines
5	0.1945	-0.1461	Mandibular	Premolars + Canines
5	0.2355	-0.1329	Mandibular	Premolars + Canines
5	0.164	-0.1351	Mandibular	Premolars + Canines
5	0.1839	-0.0695	Mandibular	Premolars + Canines
1	0.0954	-0.0988	Mandibular	Premolars + Canines
1	0.0945	-0.0841	Mandibular	Premolars + Canines
1	0.1134	-0.1084	Mandibular	Premolars + Canines
1	0.0906	-0.1094	Mandibular	Premolars + Canines
1	0.1175	-0.1094	Mandibular	Premolars + Canines
1	0.1172	-0.0924	Mandibular	Premolars + Canines
1	0.0981	-0.0805	Mandibular	Premolars + Canines
1	0.1046	-0.1143	Mandibular	Premolars + Canines
4	0.3302	-0.0062	Mandibular	Incisors
4	0.3756	-0.0066	Mandibular	Incisors
4	0.2841	-0.005	Mandibular	Incisors
4	0.2993	-0.0254	Mandibular	Incisors
4	0.3535	-0.0456	Mandibular	Incisors
4	0.3378	0	Mandibular	Incisors
4	0.3601	0	Mandibular	Incisors
4	0.3946	0	Mandibular	Incisors
3	0.0775	-0.0784	Mandibular	Incisors
3	0.0839	-0.0566	Mandibular	Incisors
3	0.0891	-0.0842	Mandibular	Incisors
3	0.0868	-0.0937	Mandibular	Incisors
3	0.1121	-0.0322	Mandibular	Incisors
3	0.1041	-0.0499	Mandibular	Incisors
3	0.0844	-0.0661	Mandibular	Incisors
3	0.0913	-0.0582	Mandibular	Incisors
2	0.1859	-0.0187	Mandibular	Incisors
2	0.1659	-0.0302	Mandibular	Incisors
2	0.1341	-0.0458	Mandibular	Incisors
2	0.116	-0.0378	Mandibular	Incisors
2	0.1487	-0.0274	Mandibular	Incisors
2	0.1368	-0.0326	Mandibular	Incisors
2	0.1517	-0.0228	Mandibular	Incisors
2	0.1202	-0.0388	Mandibular	Incisors
5	0.2641	-0.0571	Mandibular	Incisors
5	0.4347	-0.0459	Mandibular	Incisors
5	0.2151	-0.0481	Mandibular	Incisors
5	0.348	0	Mandibular	Incisors
5	0.1818	-0.0769	Mandibular	Incisors
5	0.2764	-0.1056	Mandibular	Incisors
5	0.1645	-0.0515	Mandibular	Incisors
5	0.2085	-0.0391	Mandibular	Incisors

1	0.0973	-0.0728	Mandibular	Incisors
1	0.1023	-0.0277	Mandibular	Incisors
1	0.0824	-0.0336	Mandibular	Incisors
1	0.0649	-0.113	Mandibular	Incisors
1	0.0908	-0.0765	Mandibular	Incisors
1	0.0927	-0.1437	Mandibular	Incisors
1	0.1152	-0.0734	Mandibular	Incisors
1	0.1239	-0.0736	Mandibular	Incisors

PATIENT 3

Software	'+Avg''	"-Avg''	Arch	Teeth
4	0.3224	-0.0619	Maxillary	Molars
4	0.3573	-0.0552	Maxillary	Molars
4	0.3126	-0.0746	Maxillary	Molars
4	0.3664	-0.0675	Maxillary	Molars
4	0.3809	-0.042	Maxillary	Molars
4	0.2916	-0.0111	Maxillary	Molars
4	0.3099	-0.0946	Maxillary	Molars
4	0.3531	-0.0661	Maxillary	Molars
3	0.317	-0.1376	Maxillary	Molars
3	0.3001	-0.1337	Maxillary	Molars
3	0.3272	-0.0804	Maxillary	Molars
3	0.3162	-0.0674	Maxillary	Molars
3	0.3319	-0.0487	Maxillary	Molars
3	0.322	-0.095	Maxillary	Molars
3	0.3458	-0.153	Maxillary	Molars
3	0.3252	-0.0484	Maxillary	Molars
2	0.5757	-0.0144	Maxillary	Molars
2	0.5947	-0.0153	Maxillary	Molars
2	0.5681	-0.0132	Maxillary	Molars
2	0.5555	-0.0139	Maxillary	Molars
2	0.5518	-0.0147	Maxillary	Molars
2	0.5657	-0.0136	Maxillary	Molars
2	0.5646	-0.0141	Maxillary	Molars
2	0.5497	-0.0141	Maxillary	Molars
5	0.6075	-0.0164	Maxillary	Molars
5	0.5874	0	Maxillary	Molars
5	0.575	0	Maxillary	Molars
5	0.5299	-0.0169	Maxillary	Molars
5	0.5382	-0.0054	Maxillary	Molars
5	0.5315	0	Maxillary	Molars
5	0.5476	-0.0385	Maxillary	Molars
5	0.5043	0	Maxillary	Molars
1			Maxillary	Molars
1			Maxillary	Molars
1			Maxillary	Molars
1			Maxillary	Molars
1			Maxillary	Molars
1			Maxillary	Molars
1			Maxillary	Molars
1			Maxillary	Molars
4	0.164	-0.1078	Maxillary	Premolars + Canines
4	0.1798	-0.0693	Maxillary	Premolars + Canines
4	0.1313	-0.1485	Maxillary	Premolars + Canines

4	0.176	-0.0659	Maxillary	Premolars + Canines
4	0.153	-0.1671	Maxillary	Premolars + Canines
4	0.1315	-0.1351	Maxillary	Premolars + Canines
4	0.201	-0.1259	Maxillary	Premolars + Canines
4	0.1602	-0.1559	Maxillary	Premolars + Canines
3	0.1632	-0.0195	Maxillary	Premolars + Canines
3	0.1787	-0.0201	Maxillary	Premolars + Canines
3	0.1577	-0.0255	Maxillary	Premolars + Canines
3	0.1499	-0.0454	Maxillary	Premolars + Canines
3	0.1559	-0.0335	Maxillary	Premolars + Canines
3	0.1685	-0.0177	Maxillary	Premolars + Canines
3	0.1526	-0.0183	Maxillary	Premolars + Canines
3	0.1516	-0.0206	Maxillary	Premolars + Canines
2	0.231	-0.0202	Maxillary	Premolars + Canines
2	0.2008	-0.0283	Maxillary	Premolars + Canines
2	0.2012	-0.0228	Maxillary	Premolars + Canines
2	0.2372	-0.0174	Maxillary	Premolars + Canines
2	0.1971	-0.042	Maxillary	Premolars + Canines
2	0.2052	-0.0384	Maxillary	Premolars + Canines
2	0.2033	-0.0206	Maxillary	Premolars + Canines
2	0.1993	-0.0323	Maxillary	Premolars + Canines
5	0.2368	-0.0286	Maxillary	Premolars + Canines
5	0.2927	-0.0057	Maxillary	Premolars + Canines
5	0.2897	-0.0459	Maxillary	Premolars + Canines
5	0.2436	-0.061	Maxillary	Premolars + Canines
5	0.2886	-0.0474	Maxillary	Premolars + Canines
5	0.2488	-0.0428	Maxillary	Premolars + Canines
5	0.2278	-0.0441	Maxillary	Premolars + Canines
5	0.2508	-0.0466	Maxillary	Premolars + Canines
1			Maxillary	Premolars + Canines
1			Maxillary	Premolars + Canines
1			Maxillary	Premolars + Canines
1			Maxillary	Premolars + Canines
1			Maxillary	Premolars + Canines
1			Maxillary	Premolars + Canines
1			Maxillary	Premolars + Canines
1			Maxillary	Premolars + Canines
4	0.0649	-0.151	Maxillary	Incisors
4	0.0541	-0.1102	Maxillary	Incisors
4	0.0814	-0.184	Maxillary	Incisors
4	0.0652	-0.1458	Maxillary	Incisors
4	0.0719	-0.1833	Maxillary	Incisors
4	0.0777	-0.1531	Maxillary	Incisors
4	0.1211	-0.089	Maxillary	Incisors
4	0.1265	-0.1595	Maxillary	Incisors
3	0.1543	-0.0417	Maxillary	Incisors
3	0.1788	-0.043	Maxillary	Incisors

3	0.1965	-0.0408	Maxillary	Incisors
3	0.1806	-0.0435	Maxillary	Incisors
3	0.1692	-0.0442	Maxillary	Incisors
3	0.1705	-0.0424	Maxillary	Incisors
3	0.1427	-0.0448	Maxillary	Incisors
3	0.1651	-0.0433	Maxillary	Incisors
2	0.2092	-0.0381	Maxillary	Incisors
2	0.226	-0.039	Maxillary	Incisors
2	0.2344	-0.0376	Maxillary	Incisors
2	0.2228	-0.0406	Maxillary	Incisors
2	0.2254	-0.0396	Maxillary	Incisors
2	0.1841	-0.0409	Maxillary	Incisors
2	0.2134	-0.0406	Maxillary	Incisors
2	0.2018	-0.0387	Maxillary	Incisors
5	0.2537	-0.0359	Maxillary	Incisors
5	0.3647	-0.1093	Maxillary	Incisors
5	0.3455	-0.0362	Maxillary	Incisors
5	0.234	-0.0378	Maxillary	Incisors
5	0.1885	-0.0441	Maxillary	Incisors
5	0.2385	-0.0289	Maxillary	Incisors
5	0.1805	-0.1045	Maxillary	Incisors
5	0.256	-0.0175	Maxillary	Incisors
1			Maxillary	Incisors
1			Maxillary	Incisors
1			Maxillary	Incisors
1			Maxillary	Incisors
1			Maxillary	Incisors
1			Maxillary	Incisors
1			Maxillary	Incisors
1			Maxillary	Incisors
4	0.5313	-0.0358	Mandibular	Molars
4	0.5027	-0.0421	Mandibular	Molars
4	0.4684	-0.0423	Mandibular	Molars
4	0.4968	-0.0203	Mandibular	Molars
4	0.5046	-0.0297	Mandibular	Molars
4	0.43	-0.008	Mandibular	Molars
4	0.4233	-0.0405	Mandibular	Molars
4	0.4528	-0.0584	Mandibular	Molars
3	0.3343	-0.3476	Mandibular	Molars
3	0.3075	-0.1873	Mandibular	Molars
3	0.283	-0.1937	Mandibular	Molars
3	0.3005	-0.181	Mandibular	Molars
3	0.3151	-0.266	Mandibular	Molars
3	0.3134	-0.1966	Mandibular	Molars
3	0.284	-0.2295	Mandibular	Molars
3	0.2765	-0.2023	Mandibular	Molars
2	0.4369	-0.1153	Mandibular	Molars

2	0.4075	-0.1469	Mandibular	Molars
2	0.4195	-0.141	Mandibular	Molars
2	0.3969	-0.1239	Mandibular	Molars
2	0.4525	-0.1298	Mandibular	Molars
2	0.4207	-0.1122	Mandibular	Molars
2	0.4042	-0.1267	Mandibular	Molars
2	0.395	-0.0958	Mandibular	Molars
5	0.5912	-0.0001	Mandibular	Molars
5	0.683	-0.0118	Mandibular	Molars
5	0.7435	0	Mandibular	Molars
5	0.6865	-0.023	Mandibular	Molars
5	0.7688	-0.0428	Mandibular	Molars
5	0.7163	-0.0083	Mandibular	Molars
5	0.6906	-0.0214	Mandibular	Molars
5	0.7391	0	Mandibular	Molars
1			Mandibular	Molars
1			Mandibular	Molars
1			Mandibular	Molars
1			Mandibular	Molars
1			Mandibular	Molars
1			Mandibular	Molars
1			Mandibular	Molars
1			Mandibular	Molars
4	0.2469	-0.0575	Mandibular	Premolars + Canines
4	0.2363	-0.0604	Mandibular	Premolars + Canines
4	0.207	-0.0972	Mandibular	Premolars + Canines
4	0.2243	-0.055	Mandibular	Premolars + Canines
4	0.2931	-0.0751	Mandibular	Premolars + Canines
4	0.2121	-0.0707	Mandibular	Premolars + Canines
4	0.2008	-0.0457	Mandibular	Premolars + Canines
4	0.2583	-0.0807	Mandibular	Premolars + Canines
3	0.1303	-0.0594	Mandibular	Premolars + Canines
3	0.1388	-0.0709	Mandibular	Premolars + Canines
3	0.1204	-0.0676	Mandibular	Premolars + Canines
3	0.1397	-0.0681	Mandibular	Premolars + Canines
3	0.1272	-0.0672	Mandibular	Premolars + Canines
3	0.1447	-0.0667	Mandibular	Premolars + Canines
3	0.1427	-0.0689	Mandibular	Premolars + Canines
3	0.1409	-0.0669	Mandibular	Premolars + Canines
2	0.1325	-0.039	Mandibular	Premolars + Canines
2	0.1114	-0.0435	Mandibular	Premolars + Canines
2	0.11	-0.0686	Mandibular	Premolars + Canines
2	0.1509	-0.0657	Mandibular	Premolars + Canines
2	0.1364	-0.0551	Mandibular	Premolars + Canines
2	0.1291	-0.0601	Mandibular	Premolars + Canines
2	0.1263	-0.0577	Mandibular	Premolars + Canines
2	0.1149	-0.0555	Mandibular	Premolars + Canines

5	0.1585	-0.0568	Mandibular	Premolars + Canines
5	0.1643	-0.0696	Mandibular	Premolars + Canines
5	0.1928	-0.0628	Mandibular	Premolars + Canines
5	0.161	-0.0758	Mandibular	Premolars + Canines
5	0.2075	-0.0297	Mandibular	Premolars + Canines
5	0.1634	-0.0942	Mandibular	Premolars + Canines
5	0.222	-0.0434	Mandibular	Premolars + Canines
5	0.1545	-0.0971	Mandibular	Premolars + Canines
1			Mandibular	Premolars + Canines
1			Mandibular	Premolars + Canines
1			Mandibular	Premolars + Canines
1			Mandibular	Premolars + Canines
1			Mandibular	Premolars + Canines
1			Mandibular	Premolars + Canines
1			Mandibular	Premolars + Canines
1			Mandibular	Premolars + Canines
4	0.2229	-0.062	Mandibular	Incisors
4	0.1946	-0.0626	Mandibular	Incisors
4	0.2261	-0.055	Mandibular	Incisors
4	0.1764	-0.0462	Mandibular	Incisors
4	0.1575	-0.0644	Mandibular	Incisors
4	0.1663	-0.0477	Mandibular	Incisors
4	0.1422	-0.0553	Mandibular	Incisors
4	0.1964	-0.0634	Mandibular	Incisors
3	0.1402	-0.0656	Mandibular	Incisors
3	0.1194	-0.072	Mandibular	Incisors
3	0.1108	-0.0687	Mandibular	Incisors
3	0.117	-0.0678	Mandibular	Incisors
3	0.1151	-0.0671	Mandibular	Incisors
3	0.1197	-0.0694	Mandibular	Incisors
3	0.1123	-0.07	Mandibular	Incisors
3	0.1054	-0.0662	Mandibular	Incisors
2	0.2092	-0.0573	Mandibular	Incisors
2	0.1562	-0.0608	Mandibular	Incisors
2	0.1818	-0.0516	Mandibular	Incisors
2	0.1632	-0.0702	Mandibular	Incisors
2	0.1835	-0.0569	Mandibular	Incisors
2	0.1741	-0.0582	Mandibular	Incisors
2	0.1778	-0.0599	Mandibular	Incisors
2	0.1892	-0.059	Mandibular	Incisors
5	0.1893	-0.0597	Mandibular	Incisors
5	0.1729	-0.0514	Mandibular	Incisors
5	0.2368	-0.1005	Mandibular	Incisors
5	0.2132	-0.0655	Mandibular	Incisors
5	0.1913	-0.0505	Mandibular	Incisors
5	0.1459	-0.0653	Mandibular	Incisors
5	0.2159	-0.0534	Mandibular	Incisors

5	0.1898	-0.0346	Mandibular	Incisors
1			Mandibular	Incisors
1			Mandibular	Incisors
1			Mandibular	Incisors
1			Mandibular	Incisors
1			Mandibular	Incisors
1			Mandibular	Incisors
1			Mandibular	Incisors
1			Mandibular	Incisors

Trueness And Precision Of Scanners And Bracket Erase Softwares

Madison Sharp[1], C. McGill[2], W. Renne[3],

C. Webb[1,3], V. Ramakrishnan[2], S. S. Huja[1]

[1] Medical University of South Carolina, James B. Edwards College of Dental Medicine

[2] Medical University of South Carolina, Department of Public Health Sciences

[3] Private Practice

MUSC
Medical University
of South Carolina

Introduction and Background

- Digital workflows are rapidly being incorporated into clinical practice.
- One specific digital workflow is fabrication of retainers from predebond scans which can greatly improve the efficiency of orthodontic treatment delivered to our patients.

Appointment *n*: Patient scanned with brackets in place

Brackets digitally erased and retainer fabricated from new .stl model

Appointment *n+1*: Brackets debonded and retainer delivered immediately

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of South Carolina
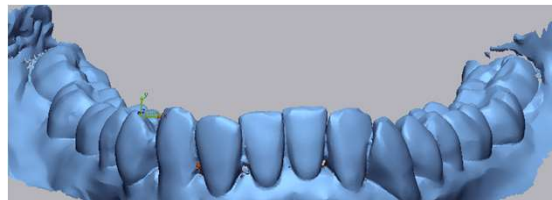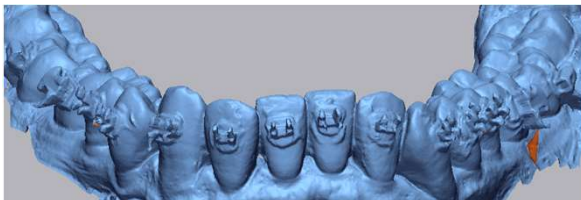
Background & Hypothesis

- Quantitative studies that provide a clinical basis of these applications are frequently lacking.
- This frequently leads to commercial and/or clinical claims that are difficult to validate.

We *hypothesize* that trueness and precision of bracket erase software is dependent on the scanner, tooth/morphology, and software used.

Materials and Methods

Intraoral Scanners (IOS) Evaluated:

3Shape Trios 4   Cerec Primescan   iTero Element 2   Medit i700   Planmeca Emerald S

Bracket Erase Software Evaluated:

Methods

STL COLLECTION – Control Data
Cadaveric data captured with ATOS Capsule scanner
Cadaver pre-bracket (T_0)
Cadaver with brackets (T_1)

Cadaver Pre-bracket STLs
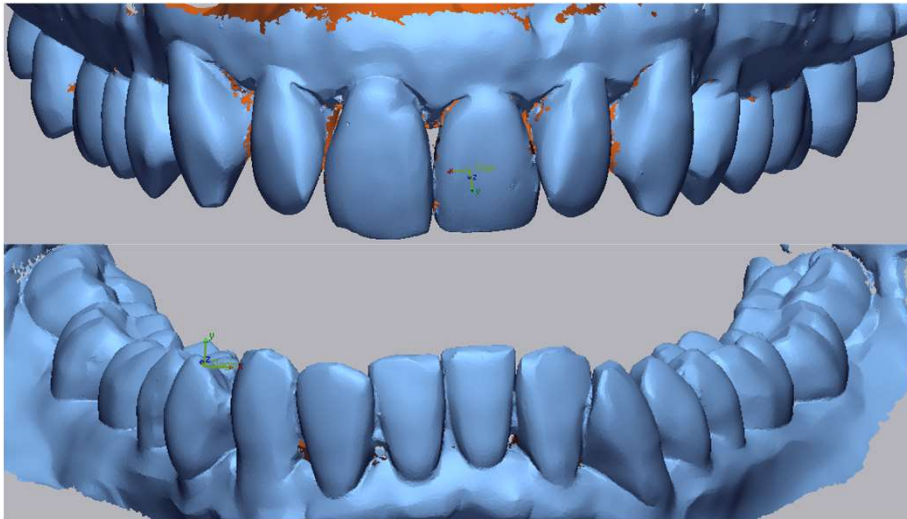
Cadaver Bracketed STLs
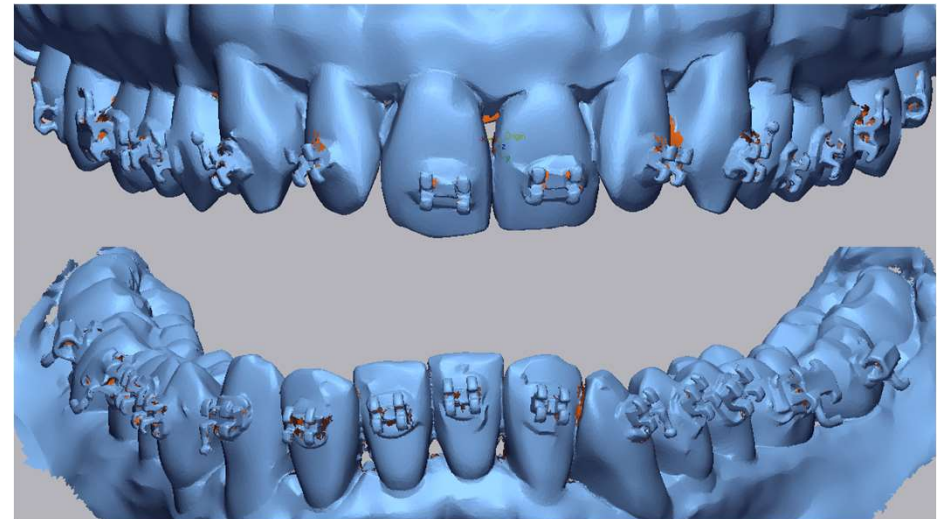
Methods

STL COLLECTION – Control Data
Cadaveric data captured with ATOS Capsule scanner
Cadaver pre-bracket
Cadaver with brackets

Scanner STL Files:
Cadaver arches pre-bracket scanned
8X/5 scanners
Cadaver arches with brackets scanned
8X/5 scanners

Bracket Erase STLs:
Bracketed cadaveric data processed
8X/arch/5 software

MUSC
Medical University
of South Carolina
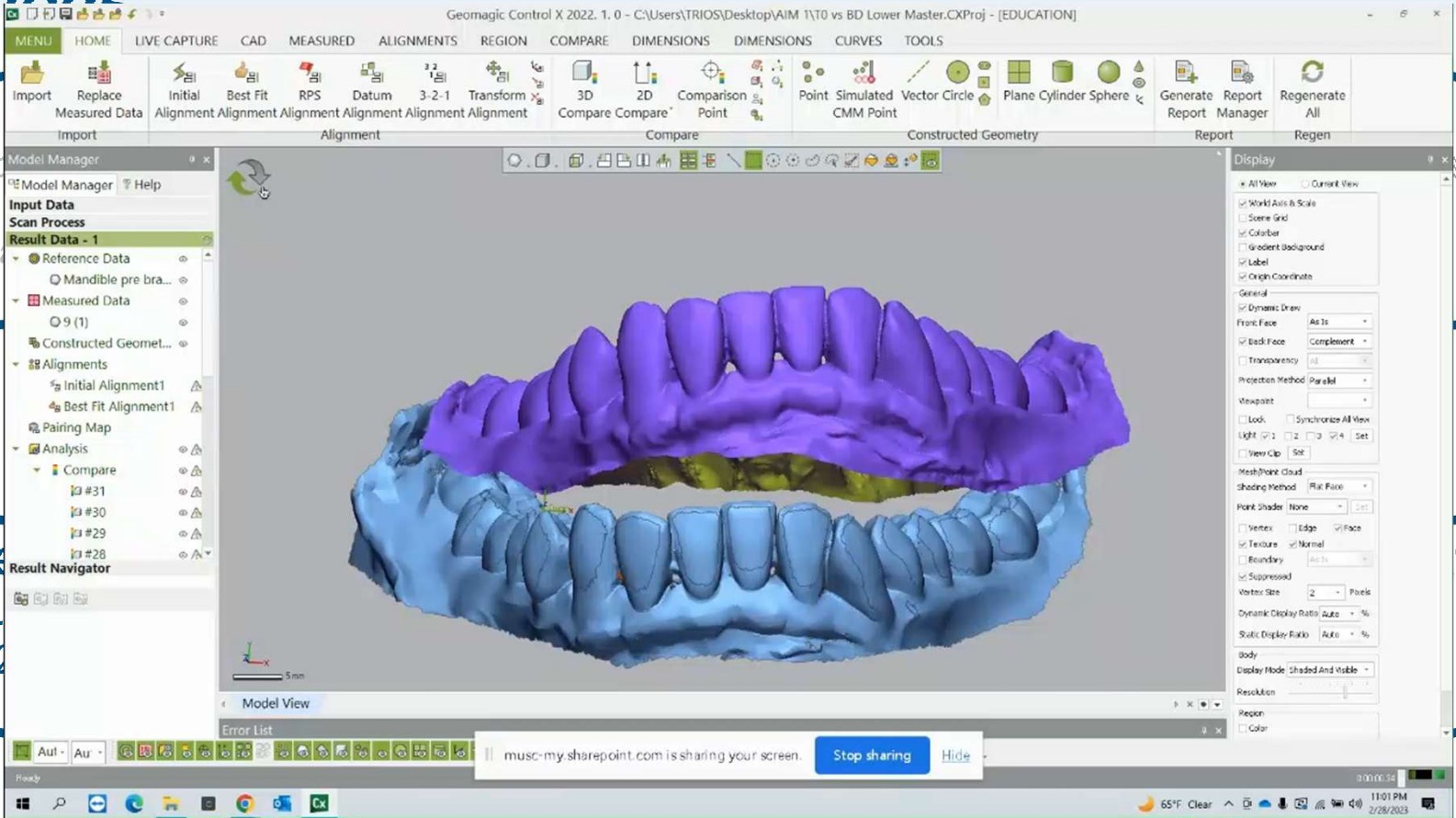
Methods

Methods

Scanner Error Data from STL files:
1. Pre-bracket ATOS vs. IOS
2. Bracketed ATOS vs. IOS

Bracket Erase Error Data from STL files:
3. Pre-Bracket ATOS vs. bracket erase

Cx Geomagic Control X

MUSC Medical University of South Carolina
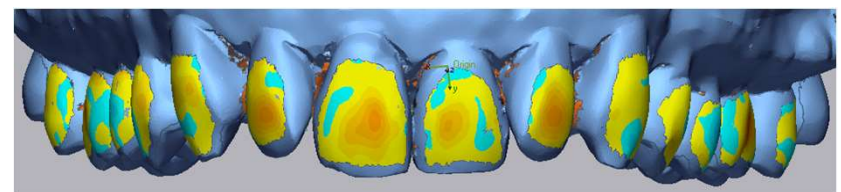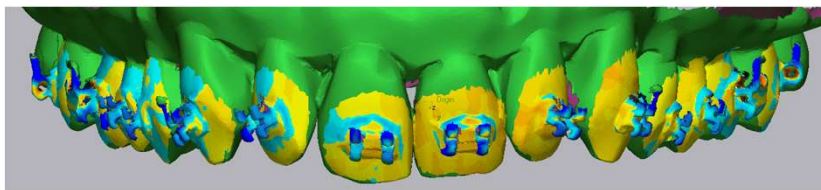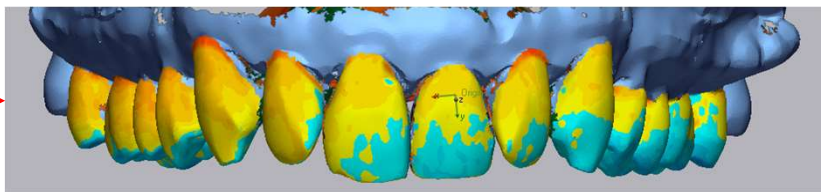
Statistical Methods and Estimated Mean Error

- In all models, a first-order autoregressive structure was used to account for the correlation between repeated measures.
- Positive and negative errors from scanning and bracket erasing were separately analyzed with linear regression models using predictors as follows.

Scanner Error in Unbracketed Teeth (T_0) Predictors:

- scanner and area(mandibular teeth, maxillary teeth, palate)

Scanner Error in Bracketed Teeth (T_1) Predictors:

- scanner, arch(mandible, maxilla), scanner*arch interaction (when indicated)

Software Error in Bracket Erasing Predictors:

- software, tooth type (molar, pre-molar and canine, anterior), software*tooth type interaction

Pre-bracket Scanner Results

IOS vs. Maxillary Pre-bracket ATOS STL
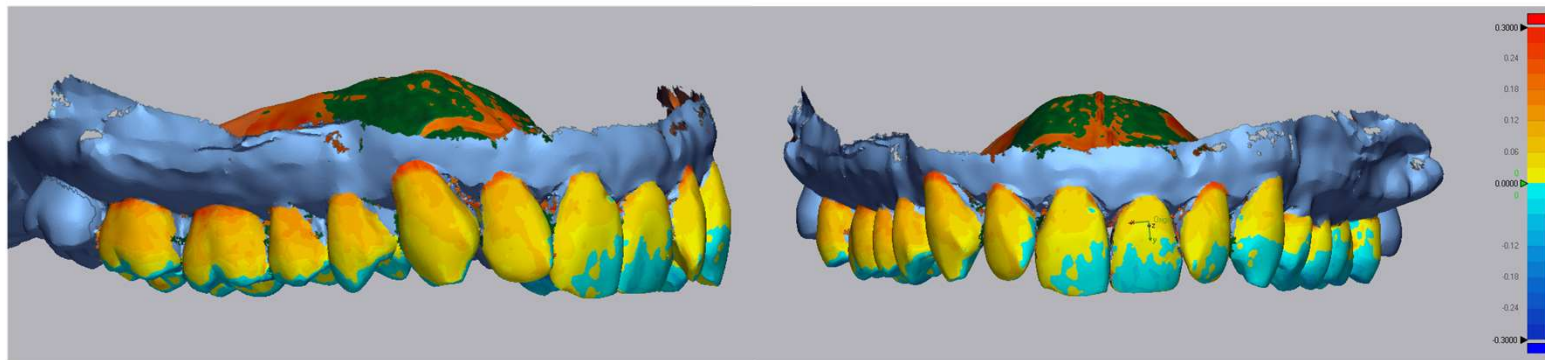
IOS vs. Mandibular Pre-bracket ATOS STL
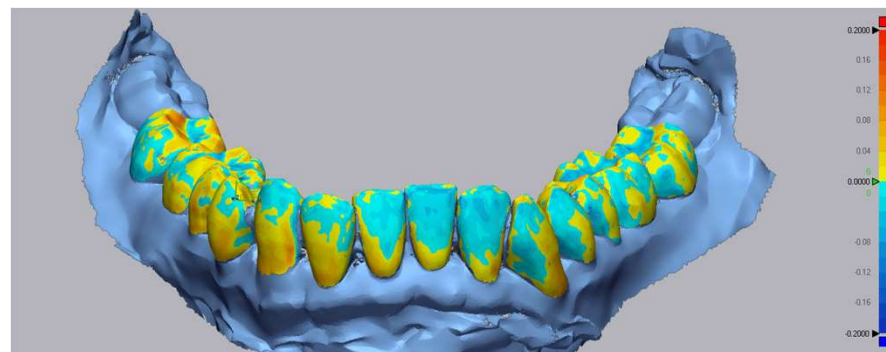
Bracketed Scanner Results

IOS vs. Bracketed Cadaver ATOS STL
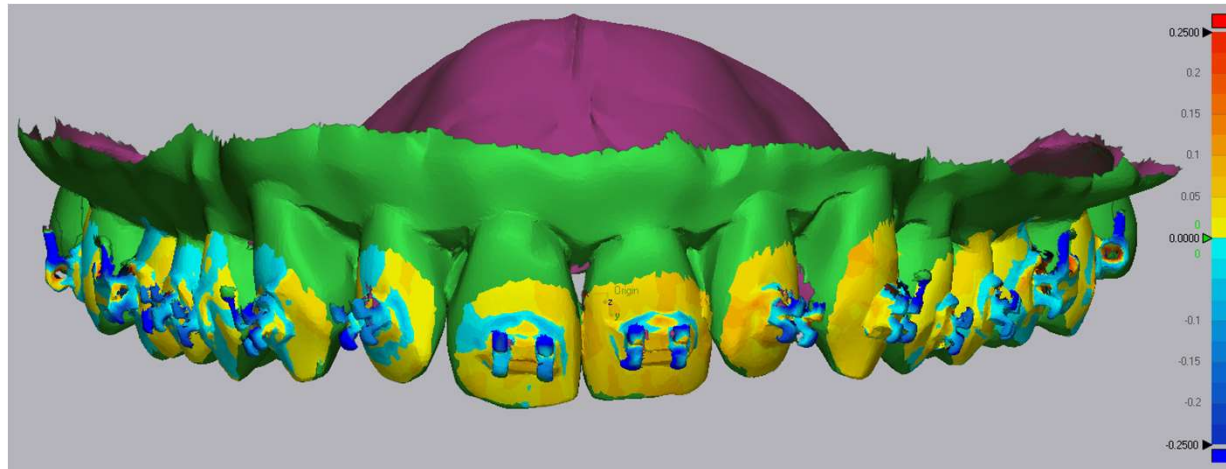
Bracketed IOS STL
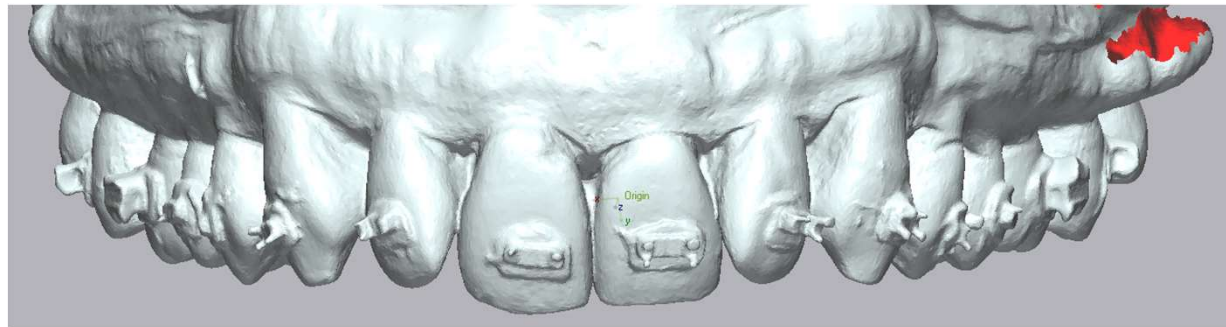
Pre-bracket and Bracketed Scanner Results

Positive IOS Error Averages and Confidence Intervals
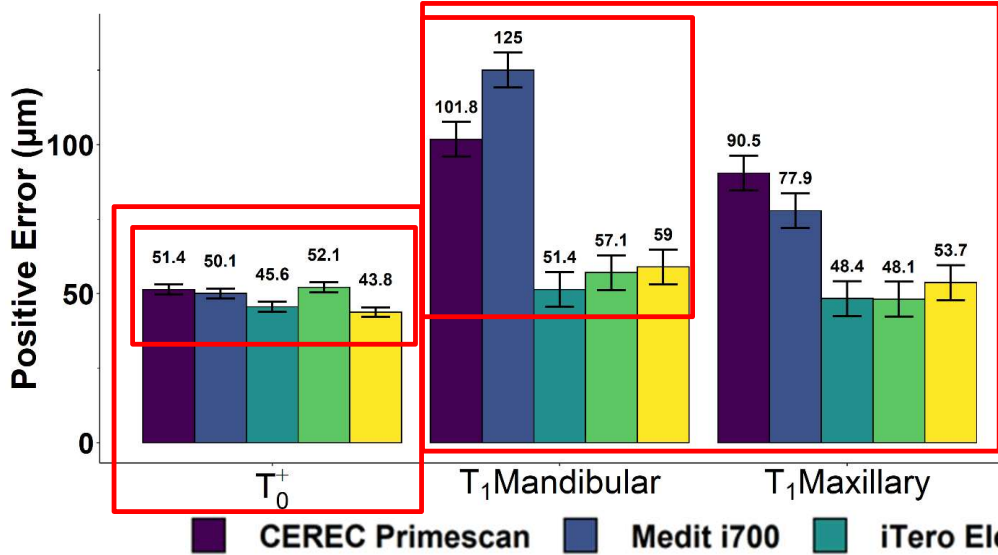
Negative IOS Error Averages and Confidence Intervals
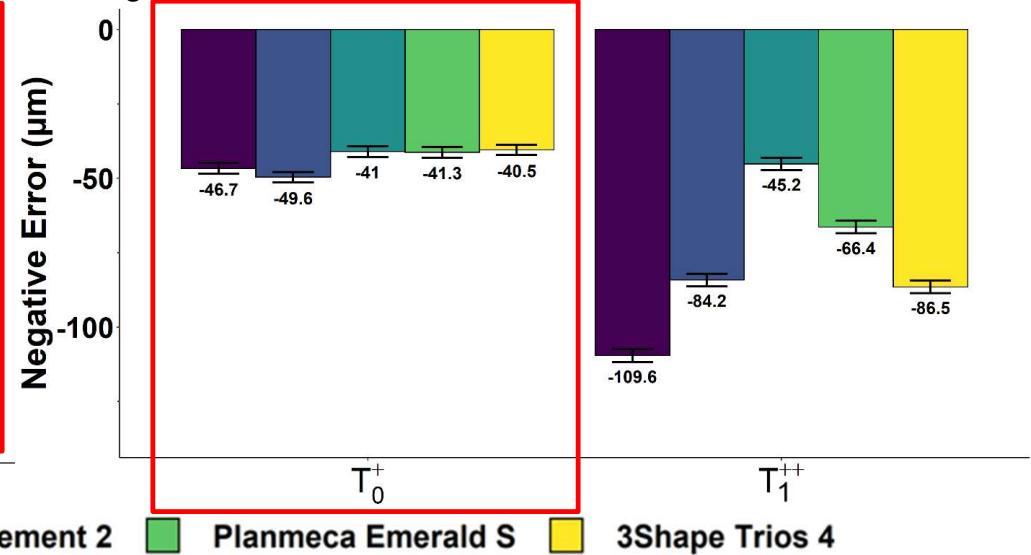
Pre-bracket Scanner Comparisons: Averages and Confidence Intervals

Error Type	Minimum Error	Maximum Error	Difference (95% CI) [μm]
Positive	3Shape Trios 4	Planmeca Emerald S	8.3 (1.7, 14.9)*
Negative	3Shape Trios 4	Medit i700	-9.2 (-16.3, -2.0)*

+Estimated means from modelling corrected for the effect of region (mandibular, maxillary, palate)
++Estimated means from modelling corrected for the effect of region (mandibular, maxillary)

*p<0.05

Understanding Bracket Erase Results

- Blue areas represent an areas where the bracket was over reduced
- Geomagic reports this error as a negative value.
- This is an area that will be filled when the retainer is fabricated resulting in a tighter retainer fit at the bracket site.
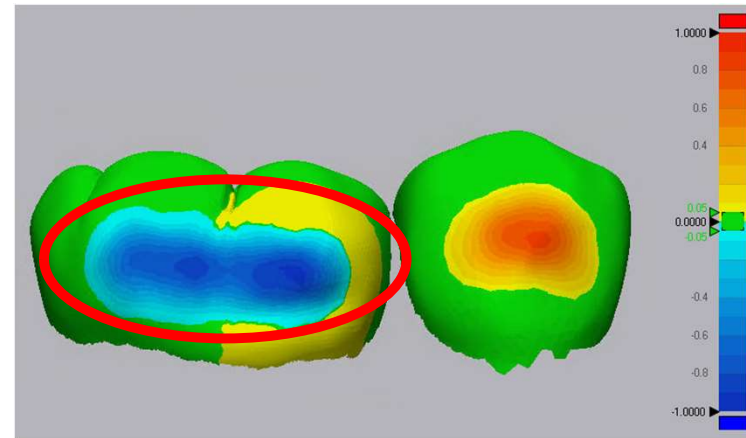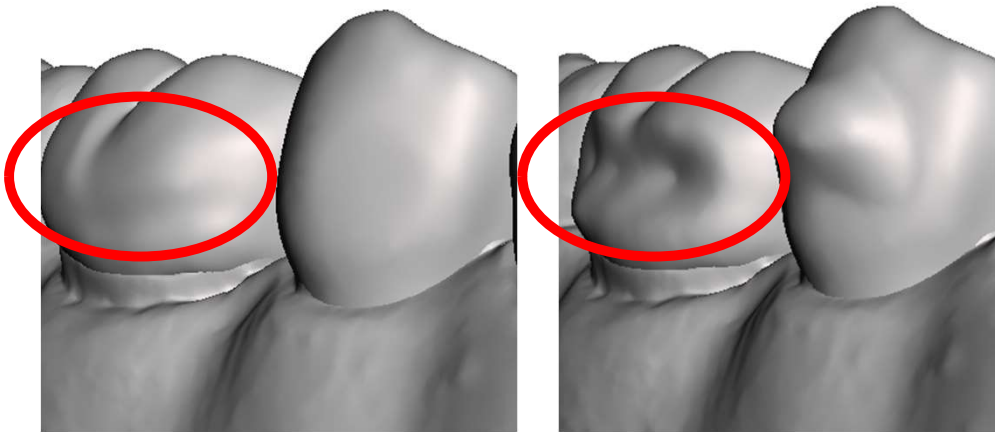
Understanding Bracket Erase Results

- Red/yellow areas represent areas where the bracket was underreduced
- Geomagic reports this error as a positive value.
- This is an area that will not contain retainer material resulting in a pocket at the bracket site
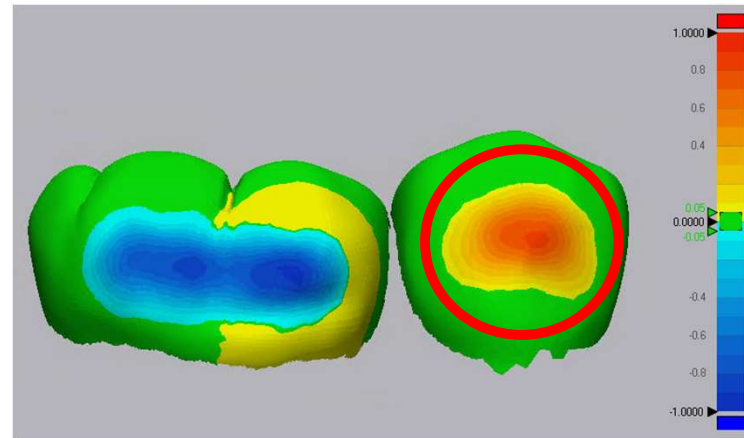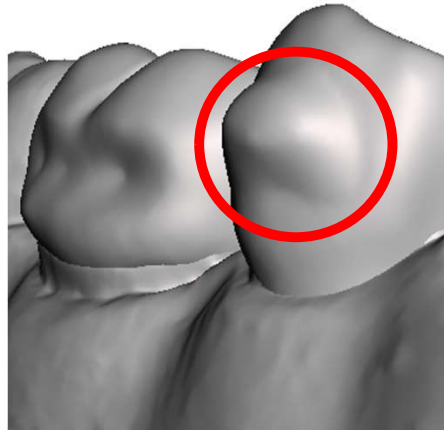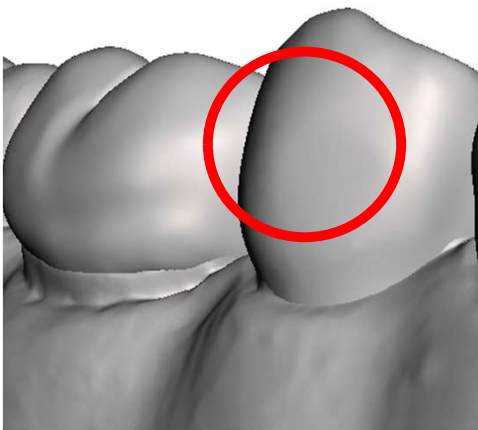
Maxillary Pre-bracket ATOS vs. bracket erase
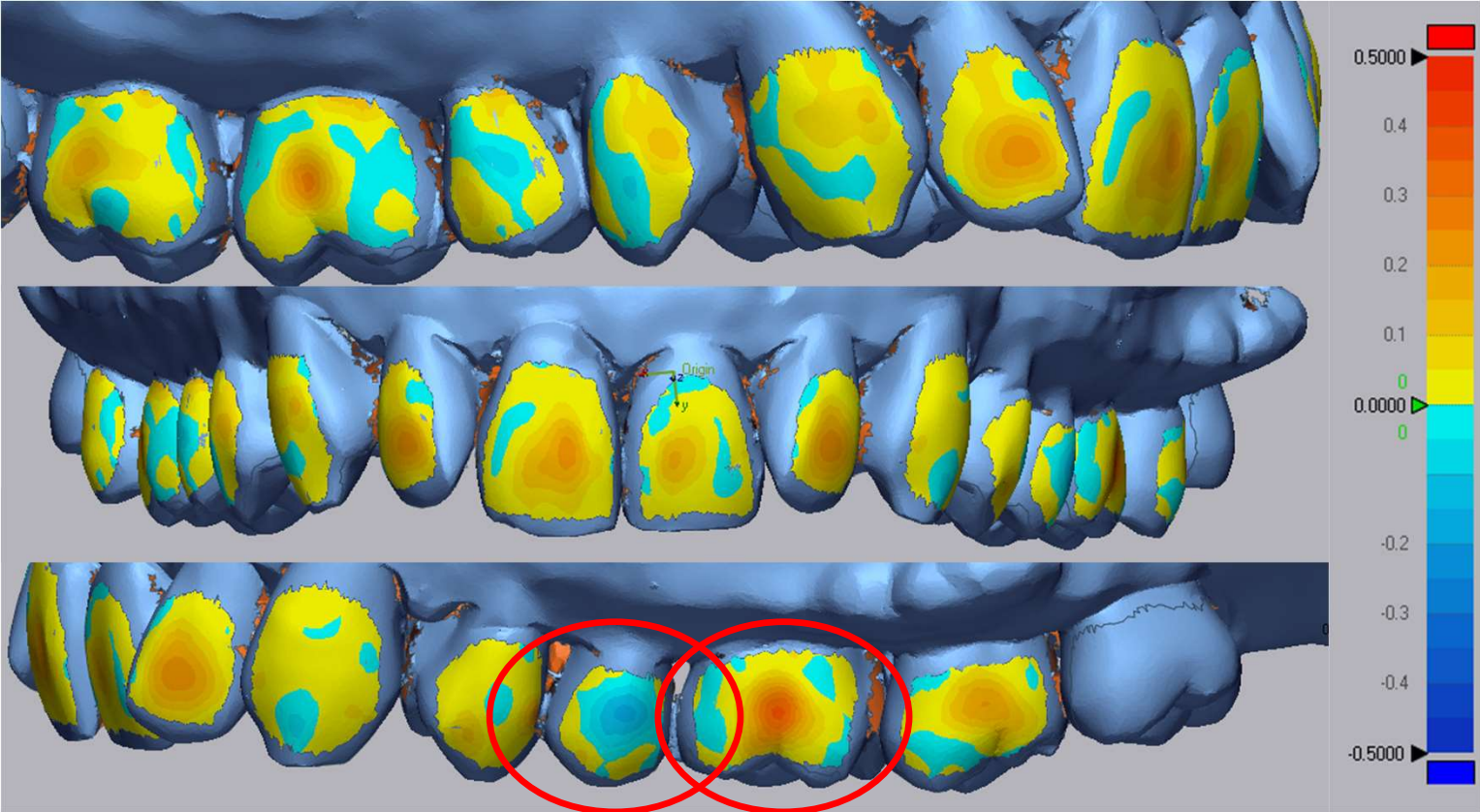
Bracket Erase Results

Positive Bracket Erase Error Averages and Confidence Intervals
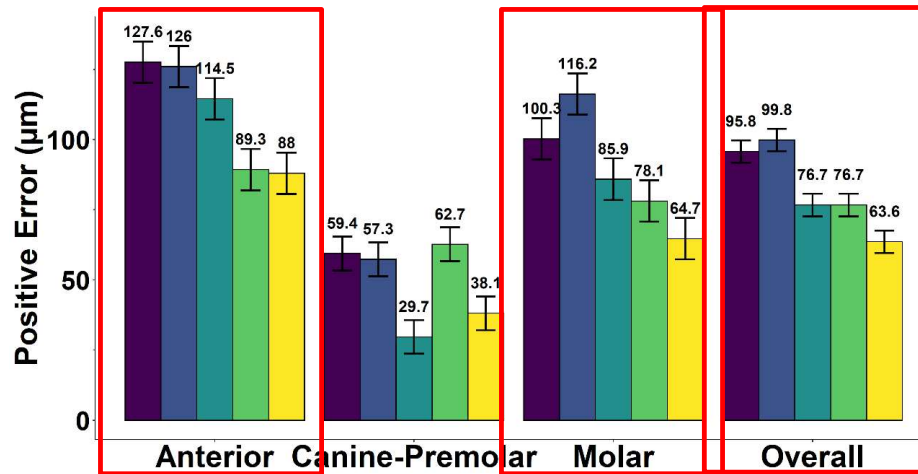
Negative Bracket Erase Error Averages and Confidence Intervals
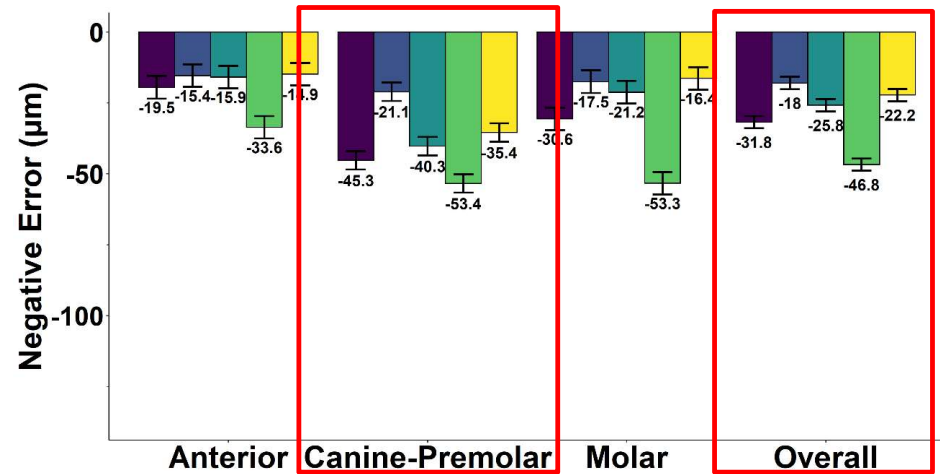
CONCLUSIONS

- All evaluated scanners have a high degree of precision and have comparable trueness.

- While scanners are very comparable in rendering naïve tooth surface, complex orthodontic bracket morphology produces greater error that may not be clinically relevant.

- Bracket erase software tend to create a pocket at a bracket site rather than create a pressure point. Most error in these software will not have a clinical impact on a patient's retainer fit.

- Digital scanners and this workflow have a level of clinical accuracy that allows for effective and efficient patient care.

Acknowledgements / Conflict of Interest

Conflicts of Interest: None

Questions?

Trueness and Precision of Scanners and Bracket Erase Software

M. Sharp[1], C. McGill[2], W. Renne[3], C. Webb[1,3], V. Ramakrishnan[2], S.S. Huja[1]

1. Medical University of South Carolina, James B. Edwards College of Dental Medicine
2. Medical University of South Carolina, Department of Public Health Sciences
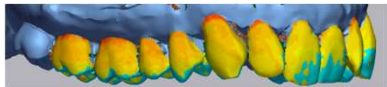3. Private Practice
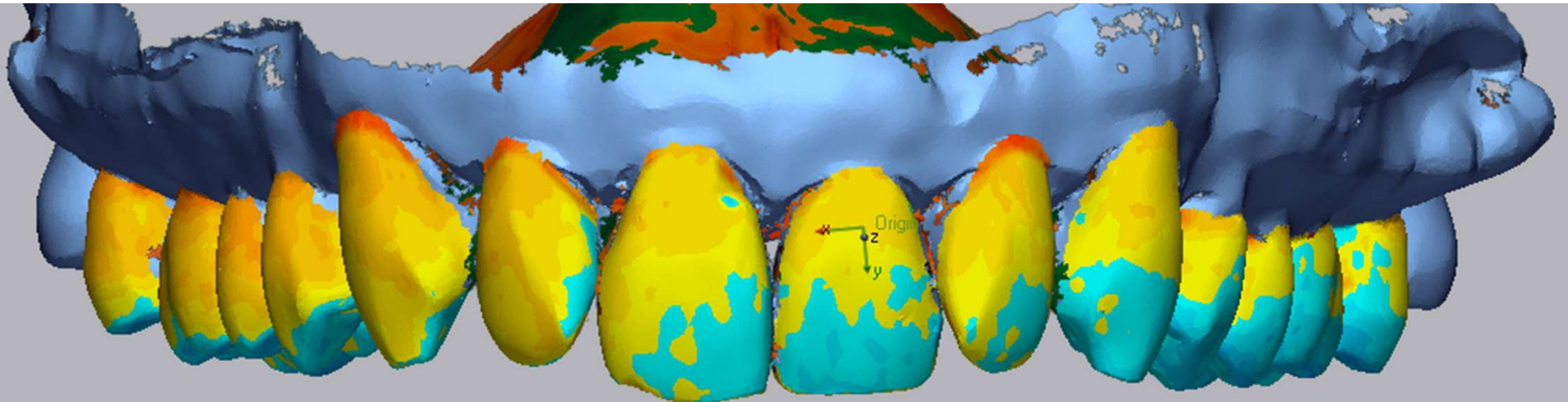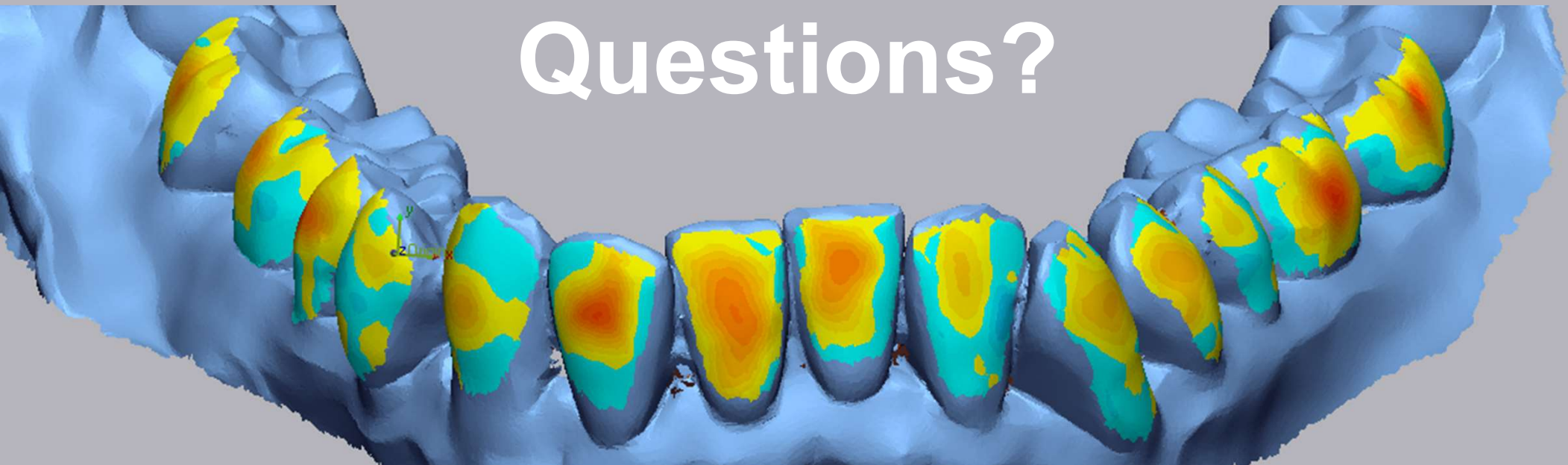
OBJECTIVE/BACKGROUND

Digital workflows are rapidly being incorporated into clinical practice. However, quantitative studies that provide a clinical basis of these applications are frequently lacking. One digital workflow is fabrication of retainers from predebond scans which greatly improve the efficiency of orthodontic treatment delivered to our patients. This study, aims 1. To evaluate trueness and precision of 5 intraoral scanners (3Shape Trios 4, Cerec Primescan, iTero Element 2, Medit i700 and Planmeca Emerald S vs. Gold standard ATOS). Scans of arches with and without orthodontic brackets will be evaluated. 2. To evaluate the trueness and precision of 5 commercially available laboratory software (EasyRx, Full Contour (3Shape), Meshmixer, New England Orthodontic Lab (NEOLab), and uLab). Impacts of tooth type/morphology will be evaluated for each software.

We hypothesize that trueness and precision of bracket erase software are impacted by the scanner used, tooth type/morphology, and the software being used.

METHODS

Figure 1. T_1 ATOS vs. IOS Comparison

STL COLLECTION
Control Data: ATOS Industrial Scanner
T_0 – Cadaver pre-bracket
T_1 – Cadaver with brackets

Scanner STL Files:
8 Scans of both T_0 and T_1 arch pairs /scanner

Bracket Erase STLs:
T_1 ATOS data processed 8X/arch/software

Scanner Error Data:
1. ATOS T_0 STLs compared to intraoral scanner STL files
2. ATOS T_1 STLs compared to intraoral scanner STL files

Bracket Erase Error Data:
ATOS T_0 STLs compared to bracket erase STL files from 5 evaluated software

Statistical Methods:
In all models, a first-order autoregressive structure was used to account for the correlation between repeated measures. Positive and negative errors from scanning and bracket erasing were separately analyzed with linear regression models using the following predictors:

Scanner Error in Unbracketed Teeth (T_0) Predictors:
• scanner and area(mandibular teeth, maxillary teeth, palate)
Scanner Error in Bracketed Teeth (T_1) Predictors:
• scanner, arch(mandible, maxilla), scanner*arch interaction (when indicated)
Software Error in Bracket Erasing Predictors:
• software, tooth type (molar, pre-molar and canine, anterior), software*tooth type interaction

Figure 2. T_1 ATOS vs. Bracket Erase Software Comparison
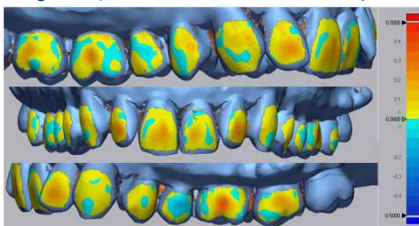
RESULTS

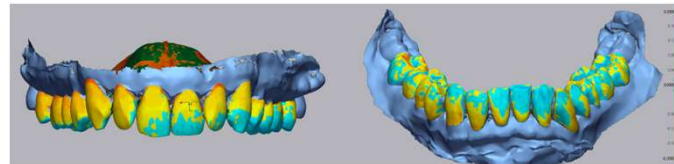**Figure 3.** Maxillary and Mandibular T_0 ATOS vs. Scanner STL Comparison

Figure 4. T_0 and T_1 Scanner Error

+Estimated means from modelling corrected for the effect of region (mandibular, maxillary, palate)
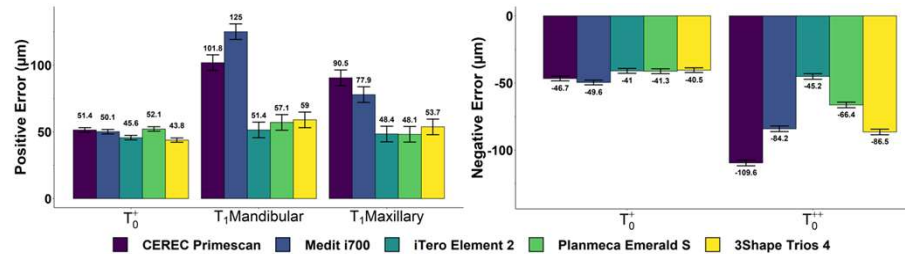++Estimated means from modelling corrected for the effect of region (mandibular, maxillary)

Table 1. T_0 Scanner Comparisons: Estimated Difference

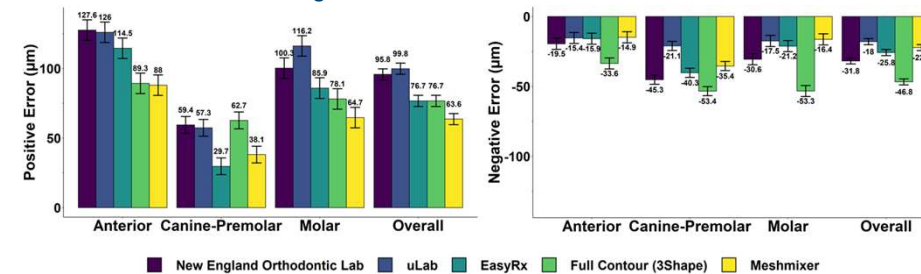| Error Type	Minimum Error (error) [µm]	Maximum Error (error) [µm]	Difference (95% CI) [µm]
Positive	3Shape Trios 4 (43.8)	Planmeca Emerald S (52.1)	8.3 (1.5, 15.1)*
Negative	3Shape Trios 4 (-40.5)	Medit i700 (-49.6)	-9.1 (-15.8, -2.6)*

*p<0.05

Figure 5. Bracket Erase Software Error

Table 2. Bracket Erase Comparisons: Estimated Difference

Region	Positive Error			Negative Error		
	Software with Least Error (error) [µm]	Software with Most Error (error) [µm]	Error Difference (95% CI) [µm]	Software with Least Error (error) [µm]	Software with Most Error (error) [µm]	Error Difference (95% CI) [µm]
Anterior	Meshmixer (88.0)	NEOLab (127.6)	39.6 (3.8, 75.3)	Meshmixer (-14.9)	Full Contour (-33.6)	-18.7 (-37.9, 0.6)
Canine – Premolars	EasyRx (29.7)	Full Contour (62.7)	33.0 (3.6, 62.3)	uLab (-21.1)	Full Contour (-53.3)	-32.2* (16.6, 48.1)
Molars	Meshmixer (64.7)	uLab (116.2)	51.5 (15.7, 87.3)	Meshmixer (-16.4)	Full Contour (-53.4)	-37.0* (-56.2, -17.7)
Overall	Meshmixer (63.6)	uLab (99.8)	36.2 (20.6, 51.9)	uLab (-18.0)	Full Contour (-46.8)	-28.8 * (-37.2, -20.4)

*p<0.05

Figure 6. Mandibular T_0 ATOS vs. Bracket Erase Software
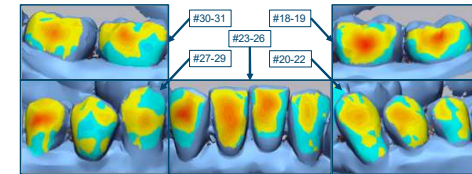
DISCUSSION

• Positive T_0 scanner error ranged from 43.8µm to 52.1µm. Negative T_0 scanner error ranged from -40.4µm to -49.6µm.

• For T_0 scanner error, no two scanners differ by more than 9.1 µm.

• The maximum width across all scanners of a CI for T_0 positive error (6.7µm) is 27.8% of the corresponding CI for T_1 positive error (24.1µm). This indicates greater precision when scanning teeth without brackets compared to teeth with brackets.

• Qualitative, this may be attributed to the ability of the ATOS industrial scanner and intraoral scanners to capture features of orthodontic brackets. We visually observed accurate scanning of bracket bases and maximum error on bracket tips.

• Bracket erase processing error ranged from 29.7µm to 127.6µm and -53.4µm to -14.9µm. All error was dependent on both software and tooth type.

• Smallest positive error values and highest negative error values were seen for premolars-canines across all software.

• Anterior and molar teeth had similar error. Anteriors had slightly higher positive error and molars had slightly higher negative error.

• When evaluating error averaged across the entire dentition, uLab software had the smallest negative error while Full Contour's software had the greatest. (a minimal 28.8 µm difference) Meshmixer had the least overall positive error and uLab software had the greatest positive error. (a minimal 36.2 µm difference)

• Negative error, which would lead to fabrication of a retainer that is too tight, was less than 53.4 µm when across all software and regions.

• Limitations of study: These bracket comparisons also includes Geomagic Control X alignment error. Additionally, T_1 ATOS data contained "holes" in tooth interproximal and on portions of brackets. Despite this challenge, all bracket erase software performed to a clinically acceptable levels.

CONCLUSIONS

• All evaluated scanners have a high degree of precision and have comparable trueness.

• Bracket erase software tend to create a pocket at a bracket site rather than create a pressure point. Most error in these software will not have a clinical impact on a patient's retainer fit.

• While scanners are very comparable in rendering naïve tooth surface, complex orthodontic bracket morphology produces greater error.

• Digital scanners and workflow have the level of clinical accuracy that would allow an option for efficient patient care.

ACKNOWLEDGMENTS